Carrying capacity of habitats used seasonally by coho salmon in the Kametolook River, Alaska Peninsula National Wildlife Refuge, 2002

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by

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Abstract

Coho salmon *Oncorhynchus kisutch* are an important subsistence resource for residents of the Native Village of Perryville, but recent returns to local streams (Kametolook, Three Star, and Long Beach rivers) have declined and residents can no longer meet their subsistence needs. Several reasons for the decline have been suggested, including a decrease in carrying capacity from changes in habitat, and over fishing (in-river and in the ocean). This project was implemented to assess the quantity and quality of freshwater habitats used for spawning and rearing by coho salmon in streams near Perryville, and to use these data to conduct a limiting habitat analysis. The survey was repeated on Clear Creek, a neighboring drainage that supports viable runs of coho salmon. Work completed in 2002 includes: 1) completion of a habitat inventory on Kametolook River tributaries and on Clear Creek, 2) sampling of juvenile coho salmon in Clear Creek, 3) escapement monitoring in Clear Creek (weir) and streams near Perryville (walking surveys), and 4) application of a habitat limiting factor model to both systems. Over 43 km of stream in the Kametolook drainage and 12 km of stream in Clear Creek were surveyed in 2002. Habitat composition and quality were similar between systems. Juvenile coho salmon densities in Clear Creek in 2002 were similar to values reported in the literature. Based on length frequency data, it appears that only age 0+ coho salmon were present in Clear Creek (few if any age 1+ were observed). Scale samples will be collected concurrently with length data in 2003 to define the length at age relationships for juvenile coho salmon in Clear Creek. One thousand ninety-seven coho salmon were counted past the Clear Creek weir in 2002. Extrapolated counts of coho salmon were 337 (Three Star River), 342 (Artemie's Creek), and 37 (Cross Creek Slough) in streams near Perryville. The count of adult coho salmon in Clear Creek is a minimum estimate as the weir failed at several critical times during the season. Preliminary results from the habitat limiting factor analysis indicates that Clear Creek can support over 1,100 adult coho salmon, and the Kametolook system can support over 4,000 adult coho salmon. Estimates are considered minimum, as over 3,000 adult coho salmon have been observed in Clear Creek in past years.

Introduction

The residents of Perryville depend on fish and wildlife resources for subsistence, and salmon (primarily coho salmon *Oncorhynchus kisutch*) accounts for more than half of the subsistence food they consume (Hutchinson-Scarborough and Fall 1993). The average harvest of coho salmon in the Perryville area from 1993 to 2000 was estimated to be over 1,900 fish, with a range from 993 (1995) to 3,501 (1994) (Alaska Department of Fish and Game (ADFG) 2002). Recent runs of coho salmon in the Kametolook, Three Star, and Long Beach rivers have declined, with escapement estimated at about 200 fish in 1996 (ADFG 1997). Concerns over poor returns and the inability of local residents to meet their subsistence needs motivated the Native Village of Perryville to pass an ordinance that prohibits subsistence harvest in the Kametolook River. In addition, the ADFG engaged in a project in 1996 to rebuild coho salmon stocks in the Kametolook River drainage using incubation boxes, with the intent of increase adult returns by increasing survival from the green egg to swim-up fry stage (ADFG 1997).

Several reasons for the decline of coho salmon stocks in the Kametolook River drainage have been suggested, including a decrease in carrying capacity resulting from changes in habitat, over fishing in-river, and over fishing in the ocean. As the availability and quality of spawning and rearing habitats are not known, it is difficult to determine the bottlenecks that limit current production. This project was implemented to assess the freshwater habitat for coho salmon, and the objectives are to:

1. Inventory the physical habitat of the clear-water tributaries in the Kametolook, Three Star, and Long Beach river drainages, and use the resulting data to estimate seasonal carrying capacities of spawning, summer rearing, and overwintering habitats for juvenile coho salmon.
2. Calculate a minimum index of escapement of adult coho salmon in the Kametolook, Three Star, and Long Beach rivers based on juvenile carrying capacities.
3. Estimate habitat-type specific densities of juvenile coho salmon that can be compared with values reported in the literature and with habitat condition data collected in the physical habitat inventory, and to validate carrying capacity estimates.
4. Collect data referenced in objectives 1 - 3 on Clear Creek, a small neighboring drainage that supports a significant run of coho salmon and compare the results to the Kametolook, Three Star, and Long Beach river drainages.
5. Estimate escapement of adult coho salmon in the Kametolook, Three Star, and Long Beach river drainages, and in Clear Creek.

The quantity and quality of adult spawning and juvenile rearing habitat for coho salmon will be measured in the Kametolook, Three Star, and Long Beach rivers using a modification of the stream survey methods developed by Hankin and Reeves (1988). Results from these surveys will be compared to those of a parallel survey being conducted on Clear Creek, a clear-water stream located near the Yantarni Airstrip (Figure 1), in an effort to better understand the factors limiting smolt production. Stream survey data will be used to conduct a limiting habitat analysis for coho salmon in the drainages. This method, as detailed by Reeves et al. (1989), uses habitat data to model the survival of a single cohort over time, by life-stage and season (i.e. spawning, and spring, summer, and winter rearing) to identify the principle bottleneck(s) that limit theoretical smolt production. The model is based on the assumption that when a specific habitat is in short supply, a bottleneck exists that may subject a cohort to density-dependent mortality, which may lead to an under seeding of habitats used by subsequent life stages. Results of the limiting habitat analysis, comparison of habitat-based carrying capacities to actual estimates of juvenile coho salmon densities, and current indices of adult escapement will be used to determine what factors are limiting production of coho salmon in the Kametolook, Three Star, and Long Beach rivers.

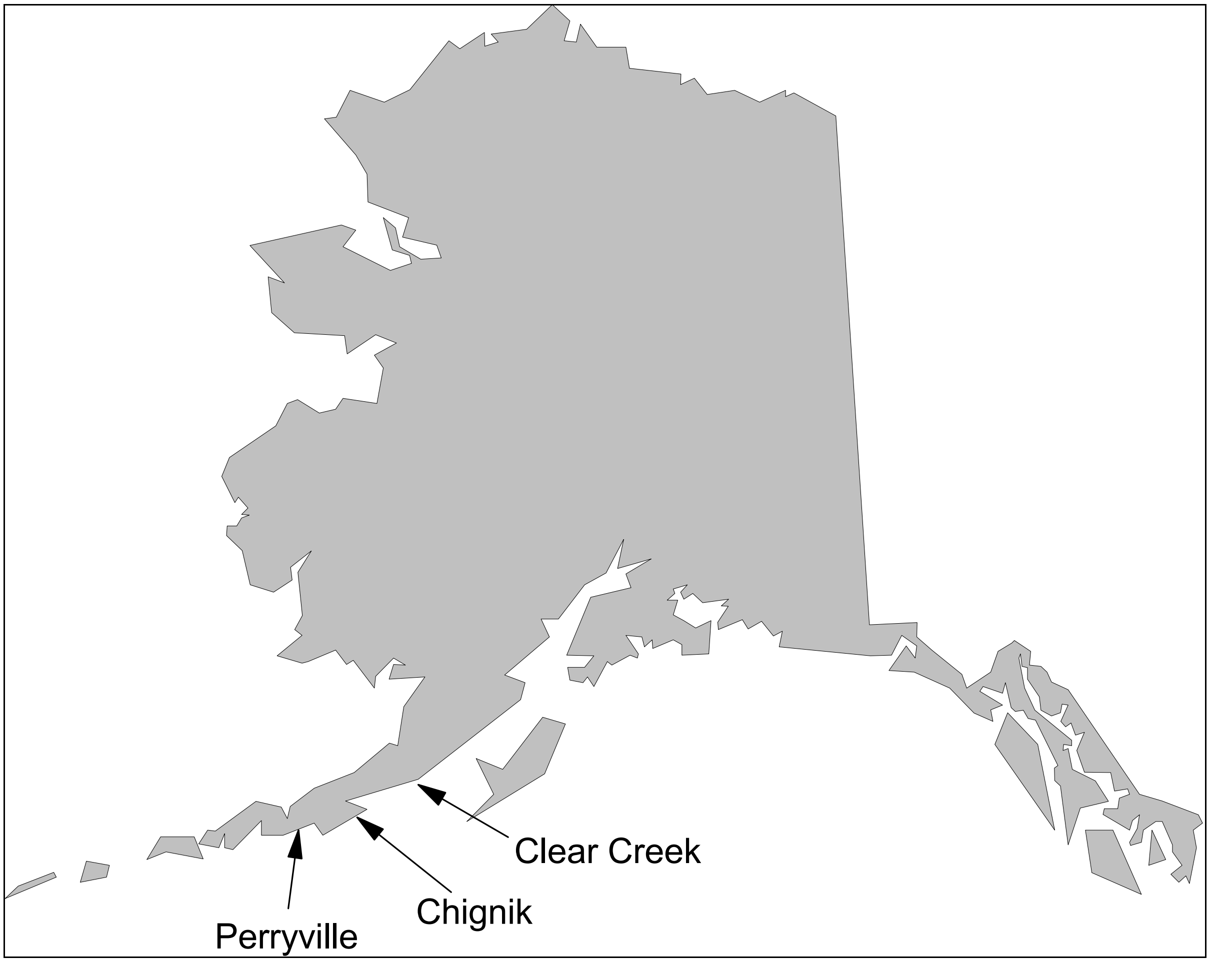


Figure 1. Location of Perryville and Clear Creek, Alaska Peninsula National Wildlife Refuge.

Study Area

The Kametolook, Three Star, and Long Beach rivers are located below Mount Veniaminof volcano on the South Alaska Peninsula and share a common valley bottom (Figure 2). The entire area is located within the boundaries of Alaska Peninsula National Wildlife Refuge.

The three drainages are highly braided and stream capture events have been documented to occur between the systems. When the village of Perryville was founded in 1912, the Long Beach River provided the bulk of fish for the community. About 20 years ago, however, a stream capture event diverted highly turbid glacial water draining off the base of Mount Veniaminof into the Long Beach River. Since then, the Kametolook River has been the primary producer and most accessible significant source of coho salmon available to subsistence users in the local area.

Camp Creek is located on the South Alaska Peninsula near the Yantarni Airstrip, 60 miles north of Chignik (Figure 3). The Camp Creek drainage undergoes similar morphological changes as the Kametolook system in that they are both glacial, undergo stream capture events, and are constantly changing. Clear Creek flows into Camp Creek about 2 km upstream from Camp Creek's confluence with the Pacific Ocean. Clear Creek is a clear-water stream and is about 13 km long, but a waterfall located 9 km upstream from its mouth blocks fish passage. Clear Creek supports a moderate run of coho salmon, with escapement estimated at greater than 3,000 adults in 1995 and 1996 (Hetrick and Nemeth 2003). Coho, chinook *O. tshawytscha*, pink *O. gorbuscha*, chum *O. keta*, and sockeye *O. nerka* salmon, and Dolly Varden *Salvelinus malma* are present in both the Perryville area streams and in Clear Creek.

Methods

Habitat Inventory

The habitat inventory for the Kametolook River in 2002 concentrated on clear water tributaries. Because of turbidity resulting from glacial outflow, we believe that much of the Kametolook, Three Star, and Long Beach rivers function only as corridors that are used by coho salmon to access clear water areas for spawning and rearing. The entire Clear Creek watershed was inventoried. Methods used to classify habitat types were modified from Hankin and Reeves (1988), Bisson et al. (1982), and Overton et al. (1997). The habitat type classifications of Nickelson (1998) were used for later compatibility with his habitat limiting factor analysis model. Habitat types were classified as either cascades, rapids, riffles, glides, trench pools, plunge pools, lateral scour pools, mid-channel scour pools, dam pools, alcoves, or beaver ponds. The terminology of Overton et al. (1997) was used to describe the formative features of pool types. Physical habitat features were compared between the Kametolook system and Clear Creek.

The inventory was completed by beginning at the mouth of each clear-water tributary and working upstream until a barrier to upstream migration was reached (i.e., a waterfall), a terminal spring source was encountered, or the system became dispersed through vast marshy areas with no apparent feeder source. All lentic and lotic waters of each tributary stream were surveyed. Individual habitat units were classified based on habitat type, and length, width, and depth measurements were taken. Length was measured along the thalweg. A minimum of three widths were measured perpendicular to the thalweg at evenly dispersed cross-sections throughout the unit, and a mean width was calculated. Surface area of each habitat unit was calculated by multiplying the measured length of the unit by its mean width. Mean depth of each unit was measured following the procedures of Overton et al. (1997). Maximum depth for pools was also measured following the procedures of Overton et al. (1997).

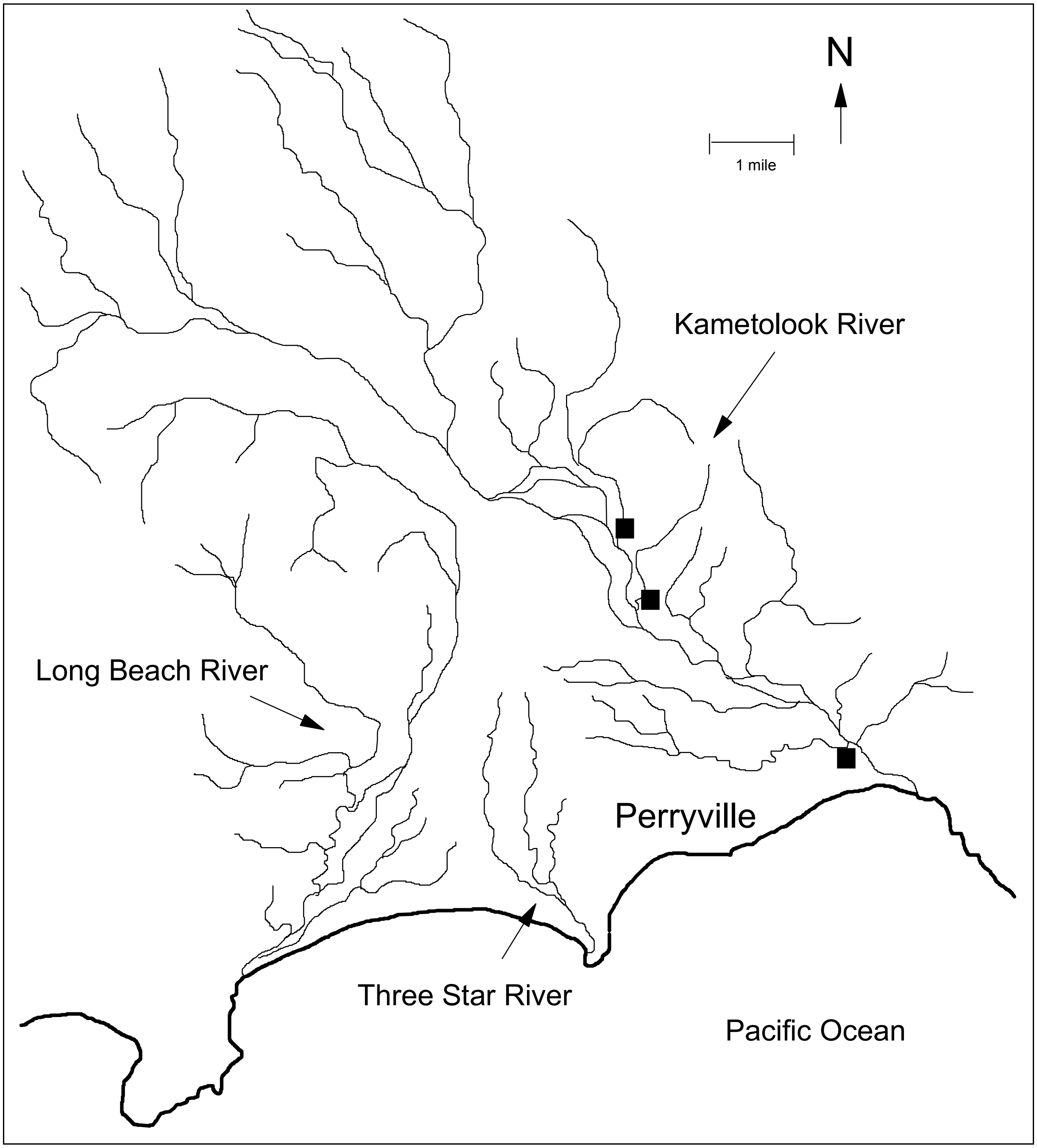


Figure 2. Kametolook, Three Star, and Long Beach rivers near Perryville, Alaska Peninsula National Wildlife Refuge. Also shown are locations of thermographs deployed in 2002 (solid squares).

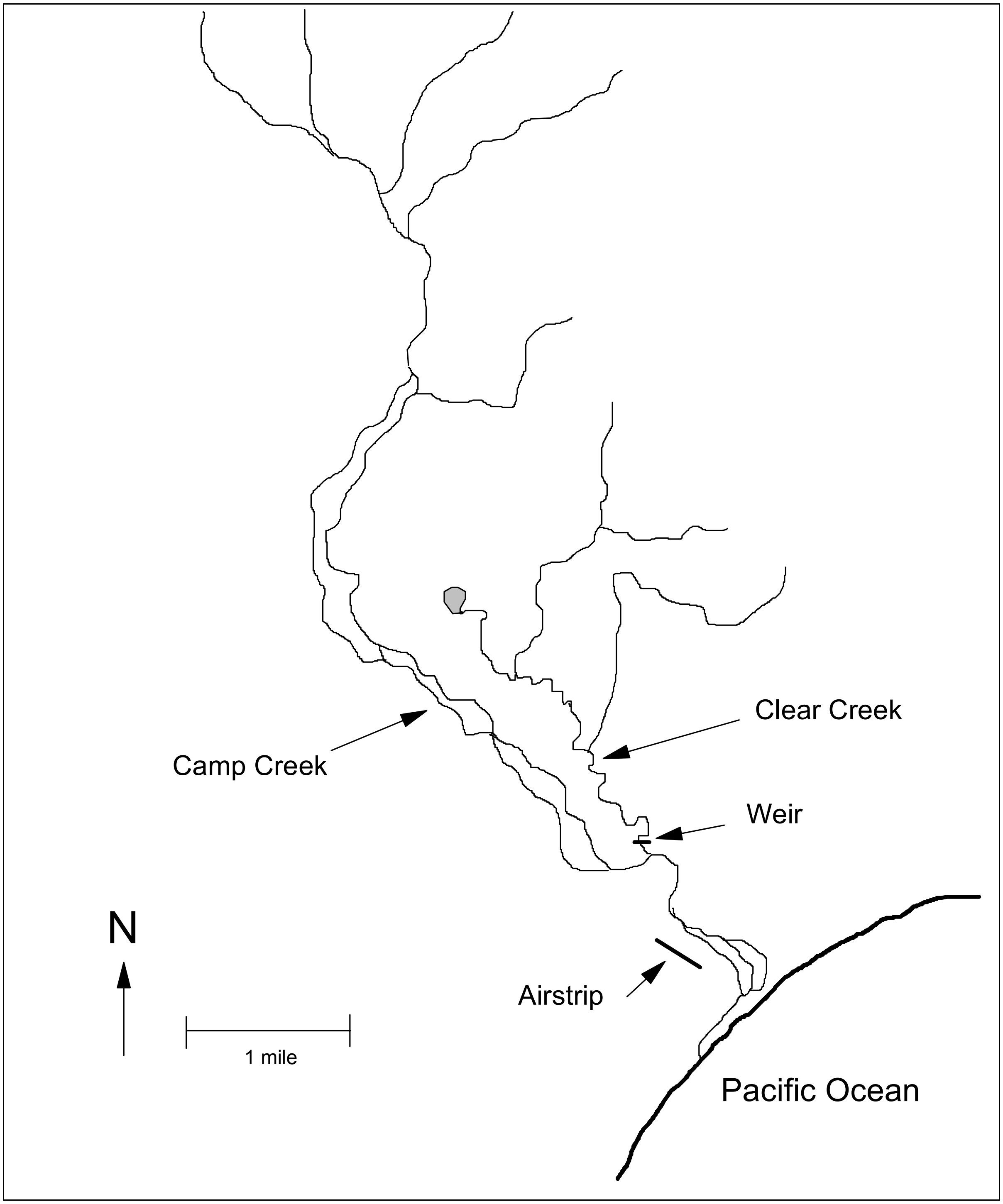


Figure 3. Clear Creek study area, Alaska Peninsula National Wildlife Refuge.

At each habitat unit, cover provided by turbulence, boulders, overhead vegetation, undercut banks, and pocket water were visually estimated and expressed as a percentage of the total surface area. The percent of each habitat unit containing large woody debris (LWD) was also visually estimated. LWD was also categorized by quantity (single pieces, aggregates (2 - 4 pieces), and groups (> 4 pieces)) and type (rootwad, log jam, growth, or a combination of types). The percent of each habitat unit that was suitable for salmonid spawning was also estimated visually. Spawning habitat was also classified qualitatively as poor, fair, or good based on best professional judgment.

Surface substrate composition was estimated using a modified version of the pebble count procedure described by Bevenger and King (1995). The procedure differed from that described by Bevenger and King (1995) in that only low gradient riffles suitable for salmonid spawning were sampled, and particles were selected by walking heel-to-toe and picking rocks from beneath our toes every one or two steps instead of at seven-foot intervals. A minimum of 100 particles were sampled along three to six transects across a riffle. Particles were measured to the nearest 1 mm along the longest axis with a ruler and categorized according to a modified version of the size classes (Wentworth Scale) described by Platts et al. (1983) (Table 1). Riffles sampled for substrate analysis were spaced evenly throughout the length of individual streams. At each unit where pebble counts were performed, substrate embeddedness was visually estimated according to what percentage the larger particles were embedded by sand or finer sediments (0-25%, 26-50%, 51-75% or 76-100%).

Three thermographs were deployed in selected tributary streams in the Kametolook drainage (Figure 2), and one was deployed in Clear Creek at the weir to monitor water temperatures. Thermographs recorded temperature every two hours and were placed in secure, well-mixed, shaded sites.

Clear Creek Juvenile Sampling

In 2002, habitat type-specific densities of juvenile coho salmon in Clear Creek were estimated for selected habitat units as suggested by Reeves et al. (1989). Clear Creek was delineated into strata based on stream size, and habitat inventory data were summarized to determine total surface areas for each habitat type by stratum. Based on logistical constraints, 15 sites per stratum were selected for snorkel surveys. Sites were allocated to the different habitat types in proportion to the habitat type-specific surface areas in each stratum, and were selected systematically using a random start (Hankin 1986). Juvenile fish counts were conducted during periods of low flow in late August. Snorkel surveys were performed in discrete habitat units using standardized underwater observation techniques, and were only conducted when the minimum depth, visibility, and water temperature criteria of Thurow (1994) were met or exceeded. Fish were counted by one or two observers, depending on stream width and visibility, as they moved upstream through the habitat unit. Densities (number of fish/m^2) for each species were calculated by dividing the number of fish observed by the surface area of the site, and were then averaged by habitat type.

Table 1. Modified Wentworth particle size categories used to classify stream substrate particles.

Category	Particle Size (mm)
Organics	
Clay/Silt	$\leq$ 0.063
Sand	0.063 – 2
Small Gravel	2 – 4
Medium Gravel	4 – 32
Large Gravel	32 – 64
Small Cobble	64 – 128
Large Cobble	128 – 256
Boulder	> 256
Bedrock	

Passive capture removal techniques were also used to estimate juvenile coho salmon densities in Clear Creek in 2002. Minnow traps were used to capture and remove fish from selected pools following the procedures of Bryant (2000). Block nets were used at the upstream and downstream ends of the habitat units to prevent immigration and emigration of fish during the removal events. Three to four capture events were used in each habitat unit. Between eight and 20 minnow traps were set on each event depending on the size of the habitat unit. Distances between traps depended upon habitat complexity, but traps were generally separated by about 1.5 m. Traps were set more densely in complex habitats, usually in pools with large amounts of woody debris. Traps were set on the stream bottom near large woody debris, root wads, or undercut banks where juvenile salmonids were suspected to be present, but were also distributed to cover the entire pool. Traps were baited with pink or coho salmon eggs (collected locally), placed on the stream bottom, and left undisturbed for 60 ± 5 min and were picked up in the order in which they were set. Between capture occasions, juvenile fish were removed from the traps, identified, enumerated, and placed in a live well or released below the sample area. Traps were then re-set in their original locations, and the procedure was repeated.

Removal estimates and probabilities of capture (P_c) for coho salmon were computed by the CAPTURE program (White et al. 1982). The CAPTURE program tests two different models. The first model uses a constant P_c through all capture occasions, and the second model uses two different probabilities, one P_c for the first capture occasion and a different P_c for the remaining capture occasions. CAPTURE also performs a chi-square goodness of fit test for each model, and White et al. (1982) recommend using only models with p-values for the chi-square goodness of fit test greater than 0.20 to avoid bias. At least three capture occasions were necessary to test the assumption of equal and constant P_c, and four capture occasions were needed to use the model with two different P_c values (White et al. 1982). The model with the lowest chi-square goodness of fit test statistic was chosen for analysis purposes, and models were rejected if $p > 0.20$ for any model goodness of fit test. Density (number of fish/m^2) for each habitat unit was calculated by dividing the population estimate generated by the CAPTURE program by the surface area of the site. Mean densities of coho salmon by habitat type were estimated by averaging species densities for each habitat type. Over 100 juvenile coho salmon were also measured for total length (mm) in 2002.

Escapement Monitoring

In the Perryville area, coho salmon escapement was estimated in selected streams using multiple-pass stream walking surveys. Streams were selected following consultations with local residents to determine which streams would be likely to still support coho salmon spawning. Foot surveys with a crew of two observers were scheduled at two-week intervals beginning in early October and ending in December. Surveys began at the mouth and proceeded upstream in all waters of the selected streams accessible to adult salmon. Observers selected the route that maximized the visibility of salmon with respect to the angle of the sun, water clarity, and wind. Surveyors wore polarized glasses to reduce water surface glare. When oxbows, side channels, and backwaters were encountered, one observer maintained the count from a stationary position on the main channel while the other observer counted fish in the off-channel habitat. Streams were divided into approximately 1 km transects, and the following data were recorded for each transect: number and species of fish observed, time, water clarity (excellent, good, or poor), lighting conditions (sun, partial overcast, overcast), and wind generated surface turbulence (calm, moderate, rough).

Escapement estimates were generated for the selected streams by extrapolating the individual stream counts using the trapezoidal approximation of the area-under-the-curve (AUC) model described by English et al. (1992) and Hilborn et al. (1999) approximated as

$$AUC = \sum_{i=2}^{n} (t_i - t_{i-1}) \frac{(x_i - x_{i-1})}{2},$$

where t_i is the day of the year and x_i is the number of salmon observed for the ith survey. Attempts were made to begin the surveys before any coho salmon were present in the streams and to complete the final survey after all fish had died. When the first or last survey was not zero, the trapezoidal approximation fails (Hilborn et al. 1999), and the equations of Bue et al. (1998) were used to estimate AUC for the first and last survey periods. This method is unbiased for estimates of total season escapement, but can be biased if used for partial-season estimates (Hilborn et al. 1999). When coho salmon were observed on the first survey, the AUC prior to the first survey (AUC_{first}) was estimated as

$$AUC_{first} = \frac{x_1 s}{2},$$

where *s* is the stream life. When coho salmon were observed on the last survey, AUC after the final survey (AUC_{last}) was estimated as

$$AUC_{last} = \frac{x_{last} s}{2}.$$

Total escapement ($\hat{E}$) was then estimated as

$$\hat{E} = \frac{AUC}{s} v,$$

where *v* is a correction for observer efficiency. Values used for stream life and observer efficiency were taken from a multi-year project investigating stream life and observer efficiencies using stream walking surveys for coho salmon on the South Alaska Peninsula (Hetrick and Nemeth 2003); 13.7 d was used for average stream life, and an average observer efficiency value of 0.74 was used.

A fixed picket weir was installed on Clear Creek to estimate coho salmon escapement. The weir was constructed of 12 mm diameter electrical metal tubing pickets separated by 38 mm lengths of polyvinyl chloride pipe. Aircraft cable was used to string the pickets and spacers together, and clamps were attached to the ends of the cables to create 3 m long weir panels of varying heights to accommodate differences in channel depth. Weir panels were supported by fence posts and galvanized aircraft cable stretched across the stream. The supporting cable was anchored to the stream banks using "dead men" buried vertically at a depth that allowed the cable to be suspended just above the water surface. Weir panels were connected together and placed across the channel at an angle to direct upstream migrant fish to the trap box. The continuous panel was tilted downstream in relation to the stream bed to shunt debris to the water surface, thereby maintaining free-flow of water through the pickets. The tops of the panels were wired to the supporting cable. Stream banks at each end of the weir were armored with geotextile cloth to prevent erosion.

A fyke was installed in the weir, leading to an upstream migrant holding pen. The fyke was located as close to the stream bank as adequate depth would allow. The depth in the holding pen was greater than 0.5 m to help minimize fish escaping from the pens. The entire weir was inspected, cleaned, and maintained daily to insure integrity. Migrant fish were counted and identified as they were passed through a counting panel in the weir or while they were being sampled in the holding pen. Fish were not allowed to hold downstream of the weir to minimize any negative effects of delayed migration timing. When many fish were holding below the weir, the fyke was closed and the counting panel was opened to facilitate upstream passage.

Age, Sex, and Length Data

Data on coho salmon age, sex, and length (ASL) were collected using a temporally stratified sampling design (Cochran 1977) with statistical weeks defining strata. Coho salmon were sampled most weeks for ASL information, and to the extent logistically feasible, the sample was collected uniformly throughout each week. Coho salmon were sampled primarily in the mornings and evenings. To avoid potential bias by the selection or capture of individual fish, all fish within the trap were included in the sample, even if the target number of fish was exceeded. Although the weir was in place during the entire season, strata used for analysis of Clear Creek coho salmon biological data only included weeks in which biological samples were collected (Table 2).

Sample size goals were established so that simultaneous 90% interval estimates of the sex and age composition for each week had maximum widths of 0.20 (Bromaghin 1993). Sample sizes obtained using this method were increased to account for the expected number of unreadable scales. The weekly sample size goal for coho salmon at Clear Creek in 2002 was 120 fish. This weekly sample size goal was expected to be a substantial fraction of the weir passage in some weeks (Hetrick and Nemeth 2003). Therefore, a target of about 20% of the weekly escapement was sampled during weeks of low passage when the maximum sample size goal could not be practically obtained. This was sufficient to describe the age composition and reduced the number of fish handled at the weir.

Samples for ASL data were collected using a dip net to remove fish from the holding pen at least once daily or more often as the number of fish moving through the weir increased. Coho salmon were measured to the nearest mm (mid-eye to fork length) and the sex of the fish was determined when possible. Three scales from each coho salmon were removed from the preferred area on the left side (Jearld 1983), cleaned, and mounted on gummed scale cards. Scales were pressed and aged following the field season by USFWS personnel. Standards and guidelines of Mosher (1968) were used in

Table 2. Strata (time periods) used for analysis of Clear Creek weir coho salmon biological data.

Stratum	Dates
1	Sept. 8 - Sept. 14
2	Sept. 15 - Sept. 21
3	Sept. 22 - Sept. 28
4	Sept. 29 - Oct. 5
5	Oct. 6 - Oct. 12
6	Oct. 13 - Oct. 19

aging scales. Salmon ages are reported according to the European method described by Jearld (1983) and Mosher (1968), where the number of winters the fish spent in fresh water and in the ocean is separated by a decimal.

Characteristics of coho salmon passing through the weir were estimated using standard stratified random sampling estimators (Cochran 1977). Within a given stratum *m*, the proportion of species *i* passing the weir that are of sex *j* and age *k* (p_{ijkm}) was estimated as

$$\hat{p}_{ijkm} = \frac{n_{ijkm}}{n_{i++m}},$$

where n_{ijkm} denotes the number of fish of species *i*, sex *j*, and age *k* sampled during stratum *m* and a subscript of "+" represents summation over all possible values of the corresponding variable, e.g., n_{i++m} denotes the total number of fish of species *i* sampled in stratum *m*. The variance of $\hat{p}_{ijkm}$ was estimated as

$$\hat{v}(\hat{p}_{ijkm}) = \left(1 - \frac{n_{i++m}}{N_{i++m}}\right)\frac{\hat{p}_{ijkm}\left(1 - \hat{p}_{ijkm}\right)}{n_{i++m} - 1},$$

where N_{i++m} denotes the total number of species *i* fish passing the weir in stratum *m*. The estimated number of fish of species *i*, sex *j*, age *k* passing the weir in stratum *m* ($\hat{N}_{ijkm}$) was

$$\hat{N}_{ijkm} = N_{i++m}\hat{p}_{ijkm},$$

with estimated variance

$$\hat{v}(\hat{N}_{ijkm}) = N_{i++m}^{2}\hat{v}(\hat{p}_{ijkm}).$$

Estimates of proportions for the entire period of weir operation were computed as weighted sums of the stratum estimates, i.e.,

$$\hat{p}_{ijk} = \sum_{m}\left(\frac{N_{i++m}}{N_{i+++}}\right)\hat{p}_{ijkm}$$

and

$$\hat{v}\left(\hat{p}_{ijk}\right) = \sum_{m}\left(\frac{N_{i++m}}{N_{i+++}}\right)^{2}\hat{v}\left(\hat{p}_{ijkm}\right).$$

The total number of fish in a species, sex, and age category passing the weir during the entire period of operation was estimated as

$$\hat{N}_{ijk} = \sum_m \hat{N}_{ijkm}$$

with estimated variance

$$\hat{v}(\hat{N}_{ijk}) = \sum_m \hat{v}(\hat{N}_{ijkm}).$$

If the length of fish of species i, sex j, and age k sampled in stratum m is denoted x_{ijkm}, the sample mean length of fish of species i, sex j, and age k within stratum m was calculated as

$$\bar{x}_{ijkm} = \frac{\sum x_{ijkm}}{n_{ijkm}}$$

with corresponding sample variance s^2_{ijkm}

$$s^2_{ijkm} = \left(1 - \frac{n_{ijkm}}{\hat{N}_{ijkm}}\right)\frac{\sum\left(x_{ijkm} - \bar{x}_{ijkm}\right)^2}{n_{ijkm} - 1}.$$

The mean length of all fish of species i, sex j, and age k ($\hat{\bar{x}}_{ijk}$) was estimated as a weighted sum of the stratum means, i.e.,

$$\hat{\bar{x}}_{ijk} = \sum_m \left(\frac{\hat{N}_{ijkm}}{\hat{N}_{ijk}}\right)\bar{x}_{ijkm}.$$

An approximate estimator of the variance of $\hat{\bar{x}}_{ijk}$ was obtained using the delta method (Seber 1982),

$$\hat{v}(\hat{\bar{x}}_{ijk}) = \sum_m \left\{ \hat{v}(\hat{N}_{ijkm}) \left[\frac{x_{ijkm}}{\sum_x \hat{N}_{ijkx}} - \sum_y \frac{\hat{N}_{ijky}}{\left(\sum_x \hat{N}_{ijkx}\right)^2} x_{ijky} \right]^2 + \left(\frac{\hat{N}_{ijkm}}{\sum_x \hat{N}_{ijkx}} \right)^2 s^2_{ijkm} \right\}.$$

Carrying Capacity Estimates

The habitat limiting factor model (HLFM) of Nickelson (1998) was used to examine potential habitat factors that could be limiting production, and to estimate carrying capacities in the Kametolook system and in Clear Creek. Results of the model for Clear Creek were compared to previous year's escapement estimates (Hetrick and Nemeth 2003) as a benchmark for model performance. The HLFM uses available habitat (surface area) for each habitat type as measured in the habitat inventory. The model then applies habitat-type specific potential juvenile coho salmon rearing densities over three seasons (spring, summer, and winter; Table 3) to estimate total system production potential for each season, and also uses available spawning habitat to estimate potential egg production. Density-independent survival rates (Table 4) are then applied to the potential seasonal carrying capacity estimates to generate potential smolt production estimates for each season. The specific life-stage that limits production of smolts in the system is that which produces the lowest number of smolts.

Table 3. Seasonal juvenile coho salmon potential densities (fish/m^2) by habitat type used in the habitat limiting factor model of Nickelson (1998).

Habitat Type	Spring	Summer	Winter
Cascade	0.00	0.24	0.00
Rapid	0.60	0.14	0.01
Riffle	1.20	0.12	0.01
Glide	1.81	0.77	0.12
Trench Pool	0.99	1.79	0.15
Plunge Pool	0.84	1.51	0.28
Scour Pool	1.29	1.74	0.35
Dam Pool	2.56	1.84	0.56
Alcove	5.75	0.92	1.84
Beaver Pond	2.56	1.84	1.84
Backwater	5.75	1.18	0.58

Table 4. Density-independent survival rates (survival to smolt) from specific life stages used by the habitat limiting factor model of Nickelson (1998).

Life stage	Survival rate to smolt
Egg	0.32
Spring fry	0.46
Summer parr	0.72
Winter pre-smolt	0.90

Once an estimate of smolt production was obtained from the HLFM, back-calculations were used to determine the number of adult coho salmon necessary to fully seed the available habitat in the Kametolook and Clear Creek systems and to estimate potential production. The following equations are taken from Nickelson (1998). Potential smolt density (C, fish/m^2) was calculated as

$$C = \frac{M}{SA},$$

where M is the maximum smolt capacity from the HLFM model and SA is the total surface area measured in m^2. Survival to the smolt stage (S_{smolt}) was then calculated as

$$S_{smolt} = S_{egg} * S_{ow},$$

where S_{egg} was a constant egg-to-summer parr survival rate of .072 and overwinter survival (S_{ow}) was calculated as

$$S_{ow} = 0.1361 * \log_e C + 0.487 + E,$$

where E is an error term. The egg deposition (D_M) needed to produce the maximum smolt capacity (M) was then calculated as

$$D_M = \frac{M}{S_{smolt}}.$$

The minimum number of spawners necessary (A_M) to produce the required egg deposition was calculated as

$$A_M = \left(\frac{D_M}{2{,}500}\right) * 2,$$

which assumed a 1:1 sex ratio and 2,500 eggs per female. The potential production (PP_x) of the system was then determined as

$$PP_x = M * x,$$

where x represents the marine survival rate. For this analysis, three different marine survival rates (x = 0.03, 0.05, and 0.10) were used. Although the model of Nickelson (1998) recommends measuring available habitat for each season used in the model, only summer habitat was measured for logistical reasons in 2002. The assumption was that if our observed summer densities of juvenile coho salmon were similar to those of Nickelson (1998), the potential spring and winter juvenile densities used in the HLFM model would be sufficient to produce a usable estimate of smolt production in the

Kametolook and Clear Creek systems. Actual estimates of coho salmon escapement in Clear Creek were also used to validate HLFM estimates.

Results

Habitat Inventory

Over 43 km of stream were surveyed in the Kametolook drainage and the entire 12 km of channel accessible to salmon was surveyed in Clear Creek during the summer of 2002 (Figure 3; Figure 4). Habitat composition was similar between the Kametolook system and Clear Creek (Table 5). Four habitat types comprised over 90% of available habitat in both systems: riffles, glides, lateral scour pools, and mid-channel scour pools (Table 5). No trench pools, dammed pools, or beaver ponds were observed in Clear Creek in 2002 and no beaver ponds were observed in the Kametolook drainage (Table 5). Small ponds and swamps in the Kametolook drainage were classified as beaver pond habitat for use in the Nickelson (1998) model.

Habitat quality was also similar between systems. The mean percent pocket water (Figure 5), boulder (Figure 5), and turbulence (Figure 6) cover types were similar between drainages. For all habitat types, mean percent overhead cover (Figure 6), large woody debris (LWD; Figure 7), and undercut bank cover (Figure 7) were generally greater in the Kametolook system than in Clear Creek. Twenty-nine percent and 16% of the total surface area in Clear Creek and the Kametolook system was categorized as usable spawning habitat, and the distribution of spawning habitat varied among habitat types (Figure 8). Over 88% of habitat units in the Kametolook system had width-to-maximum depth ratios of less than 10, and 77% of habitat units in Clear Creek had width-to-maximum depth ratios of less than 10 (Figure 9). Percent fine sediments were lower in Clear Creek than in the Kametolook system (Figure 10); percent surface fine sediments < 4 mm in Clear Creek was 12%, and was 20% in the Kametolook system. Both systems had minimal substrate embeddedness in 2002. Substrate embeddedness was estimated to be less than 50% for over 80% of the habitat units sampled in the Kametolook system and at all of the of the units sampled on Clear Creek (Figure 10).

Water temperatures were similar between tributaries in the Kametolook system and Clear Creek in 2002 (Figure 11). Stream temperatures generally declined as the season progressed from summer to fall, and fluctuations from daily minimum to daily maximum temperatures were minimal after early September. Only one of the three thermographs deployed in the Kametolook drainage provided useful data in 2002. One thermograph was lost following a flood event in mid-September, and one thermograph malfunctioned shortly after deployment.

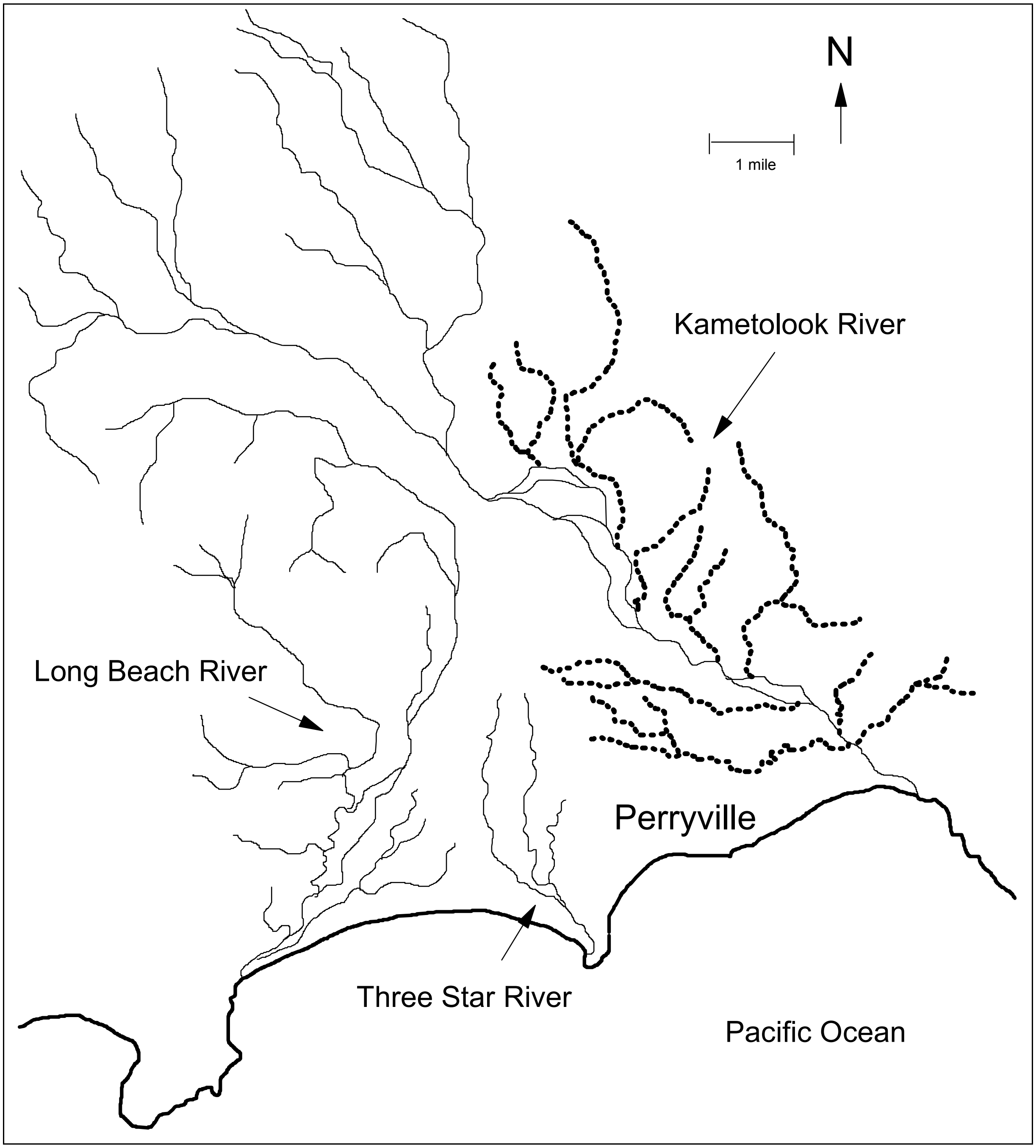
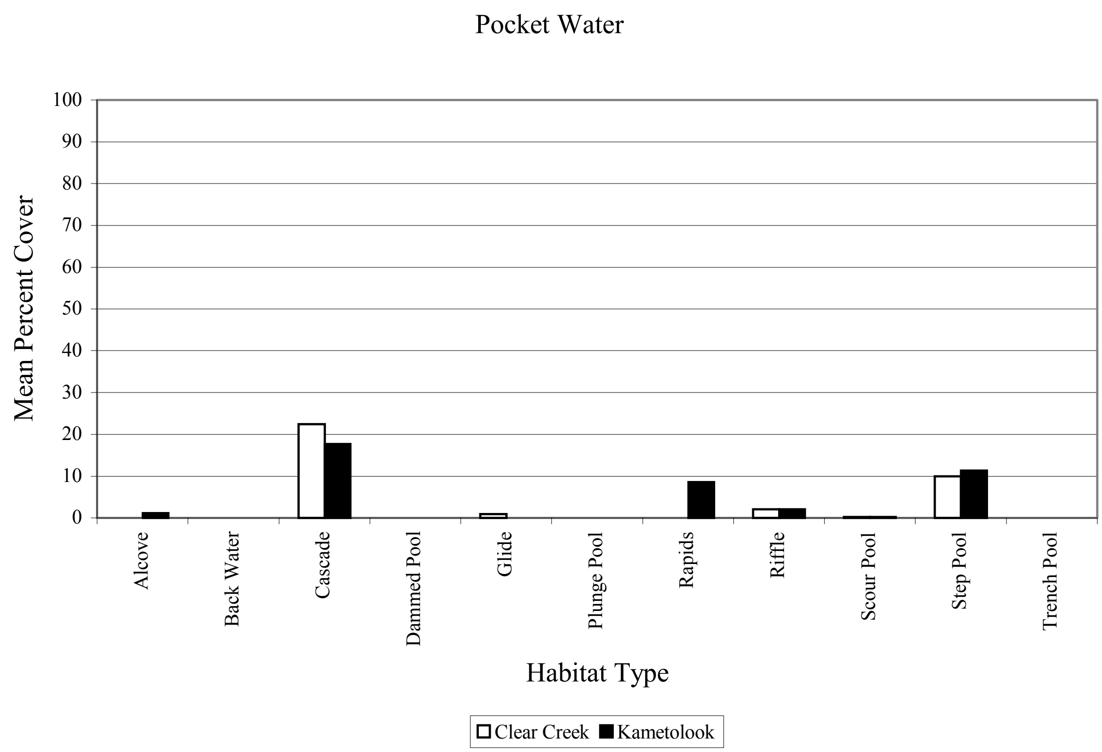


Figure 4. Streams in the Kametolook drainage where habitat inventory was completed in 2002 (heavy dashed lines).

Table 5. Summary of habitat composition surveyed in Clear Creek and the Kametolook River drainages, 2002.

	Clear Creek		Kametolook River	
Habitat Type	Surface Area (m^2)	Percent Composition	Surface Area (m^2)	Percent Composition
Cascade	152	< 1	1,026	< 1
Rapid	9	< 1	1,806	1
Riffle	26,695	41	50,911	32
Glide	13,389	19	42,168	26
Trench Pool	0	< 1	1,389	< 1
Plunge Pool	153	< 1	538	< 1
Lateral Scour Pool	10,602	15	31,433	20
Mid-channel Scour Pool	15,359	21	18,721	12
Dam Pool	0	< 1	115	< 1
Alcove	32	< 1	289	< 1
Beaver Pond	0	< 1	10,437[a]	6
Backwater	2,332	3	1,939	1
Total:	71,723		160,773	

[a] Beaver pond habitat in the Kametolook system consisted of small lakes and swamps.



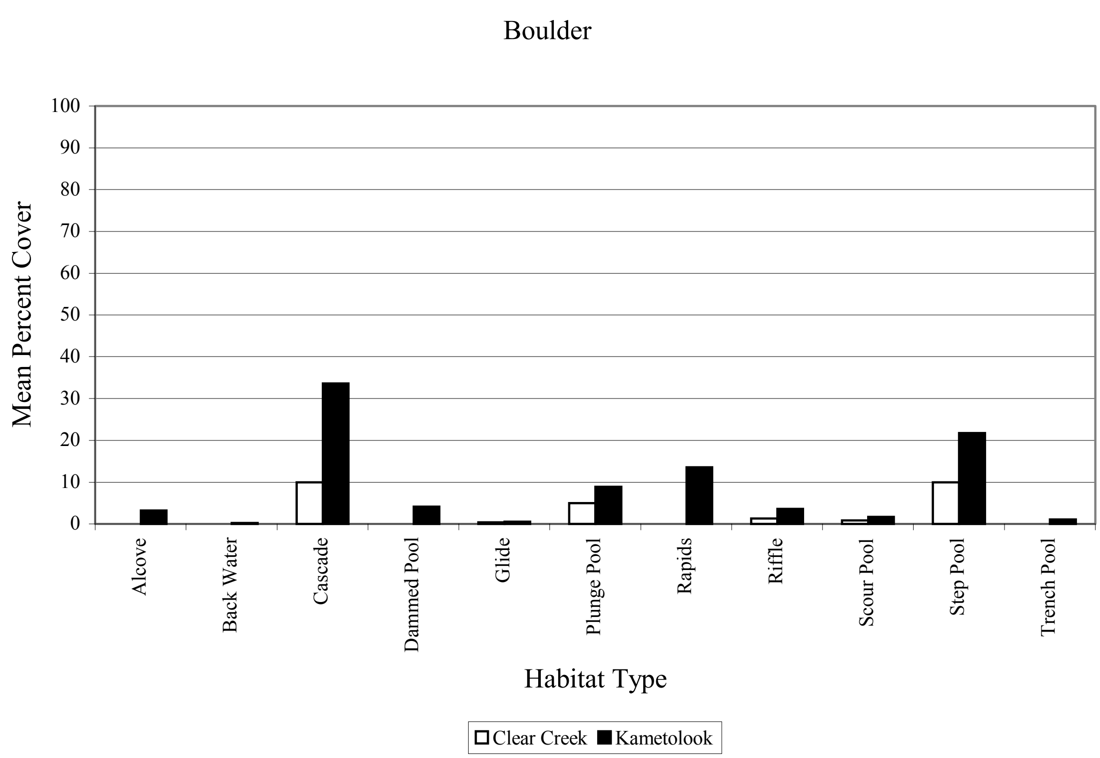
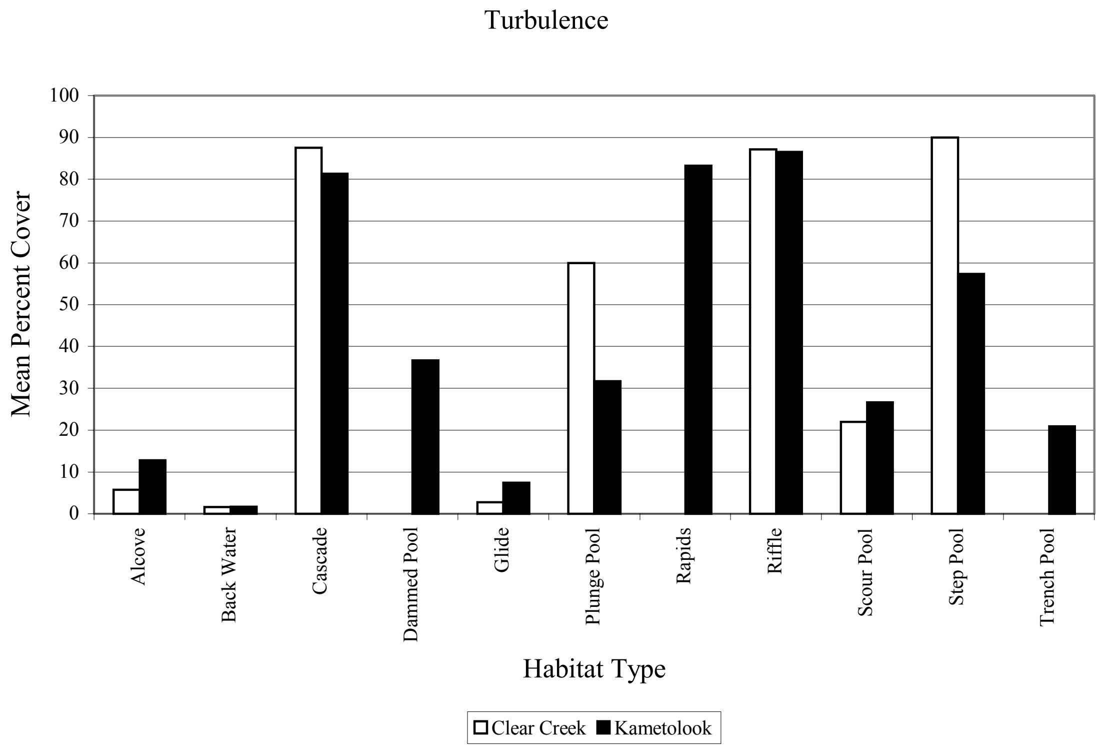


Figure 5. Mean percent pocket water and boulder cover by habitat type in the Kametolook system and Clear Creek, 2002.



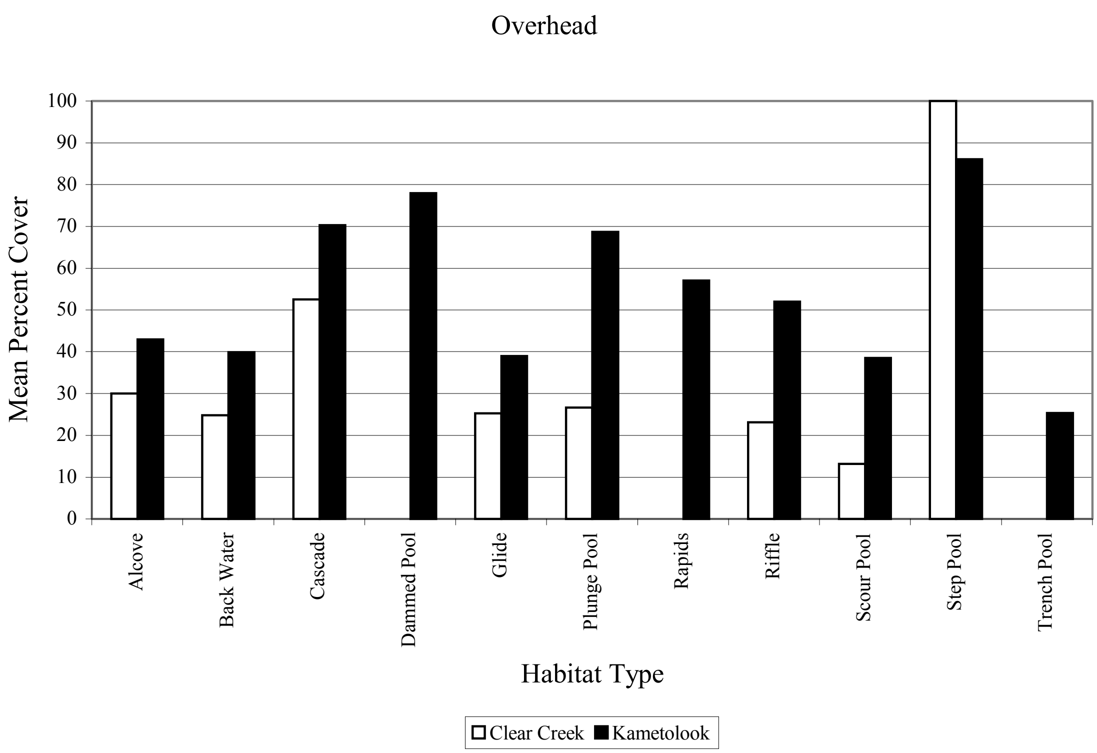
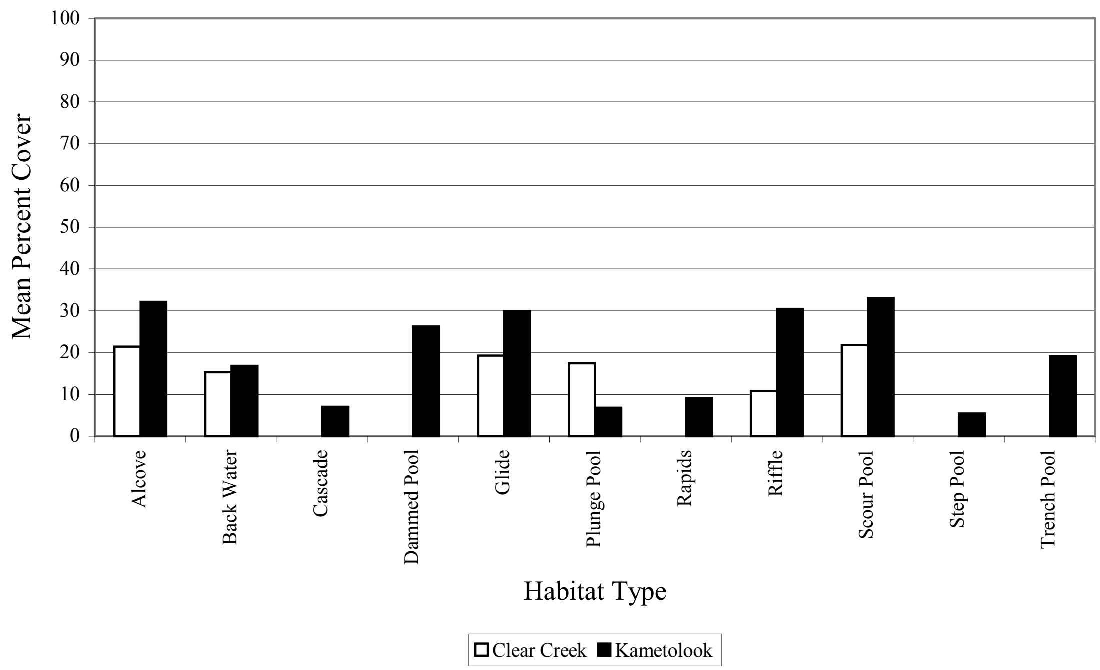


Figure 6. Mean percent turbulence and overhead cover by habitat type in the Kametolook system and Clear Creek, 2002.

Undercut Bank



Large Woody Debris

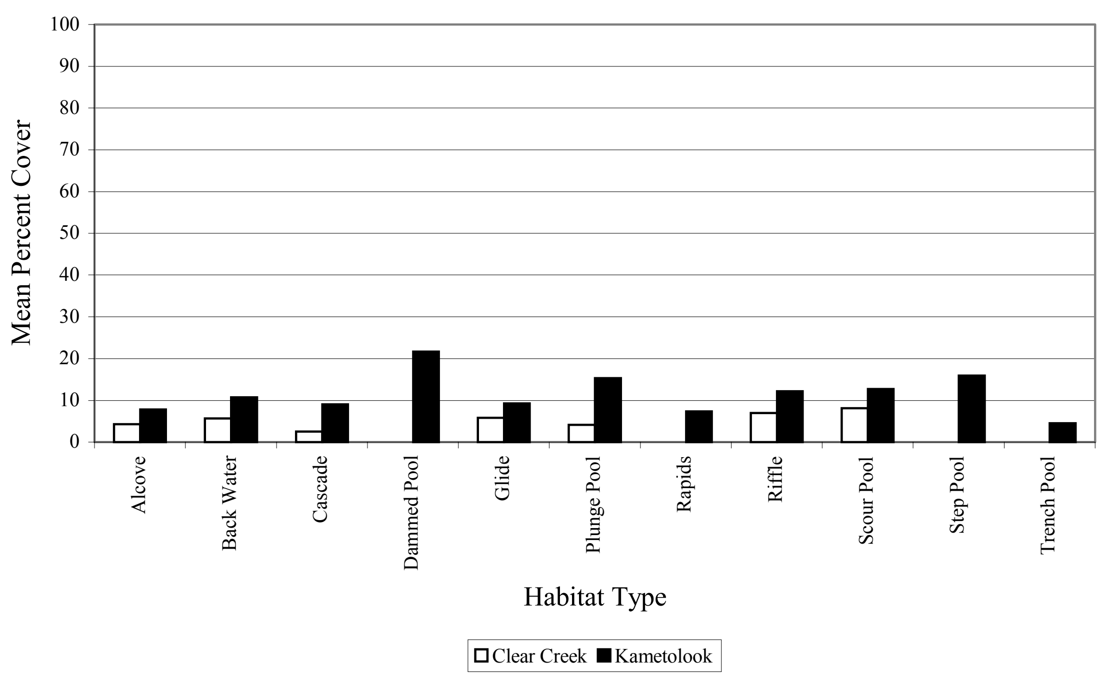


Figure 7. Mean percent undercut bank and large woody debris cover by habitat type in the Kametolook system and Clear Creek, 2002.

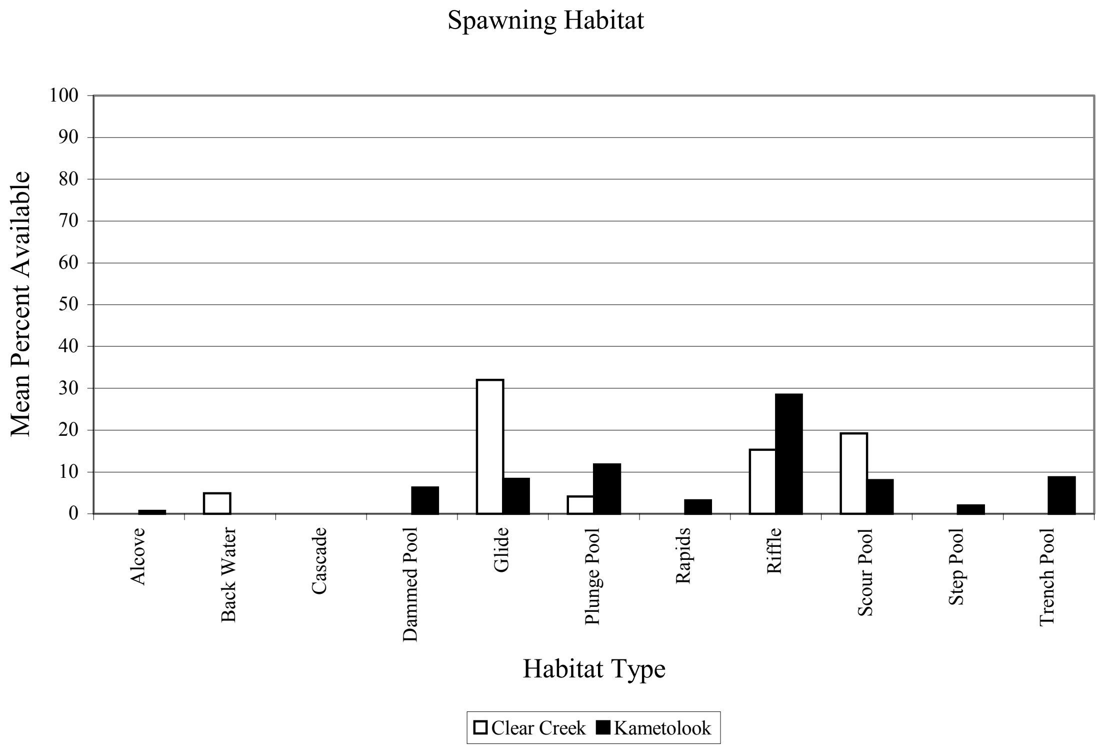


Figure 8. Mean percent available spawning habitat by habitat type in the Kametolook system and in Clear Creek, 2002.

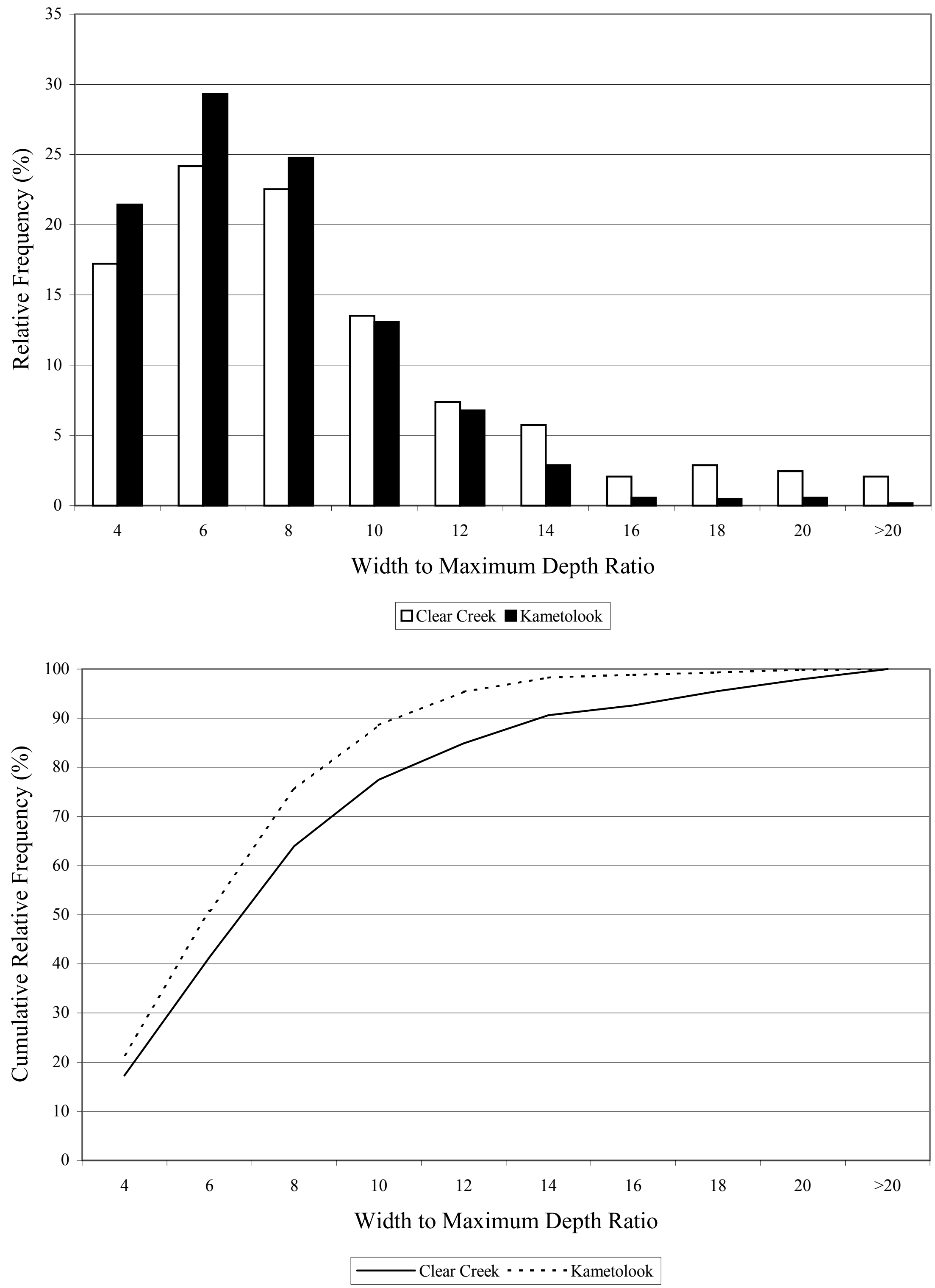


Figure 9. Relative (top) and cumulative (bottom) frequency distributions of width to maximum depth ratios in the Kametolook system and Clear Creek, 2002.

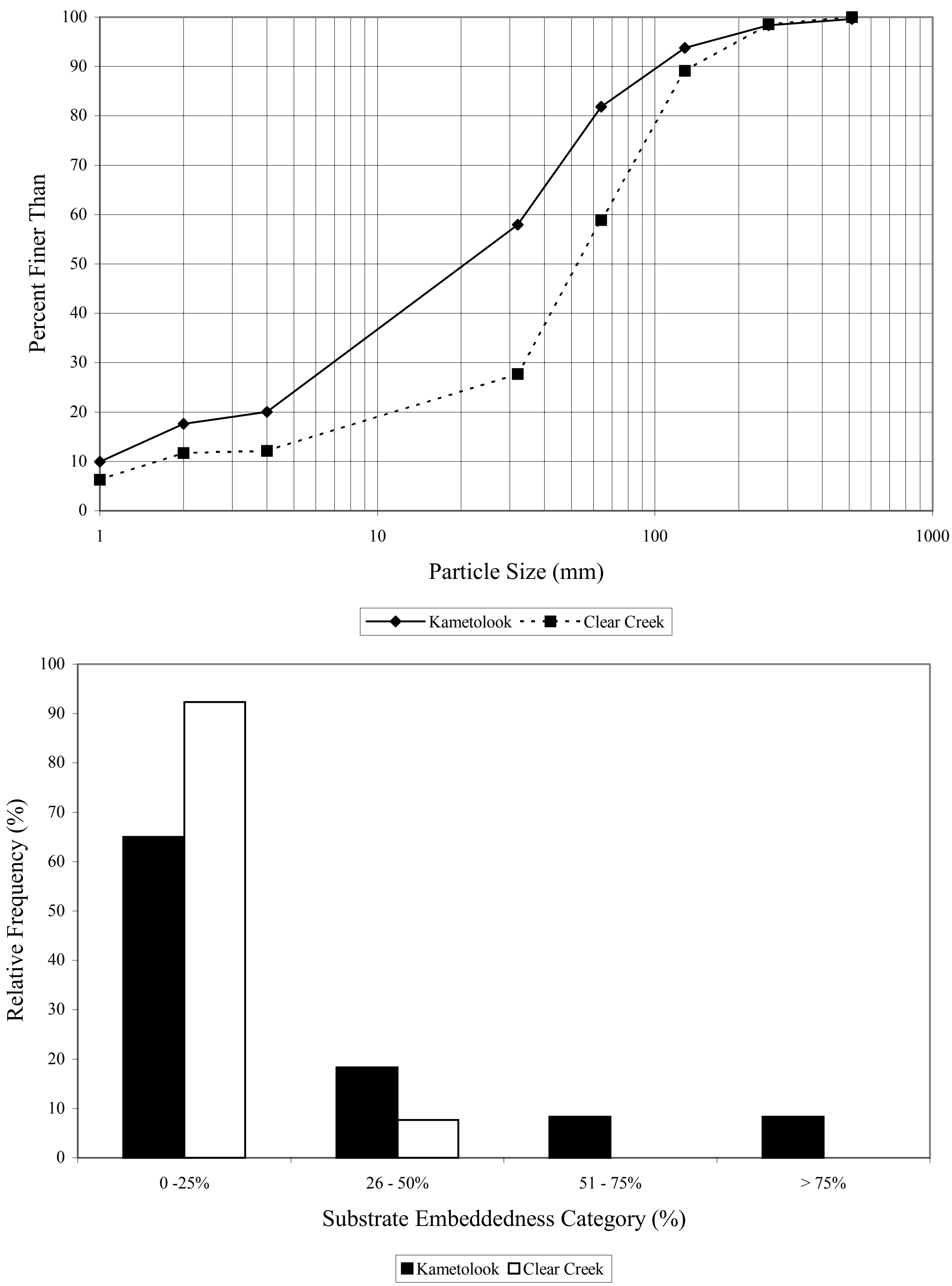


Figure 10. Summary of surface substrate particle size (top) and percent embeddedness in the Kametolook system and in Clear Creek, 2002.

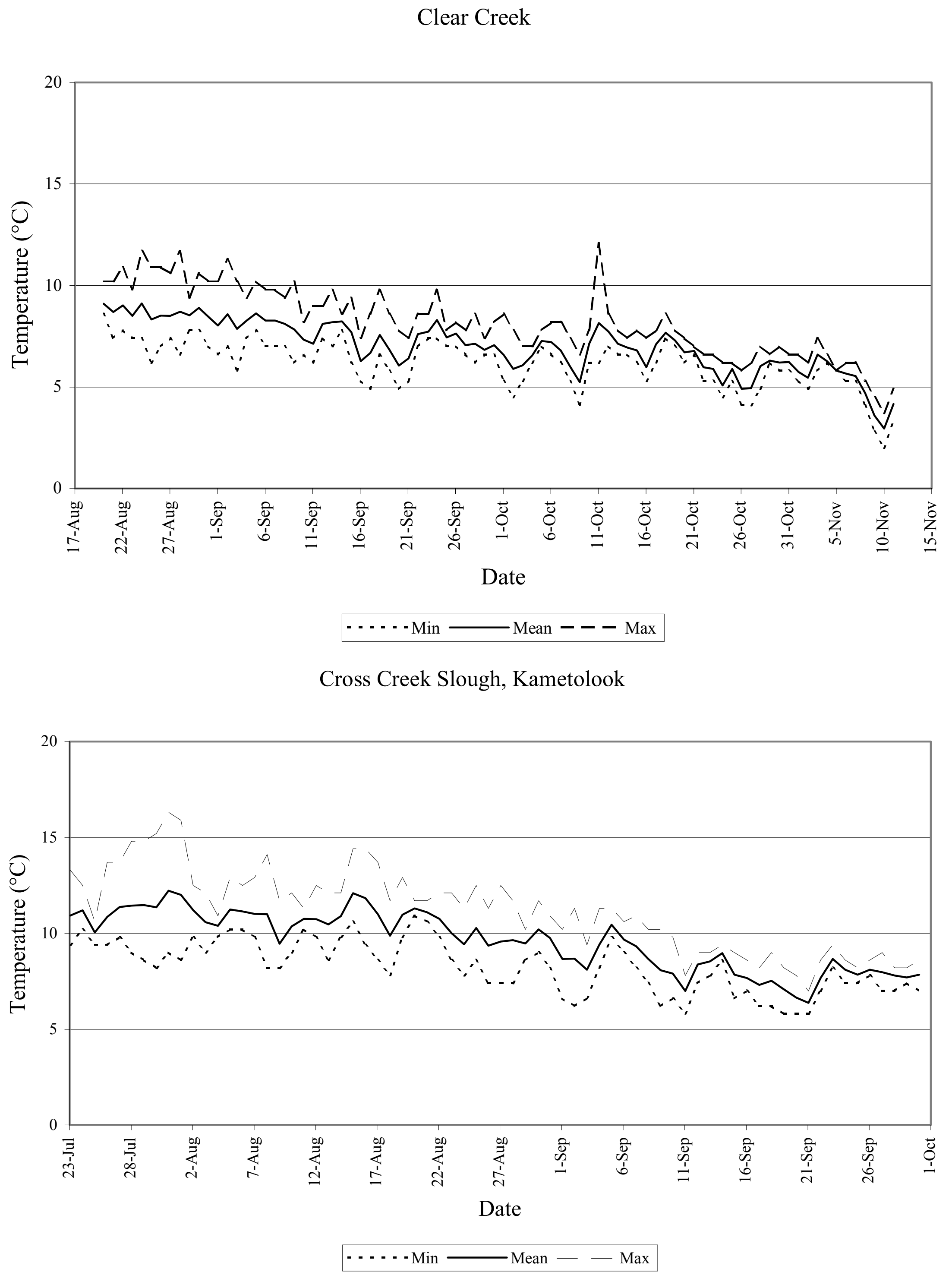


Figure 11. Daily minimum, mean, and maximum temperatures in Clear Creek and the Kametolook drainage, 2002.

Clear Creek Juvenile Sampling

Mean densities of juvenile coho salmon in Clear Creek estimated from snorkel surveys ranged from 0.00 fish/m^2 in cascades to 5.22 fish/m^2 in backwaters (Table 6). Thirty-three habitat units were surveyed in 2002. The lower mainstem of Clear Creek was not sampled in 2002 as spawning pink and chum salmon increased turbidity, creating conditions unsuitable for snorkel surveys. Based on the proportional habitat composition of Clear Creek in 2002 (Table 5), no rapids, trench pools, dammed pools, or beaver ponds were sampled. Juvenile chinook salmon and Dolly Varden were also observed during snorkel surveys in 2002. Mean densities of juvenile chinook salmon ranged from 0.00 to 0.36 fish/m^2 and were only observed in backwaters, glides, riffles, and scour pools in 2002 (Table 6). Mean densities for Dolly Varden ranged from 0.00 to 1.03 fish/m^2; and were observed in all habitat types sampled in 2002 except alcoves (Table 6).

Six scour pools and two plunge pools were sampled using minnow trap removal methods during late summer and fall of 2002. Four removal events were used in six of the eight habitat units sampled (Table 7). Using the criterion of White et al. (1982) (goodness of fit test p-value > 0.20), only two samples produced valid population and density estimates in 2002 (Table 7). Mean densities of juvenile coho salmon for the two valid removal estimates were 9.4 fish/m^2 (plunge pool) and 1.37 fish/m^2 (scour pool) (Table 7). The mean length of juvenile coho salmon measured in 2002 (n = 109) was 59.7 mm (standard error = 0.93), and ranged from 45 to 91 mm (Figure 12).

Table 6. Mean juvenile fish density estimates (#/m^2) and standard error (SE) by habitat type (number sampled in parentheses) for streams sampled with snorkel surveys in the Clear Creek drainage, 2002.

	Coho salmon		Chinook salmon		Dolly Varden	
Habitat Type	Mean Density	SE	Mean Density	SE	Mean Density	SE
Alcove (1)	0.25	--	0.00	--	0.00	--
Backwater (2)	5.22	0.43	0.36	0.36	0.19	0.19
Cascade (1)	0.00	--	0.00	--	0.69	--
Glide (7)	1.33	0.48	0.03	0.02	0.01	0.01
Plunge Pool (2)	3.63	3.16	0.00	0.00	1.03	0.64
Riffle (15)	0.21	0.07	0.02	0.01	0.21	0.06
Scour Pool (5)	1.43	0.34	0.04	0.03	0.14	0.10

Table 7. Summary of minnow trap removal estimates, 2002. Density estimates are reported as fish/m^2.

Sample Date	Habitat Type	Event 1	Event 2	Event 3	Event 4	Estimate (95% C.I.)	Model	p-value	Density (95% C.I.)
25 August	Plunge Pool	59	12	7	1	79 (79 to 79)	Equal P_c	0.2047	9.40 (9.40 to 9.40)
26 August	Scour Pool	95	24	16	45	231 (203 to 289)	Equal P_c	0.0000	2.72 (2.39 to 3.40)
27 August	Scour Pool	90	33	11	9	146 (143 to 155)	Equal P_c	0.2250	1.37 (1.34 to 1.45)
21 September	Plunge Pool	415	260	82		856 (823 to 903)	Equal P_c	0.0001	16.98 (16.33 to 17.92)
22 September	Scour Pool	41	86	94	222	--	--	--	--
28 September	Scour Pool	174	145	64	53	495 (467 to 547)	Unequal P_c	0.0322	20.68 (19.51 to 22.85)
29 September	Scour Pool	103	16	37		226 (204 to 271)	Equal P_c	0.0898	4.15 (3.74 to 4.97)
9 October	Scour Pool	25	27	16	27	674 (129 to 9,734)	Equal P_c	0.1698	5.59 (1.07 to 80.76)

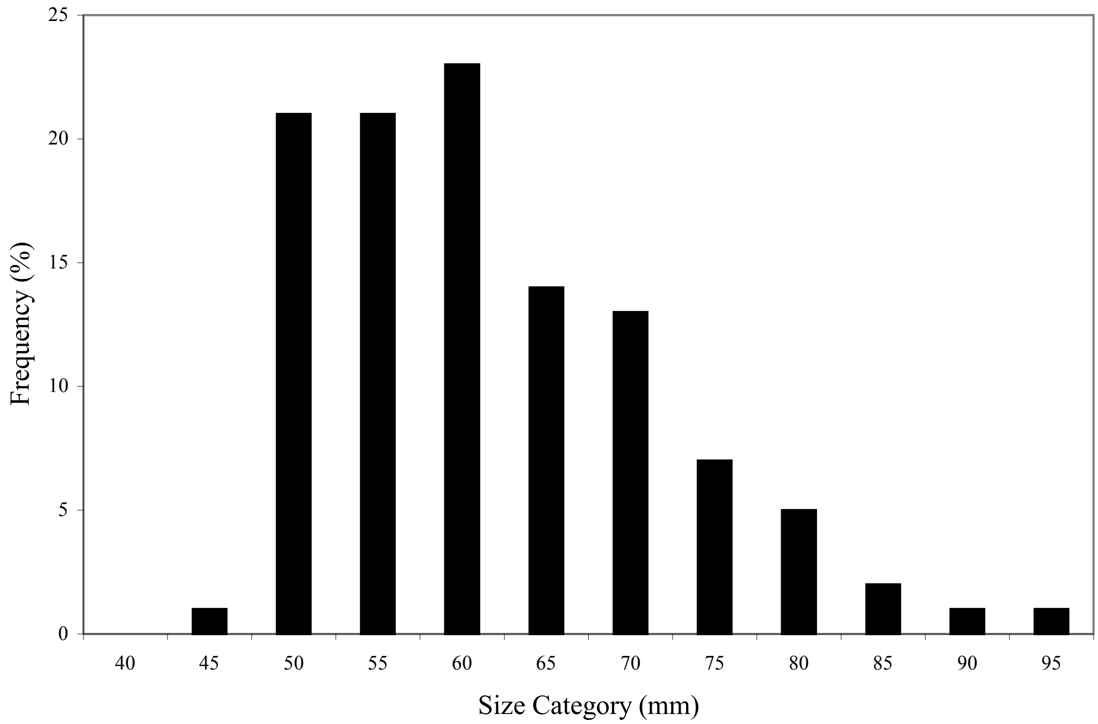


Figure 12. Length - frequency distribution of juvenile coho salmon measured in Clear Creek, 2002.

Escapement Monitoring

Based on consultations with local residents, five streams were chosen for escapement monitoring in 2002, three tributaries to the Kametolook River, the entire Three Star River, and one tributary to the Long Beach River (Figure 13). Adult surveys were initiated during the first week in October. Training was provided which included setting up reaches on the survey streams, identifying and enumerating salmon, and proper recording of data and observation conditions. The training also included the initial surveys on all five streams. Two hundred ninety coho salmon were observed in 2002, with the majority counted on the second survey of the season (Table 8). Extrapolated counts in 2002 ranged from 37 coho salmon in Cross Creek Slough to 342 coho salmon in Artemie's Creek (Table 8).

The Clear Creek weir was installed on 1 September and removed on 12 November 2002. One thousand ninety-seven coho salmon, 5,153 pink salmon, 269 chum salmon, and 32 sockeye salmon were counted past the weir in 2002 (Appendix A). Coho salmon were counted past the weir from 14 September to 11 November, and peak counts occurred in

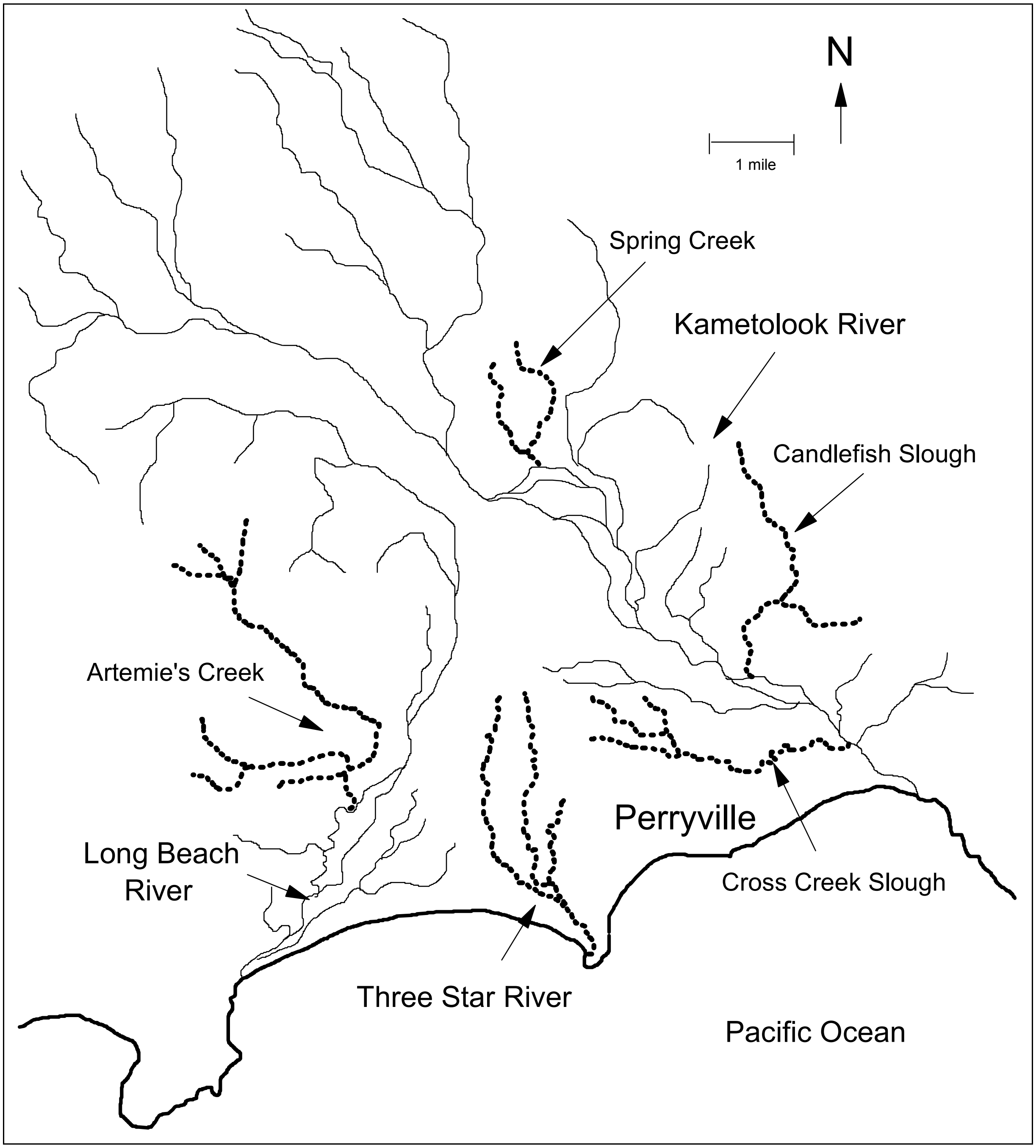


Figure 13. Streams near Perryville where stream walking surveys for adult coho salmon were completed in 2002 (heavy dashed lines).

Table 8. Numbers of coho (CO), pink (PK), and sockeye (SE) salmon observed during stream walking surveys and extrapolated estimates for coho salmon in streams near Perryville, 2002.

	Three Star River			Artemie's Creek			Cross Creek Slough			Spring Creek			Candlefish Slough		
Survey Period	CO	PK	SE	CO	PK	SE	CO	PK	SE	CO	PK	SE	CO	PK	SE
1 - 3 October	14	0	10	1	4	7	2	1	28	15	11	36	0	5	3
15 - 16 October	117	0	2	128	0	0	13	0	0	NC	NC	NC	NC	NC	NC
25 - 26 November	0	0	0	0	0	0	0	0	0	NC	NC	NC	NC	NC	NC
Estimate:	337	*	*	342	*	*	37	*	*	*	*	*	*	*	*

NC = Stream could not be counted due to high water.
* An estimate was not calculated.

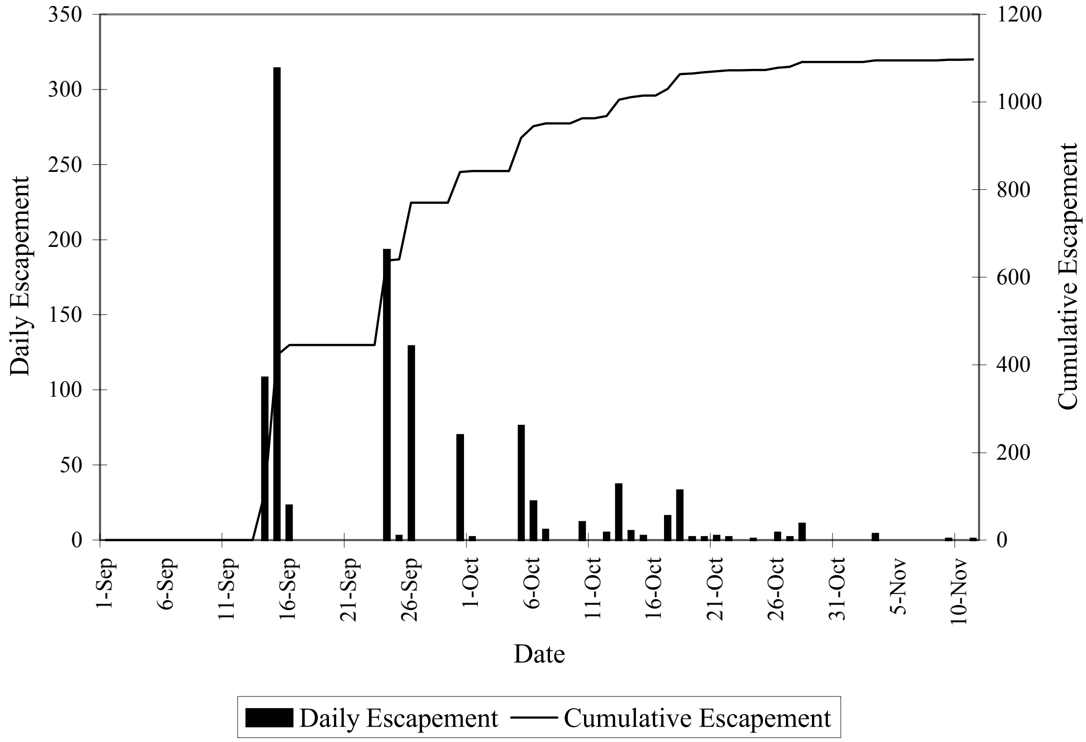


Figure 14. Daily and cumulative escapement of coho salmon past the Clear Creek weir, 2002.

mid- to late-September (Figure 14; Appendix A). Pink salmon were not counted after 4 October, chum salmon were not counted after 25 September, and all but one sockeye salmon had been counted past the weir by 24 September (Appendix A). Picket spacing (38 mm) allowed small pink salmon to pass through the weir without being counted. Although some Dolly Varden were trapped in the weir, most were small enough to pass through the pickets. The weir was nonfunctional on five different occasions for about 10 days in 2002 because of high water (Table 9).

Table 9. Summary of Clear Creek weir failures, 2002.

Date/Time down	Date/Time repaired	Hours Not Functioning
10 October, 18:30	12 October, 12:00	41
21 October, 19:00	22 October, 15:00	20
24 October, 19:00	26 October, 15:00	44
29 October, 17:00	1 November, 14:00	69
4 November, 17:00	7 November, 09:00	64
	Total:	238

Age, Sex, and Length Data

One hundred seventy-five adult coho salmon were sampled for ASL data from 14 September to 18 October 2002. Three age classes were identified from scale samples of 147 of the 175 fish sampled at the Clear Creek weir in 2002; 28 samples (16%) were unreadable. Fish that could not be aged were not included in the ASL data analyses. Thirty-two coho salmon passed the weir after 19 October that were not sampled so estimates of ASL compositions are only valid for the 1,065 coho salmon that passed the weir prior to 19 October. Over all strata, ages 2.1 (61%) and 1.1 (39%) were the most common age classes sampled in 2002 (Table 10). Only one age 3.1 coho salmon was observed in 2002. Age composition varied by week, ranging from 44% age 2.1 coho salmon in stratum 4 to 77% age 2.1 in stratum 6 (Table 10). Age 2.1 coho salmon comprised at least 58% of the run in all strata except stratum 4 (Table 10). Overall sex composition of coho salmon sampled at the Clear Creek weir in 2002 was 54% males and 46% females (Table 11). Sex composition varied by strata, ranging from 44% males in stratum 4 to 64% males in stratum 5 (Table 11); male coho salmon comprised at least 53% of the run in all strata except stratum 4. Lengths of coho salmon sampled in 2002 ranged from 530 to 691 mm for females, and from 508 to 693 mm for males (Table 12; Figure 15). In general, mean lengths of age 2.1 coho salmon were greater than age 1.1 coho salmon, and mean lengths of females were slightly greater than males (Table 12).

Carrying Capacity Estimates

Minimum escapement estimates of 1,493 and 531 adult coho salmon for the Kametolook and Clear Creek systems are necessary to fully seed available habitat (Table 13). Habitat composition in the Kametolook system resulted in slightly higher overwinter survival (S_{ow}) and egg-to-smolt survival (S_{smolt}) estimates than in Clear Creek (Table 13). These parameters resulted in higher production capacity estimates in the Kametolook system than in Clear Creek. Although the total surface area of the Kametolook system was 2.2 times greater than in Clear Creek, the minimum adult escapement estimate (A_M) was 2.8

Table 10. Estimated age composition (percent and number) and standard error (SE) of coho salmon by stratum in Clear Creek, 2002.

					Escapement											
	Sample				1.1				2.1				3.1			
Stratum	n	1.1	2.1	3.1	Percent	SE	Number	SE	Percent	SE	Number	SE	Percent	SE	Number	SE
1	15	4	11	0	27	11.0	29	11.8	73	11.0	79	11.8	0	--	--	--
2	38	16	22	0	42	7.6	142	25.8	58	7.6	195	25.8	0	--	--	--
3	54	20	34	0	37	6.1	120	19.7	63	6.1	205	19.7	0	--	--	--
4	16	9	7	0	56	12.1	83	17.9	44	12.1	65	17.9	0	--	--	--
5	11	3	7	1	27	12.4	14	6.2	64	13.4	32	6.7	9	8.0	5	4.0
6	13	3	10	0	23	11.3	22	11.0	77	11.3	75	11.0	0	--	--	--
Total:	147	55	91	1	39	3.8	410	40.9	61	3.8	650	41.0	<1	0.4	5	4.0

Table 11. Estimated sex composition and standard errors (SE) of coho salmon by stratum in Clear Creek, 2002.

				Escapement						
	Sample			Percent			Number			
Stratum	n	Male	Female	Male	Female	SE	Male	Female	SE	Total
1	15	8	7	53	47	12.4	58	50	13.4	108
2	38	20	18	53	47	7.7	177	160	26.1	337
3	54	30	24	56	44	6.2	181	144	20.3	325
4	16	7	9	44	56	12.1	65	83	17.9	148
5	11	7	4	64	36	13.4	32	18	6.7	50
6	13	8	5	62	38	13.1	60	37	12.7	97
Total:	147	80	67	54	46	4.0	572	493	42.4	1,065

Table 12. Average, standard error (SE), range, and sample size of mid-eye-to-fork lengths (mm) by age class taken from coho salmon at the Clear Creek Weir, 2002.

	Age Class		
	1.1	2.1	3.1
Females			
Mean Length	617	633	--
SE	15.4	10.4	--
Range	530 - 691	580 - 680	--
Sample Size	28	39	0
Males			
Mean Length	606	623	631
SE	17.5	15.6	--
Range	508 - 671	546 - 693	--
Sample Size	27	52	1
All Fish			
Mean Length	612	627	631
SE	16.1	13.7	--
Range	508 - 691	546 - 693	--
Sample Size	55	91	1

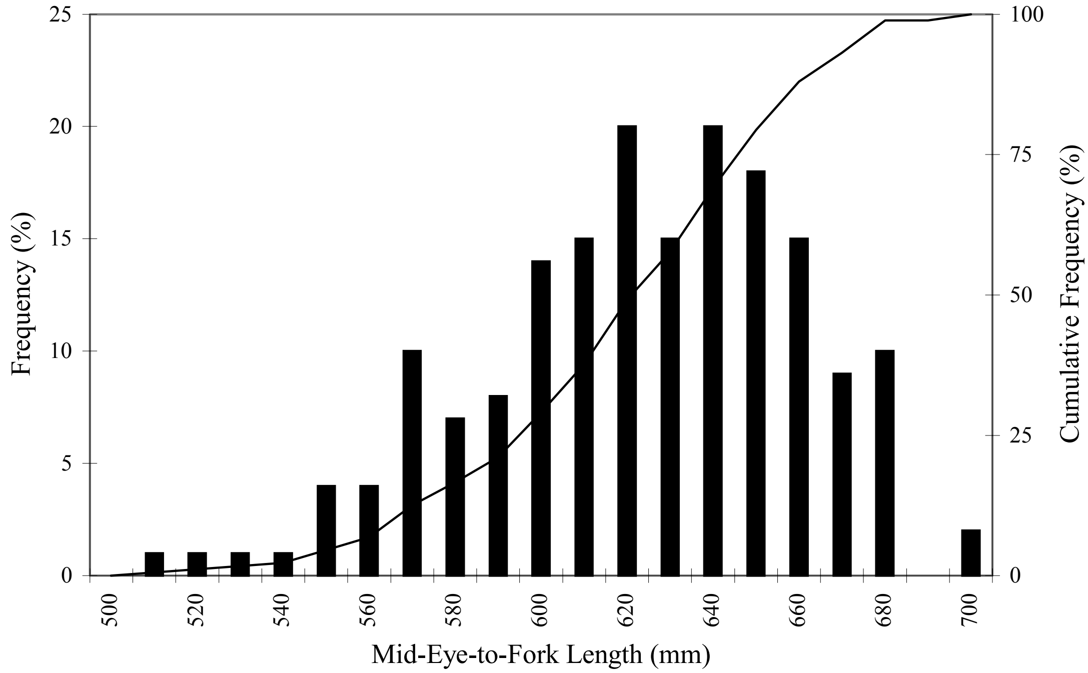


Figure 15. Length-frequency distribution and cumulative length distribution of adult coho salmon sampled at the Clear Creek weir, 2002.

Table 13. Summary of results of the habitat limiting factor model of Nickelson (1998) as applied to the Kametolook and Clear Creek systems, 2002.

Model parameter	Kametolook	Clear Creek
Surface area (m^2)	160,773	71,723
Maximum smolt capacity (M)	40,000	11,200
Potential smolt density (C, fish/m^2)	0.25	0.16
Overwinter survival (S_{ow})	0.30	0.23
Egg-to-smolt survival (S_{smolt})	0.021	0.017
Required egg deposition (D_M)	1,866,351	663,985
Minimum number of adults necessary (A_M)	1,493	531
Potential production (PP_x)		
10% marine survival (PP_{10})	4,000	1,120
5% marine survival (PP_5)	2,000	560
3% marine survival (PP_3)	1,200	336

times greater and the potential production estimate (PP_x) was over 3.5 times greater for the Kametolook system than for Clear Creek (Table 13).

Discussion

Habitat composition and quality was similar between the Kametolook system and Clear Creek in 2002 (Table 5, Figures 5 – 11). Percent surface fine sediments were also relatively low for both systems. Excessive amounts of fine sediments in spawning substrates decrease egg-to-fry survival by reducing flow through the redd, vital for providing oxygen and removing waste (Iwamoto et al. 1978). Fine sediments can also block interstitial spaces in the substrate, making it difficult for fry to emerge from the redd (Iwamoto et al. 1978). Sediment also decreases suitable rearing habitat for fish by filling pools and interstitial spaces and reducing macroinvertebrate production (Bjornn et al. 1977). Although excessive amounts of fine sediments in the substrate can limit survival throughout the freshwater rearing period, the values observed in both systems in 2002 should have a minimal effect on egg-to-parr survival rates. Bjornn and Reiser (1991) show that embryo survival is relatively unchanged when the substrate composition is less then 25 % fine sediments (< 6.35 mm). Chapman and Mcleod (1987) estimated survival to emergence (STE) for chinook salmon was near 80% for fine sediment (< 6.4 mm) levels near 20%, that STE declines rapidly as fine sediment levels reach 30%, and that STE decreases to 25% at fine sediment levels near 45%. Based on substrate compositions we measured in the Kametolook system (20% fines) and Clear Creek (12% fines) STE for both systems is expected to be near 80%.

Summer densities of juvenile coho salmon observed during snorkel surveys in Clear Creek in 2002 were similar to those used by Nickelson (1998) to determine habitat-type specific seasonal carrying capacities (Table 14). Although not compared statistically, mean density estimates in Clear Creek for cascades, alcoves, and scour pools were less than those used by Nickelson (1998), and mean density estimates in Clear Creek for backwaters, glides, plunge pools, and riffles were greater than those of Nickelson (1998) (Table 14). With the exception of backwaters and plunge pools, differences between observed Clear Creek mean densities and those of Nickelson (1998) were minimal (Table 14). Only two backwater habitat units were sampled in Clear Creek in 2002, and both had high densities compared to the adjacent units. Fifty-two coho salmon were observed in one backwater that was situated in the middle of a long glide with minimal cover. The other backwater unit was located near the end of a long riffle, and 101 juvenile coho salmon were observed near a large rootwad. A similar situation occurred in one of the two plunge pools sampled in 2002: 57 juvenile coho salmon were observed in a relatively short (3.5 m) pool with abundant cover provided by LWD. Mean juvenile coho salmon densities observed in Clear Creek in 2002 were also similar to those observed by Crone and Bond (1976) in a southeast Alaska system. The scour pool density estimate of 1.43 fish/m^2 is near levels reported for systems at or near carrying capacity (1.5 - 2.0 parr/m^2 of pool; Nickelson et al. 1992).

Table 14. Habitat-type specific mean summer densities of coho salmon observed in Clear Creek in 2002 and those used by Nickelson (1998).

	Mean Summer Density (fish/m^2)	
Habitat Type	Nickelson (1998)	Clear Creek, 2002
Cascade	0.24	0.00
Rapid	0.14	--
Riffle	0.12	0.21
Glide	0.77	1.33
Trench Pool	1.79	--
Plunge Pool	1.51	3.63
Scour Pool	1.74	1.43
Dam Pool	1.84	--
Alcove	0.92	0.25
Beaver Pond	1.84	--
Backwater	1.18	5.22

Minnow trap removal estimates were not effective for sampling juvenile coho salmon in 2002, as only two of the eight habitat units sampled provided usable estimates. Two of the six units sampled using four capture events had usable estimates (Table 7). Depletion for all four events was not achieved in three units. For one unit, depletion was achieved between capture events, but the chi-square goodness of fit test indicated that the capture probabilities (P_c) between events were not constant (Table 7). One of the units sampled with four capture events actually produced inverse depletion. There is no logical explanation for this: the block nets were functioning (no immigration), traps were set in the same places for each capture event, there were no areas where fish were congregated or observed in schools between capture events, and there were no localized areas of cover present where fish could have been hiding between capture events. Of the two units sampled with three capture events, one unit did not produce depletion between all three events and one unit had unequal P_c between the first and second capture event (Table 7). If a fourth capture event had been added at this habitat unit, the unequal P_c model may have provided a usable estimate (White et al. 1982).

Snorkel density estimates in Clear Creek in 2002 are minimum estimates. Two habitat units had both snorkel counts and a removal estimate conducted within a two-day period. In both habitat units, the numbers of juvenile coho salmon observed while snorkeling were less than the cumulative number sampled with minnow traps (Table 15). Although immigration may have occurred in the time between snorkel and minnow trap sampling,

Table 15. Comparison of snorkel and minnow trap sampling techniques for two habitat units sampled in Clear Creek, 2002.

Habitat Type	Snorkel Survey			Minnow Trap Removal		
	Date Sampled	Number Observed	Density (fish/m^2)	Date Sampled	Number Observed	Density (fish/m^2)
Plunge Pool	24 August	57	6.79	25 August	79	9.40
Scour Pool	24 August	135	1.59	26 August	180	--

it is unlikely that this factor alone was responsible for the observed differences. Both habitat units sampled with snorkel and minnow trap removal techniques had distinct breaks at the upper and lower ends, and juvenile fish movement in or out of the unit was thought to be minimal. Although conditions for snorkeling were excellent (visibility was greater than 7 m in both units), many juvenile coho salmon managed to avoid detection by the snorkel teams. In the plunge pool sampled using both methods, a considerable amount of LWD and turbulence cover was present, providing ample opportunity for fish to avoid detection. In the scour pool, however, amount of cover present was minimal, and all juvenile fish should have been visible to the snorkel teams.

Extrapolated counts of adult coho salmon in the Perryville area in 2002 were not inclusive of the entire spawning run. High water due to steady rain and rain-on-snow events caused rivers to flood at different times throughout the survey period. An area-under-the-curve (AUC) estimate was not possible for Spring Creek and Candlefish Slough since high water prevented access after the first survey. The flooding also affected the planned survey intervals as the high water prevented access to all streams after mid-October (Table 8). A considerable number of coho salmon could have entered the streams, spawned, and died undetected during this period. When access to the streams was possible again in late November, coho salmon had completed spawning for the season. Hetrick and Nemeth (2003) recommended survey intervals near the expected residence time specific to the species and survey period (i.e., early or late in the season) for maximum logistical efficiency. Surveys were planned at two-week intervals for streams near Perryville in 2002 based on a mean coho salmon residence time in October of 13.7 d (Hetrick and Nemeth 2003). Bue et al. (1998) also found that accuracy and precision of AUC estimates decreased as surveys became less frequent.

High water also affected the escapement estimate at the Clear Creek weir in 2002 (Table 9). On 10 October, Clear Creek water levels rose 0.75 ft in 1 hr, taking out the weir. The crew could not safely wade to repair the damage until 12 October. On 22 October, the weir was down when the crew went to check it in the morning and it was repaired that afternoon. The weir went down sometime during the night of 24 October, and high water prevented repairs until 26 October. Clear Creek was rising following steady rains on 29 October when the crew checked the weir in the evening, and two weir panels were pulled at 1700 hours to prevent damage to the rest of the structure. The crew could not safely access the weir to affect repairs until 1 November. The same sequence occurred during the final weir failure from 4 to 6 November: weir panels were pulled at 1700 hours on 4 November and the site could not be safely accessed until 6 November.

A walking survey was conducted above the Clear Creek weir following the final high water event in early November, and resulted in a count of 50 coho salmon. Based on this count, it is unlikely that many coho salmon entered the system during the last period the weir was down. The weir failures in mid-October, however, may have allowed a considerable number of coho salmon to enter the system undetected. Escapement estimates for coho salmon in Clear Creek in 1995 (4,068) and 1996 (3,118) (Hetrick and Nemeth 2003), are considerably higher than the 1,097 coho salmon counted past the Clear Creek weir in 2002. Peak counts for coho salmon in 1995 and 1996 also occurred following high water events in mid- to late-October (Hetrick and Nemeth 2003), periods when the Clear Creek weir failed in 2002. Coho salmon often move into smaller tributary streams to spawn with the onset of fall rains and increased flows (Meehan and Bjornn 1991; Sandercock 1991). Considering the weir failures associated with high water events in 2002, the 1,097 coho salmon counted past the Clear Creek weir should only be considered a minimum escapement estimate.

Potential production estimates generated by the HLFM (Nickelson 1998) for Clear Creek were similar to the actual observed escapement in 2002. With a 10% marine survival rate, the HLFM predicts the system can support 1,120 adult coho salmon (PP_{10}; Table 13), and 1,097 adult coho salmon were actually counted past the Clear Creek weir in 2002. However, as discussed above, the value for 2002 was a minimum escapement estimate due to weir failures and the timing of adult coho salmon migration. In addition, previous data for Clear Creek indicate the system can produce over 3,000 adult coho salmon (Hetrick and Nemeth 2003). Therefore, the HLFM PP_{10} estimate of 1,100 adult coho salmon underestimates actual production potential in Clear Creek. As the estimates produced for Clear Creek by the HLFM are below observed values, the HLFM is likely underestimating actual production potential for the Kametolook system as well.

Estimates of production potential (smolt capacity) of the HLFM in Oregon were closely related to actual smolt production when summer habitat was fully seeded (Nickelson 1998). The limiting factor of the model for freshwater production in Clear Creek was winter habitat, which limits the system to production of 11,000 smolts. If this number is an accurate estimate of the production potential in Clear Creek, it would be necessary to have marine survival rates near or above 30% to produce the adult returns observed by Hetrick and Nemeth (2003) of 3,000 to 4,000 adult coho salmon. Marine survival rates for coho salmon reported in the literature for other streams ranged from 0.5 to over 40%. Observed survival rates ranged from 0.5 to 23.1% for 14 stocks of coho salmon on Vancouver Island, British Columbia, over four years in the mid-1980's (Labelle et al. 1997). Bilton et al. (1982) observed smolt-to-adult survival rates in excess of 40% for hatchery stocks of coho salmon in British Columbia. Thedinga (1986) observed marine survival rates of 4.0 to 6.5% in a southeast Alaska stream, and Bradford et al. (2000) report marine survival rates between 3% and 20% for a stream in the Straight of Georgia, British Columbia. Bradford and Irvine (2000) also report smolt-to-adult survival rates of less than 5% for Thompson River, British Columbia, hatchery-reared coho salmon from 1987 to 1998. A mean smolt-to-adult survival rate of 3.7% (range 0.12 to 11.0%) was observed for Oregon coastal and Columbia River hatchery coho salmon from 1958 to 1992 (Nickelson and Lawson 1998). Coronado and Hilborn (1998) report average smolt-to-adult survival rates for hatchery-reared coho salmon across all states and provinces in the Pacific Northwest of 4.27% (range of 0.92% to 6.21%), although within individual regions (*n* = 34 regions for all states/provinces), eight had survival rates above 8%. As reported data for marine survival rates are minimal, further investigation is needed to determine if a 30% smolt-to-adult survival rate in Clear Creek is feasible.

Another factor that may be influencing model results is the age composition of coho salmon in Clear Creek (and presumably in the Kametolook system as well). The HLFM (Nickelson 1998) was developed on coastal systems in Oregon, where age 1.1 coho salmon comprise over 90% of the runs (Nickelson and Lawson 1998). In Clear Creek in 2002, age 2.1 coho salmon made up 61% of the run, and age 1.1 coho salmon were 39% of the run. Using a single age class model in a system with multiple age classes (and dominated by the age class not included in the model) may be insufficient to describe freshwater survival of juvenile coho salmon in Alaska streams. Efforts are ongoing to either: 1) modify the HLFM to adequately model survival of two age classes of coho salmon, 2) investigate the potential of other models (i.e., Bradford et al. 2000, Bradford et al. 1997, Shae and Mangel 2001), or 3) develop a separate model based on existing research.

We did not visually observe any distinct length groups of juvenile coho salmon during snorkeling or minnow trap sampling. In addition, the length-frequency distribution of measured juvenile coho salmon (*n*=109) does not exhibit a clear break between two age classes (Figure 12). The juvenile coho salmon measured in Clear Creek are similar to age 0+ coho salmon lengths reported by Crone and Bond (1976) for a system in southeast Alaska, which are generally less than those reported by researchers for age 0+ coho salmon outside of Alaska (Table 16). Mean lengths of juvenile coho salmon measured in Clear Creek in September and October are similar to those reported for age 0+ coho salmon during the summer months for streams in Washington (Table 16).

If the length-frequency distribution observed in Clear Creek in 2002 includes age 0+ and age 1+ coho salmon, the two age classes are using similar habitats. If, however, the length-frequency distribution is primarily age 0+ coho salmon, it is unknown where the age 1+ cohort is rearing. It is possible that the available habitat in Clear Creek may not be suitable for rearing age 1+ coho salmon, and as a result, a fall migration may occur whereby the majority age 0+ juvenile fish move downstream and out of Clear Creek to overwinter in Camp Creek. Further research is planned for 2003 to determine the length-at-age for juvenile coho salmon in Clear Creek, and to determine where larger age 1+ coho salmon might be rearing.

Table 16. Mean lengths at age for juvenile coho salmon observed throughout the Pacific Northwest and Alaska.

Stream	Location	Mean Length	Age	Sample Time	Source
Clear Creek	SW Alaska	59.7	Unknown	September-October	Current Study
Sashin Creek	SE Alaska	60	0+	September	Crone and Bond (1976)
Sashin Creek	SE Alaska	80	1+ & 2+	September	Crone and Bond (1976)
Big Beef Creek	Washington	74	0+	October	Quinn and Peterson (1996)
Big Beef Creek	Washington	77	0+	October	Peterson et al. (1994)
Big Beef Creek	Washington	70	0+	July-August	Kahler et al. (2001)
Big Beef Creek	Washington	60	0+	July-August	Kahler et al. (2001)
Griffith Creek	Washington	60	0+	July-August	Kahler et al. (2001)
Shuwah Creek	Washington	67	0+	July-August	Kahler et al. (2001)
Huckleberry Creek	Washington	60	0+	August	Nielsen (1992)

Recommendations

Field work recommended for the 2003 field season includes completing the habitat inventory of the Three Star and Long Beach rivers near Perryville and to refine escapement estimates in the Perryville area and in Clear Creek. Stream walking surveys in Perryville will be repeated, and weather permitting, will be more frequent than those completed in 2002. Weekly stream walking surveys will also be done on Clear Creek to provide a back-up escapement estimate in case of a significant weir failure. Alternate locations and construction methods for the Clear Creek weir will be investigated that might minimize failures. Length-at-age of juvenile coho salmon in Clear Creek will be determined by collecting scale samples and length measurements from juvenile fish. Snorkel surveys will be repeated in Clear Creek, and will be conducted earlier in the season to minimize the effects of spawning pink and chum salmon on visibility. Snorkel surveys and minnow trap removals will be completed in Clear Creek and Camp Creek to determine where age 1+ coho salmon might be rearing.

Further research, beyond what is planned for the 2003 field season, may be necessary to develop carrying capacity estimates in the Kametolook system and in Clear Creek. The logic of the HLFM is sound for a single age class, but may be inappropriate for coho salmon populations with more than one freshwater age class. More involved studies to estimate survival from age 0+ summer parr to age 2+ smolt could be completed. This type of study would require additional fieldwork, which could include the use of passive integrated transponder (PIT) tags and rotary screw traps to determine age-specific overwinter survival and smolt migration rates. Also, if age 1+ coho salmon are found in Camp Creek instead of Clear Creek, habitat analysis of Camp Creek (and the mainstem Kametolook River) might be necessary.

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Appendix A. Summary of daily salmon passage at the Clear Creek weir, 2002.

	Coho			Sockeye	Chum	Pink
Date	Daily Count	Cumulative	Cumulative %	Daily Count	Daily Count	Daily Count
9/1/02	0	0	0	0	38	358
9/2/02	0	0	0	4	19	314
9/3/02	0	0	0	0	26	409
9/4/02	0	0	0	8	36	1265
9/5/02	0	0	0	1	44	779
9/6/02	0	0	0	2	18	391
9/7/02	0	0	0	1	14	486
9/8/02	0	0	0	4	24	698
9/9/02	0	0	0	1	10	140
9/10/02	0	0	0	1	2	33
9/11/02	0	0	0	0	2	24
9/12/02	0	0	0	0	1	20
9/13/02	0	0	0	5	19	182
9/14/02	108	108	10	1	4	8
9/15/02	314	422	38	1	3	35
9/16/02	23	445	41	1	3	4
9/17/02	0	445	41	0	5	1
9/18/02	0	445	41	0	0	1
9/19/02	0	445	41	0	0	0
9/20/02	0	445	41	1	0	1
9/21/02	0	445	41	0	0	1
9/22/02	0	445	41	0	0	0
9/23/02	0	445	41	0	0	0
9/24/02	193	638	58	1	0	1
9/25/02	3	641	58	0	1	0
9/26/02	129	770	70	0	0	0
9/27/02	0	770	70	0	0	0
9/28/02	0	770	70	0	0	0

Appendix A. continued.

Date	Coho			Sockeye	Chum	Pink
	Daily Count	Cumulative	Cumulative %	Daily Count	Daily Count	Daily Count
9/29/02	0	770	70	0	0	0
9/30/02	70	840	77	0	0	1
10/1/02	2	842	77	0	0	0
10/2/02	0	842	77	0	0	0
10/3/02	0	842	77	0	0	0
10/4/02	0	842	77	0	0	1
10/5/02	76	918	84	0	0	0
10/6/02	26	944	86	0	0	0
10/7/02	7	951	87	0	0	0
10/8/02	0	951	87	0	0	0
10/9/02	0	951	87	0	0	0
10/10/02	12	963	88	0	0	0
10/11/02	0	963	88	0	0	0
10/12/02	5	968	88	0	0	0
10/13/02	37	1005	92	0	0	0
10/14/02	6	1011	92	0	0	0
10/15/02	3	1014	92	0	0	0
10/16/02	0	1014	92	0	0	0
10/17/02	16	1030	94	0	0	0
10/18/02	33	1063	97	0	0	0
10/19/02	2	1065	97	0	0	0
10/20/02	2	1067	97	0	0	0
10/21/02	3	1070	98	0	0	0
10/22/02	2	1072	98	0	0	0
10/23/02	0	1072	98	0	0	0
10/24/02	1	1073	98	0	0	0
10/25/02	0	1073	98	0	0	0

Appendix A. continued.

	Coho			Sockeye	Chum	Pink
Date	Daily Count	Cumulative	Cumulative %	Daily Count	Daily Count	Daily Count
10/26/02	5	1078	98	0	0	0
10/27/02	2	1080	98	0	0	0
10/28/02	11	1091	99	0	0	0
10/29/02	0	1091	99	0	0	0
10/30/02	0	1091	99	0	0	0
10/31/02	0	1091	99	0	0	0
11/1/02	0	1091	99	0	0	0
11/2/02	0	1091	99	0	0	0
11/3/02	4	1095	99	0	0	0
11/4/02	0	1095	99	0	0	0
11/5/02	0	1095	99	0	0	0
11/6/02	0	1095	99	0	0	0
11/7/02	0	1095	99	0	0	0
11/8/02	0	1095	99	0	0	0
11/9/02	1	1096	99	0	0	0
11/10/02	0	1096	99	0	0	0
11/11/02	1	1097	100	1	0	0
Total:	1097			33	269	5153