Life History and Habitat Utilization of Cutthroat Trout (*Salmo clarki*) in a Headwater Stream on the Olympic Peninsula, Washington

by

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Master's Thesis

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Abstract

LIFE HISTORY AND HABITAT UTILIZATION OF CUTTHROAT TROUT (*Salmo clarki*) IN A HEADWATER STREAM ON THE OLYMPIC PENINSULA, WASHINGTON

By Jeffrey A. June

Chairman of the Supervisory Committee: Professor E. O. Salo
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A life history and habitat utilization study of cutthroat trout in Bear Creek, Washington was conducted during 1977 and 1978 to provide baseline information for a timber removal study. Life history information included upstream adult spawning migration, spawning, incubation and emergence, population dynamics, and movement. Habitat utilization included quantifying the habitat in Bear Creek, calculating probability-of-use curves by life stage of cutthroat trout for certain habitat parameters and combining the two in a habitat utilization model that calculated quality of habitat indexes. These indexes were correlated with biological measurements taken in the same sections.

Evidence suggests that Bear Creek has a sea-run and resident population of cutthroat trout though they could not be distinguished in much of the analysis. Sea-run cutthroat trout migrated into the study area from November to March of 1978. Sea-run spawning occurred in mid-January through early March while resident spawning took place in June. Sea-run fry emerged from May through mid-June and resident fry emerged during June and July.

Density and biomass estimates for age group 0+ in July 1978 were 0.263 fish/m^2 and 0.47 g/m^2 compared to 0.089 fish/m^2 and 0.10 g/m^2 in July 1977. This difference was attributed to low winter flows in 1977 reducing upstream migration of sea-run cutthroat trout over a small waterfall downstream and thus reducing recruitment. In 1978 population estimates for age group I+ fish doubled between April and July from 154 to 324. This was likely due to an upstream feeding migration from downstream overwintering habitat although enumeration of this migration was not possible. Production for all age classes from July 1977 to July 1978 was 6,662 g or 1.92 g/m^2 of which 0.66 g/m^2 was attributed to age group 0 fish.

Very little movement was observed in the study section. Emerging cutthroat trout fry appeared to move slightly downstream. An outmigration of 91 fish was observed between May and July 1977. These apparently sea-run fish were primarily age II+ (60%) fish. Movement in the study area was minimal but a positive relationship was observed between the ripeness of adult cutthroat trout and the amount of movement observed. This was possibly due to fish seeking out mates and suitable spawning habitat.

Depth, velocity, bottom composition and distance to instream, streamside and overhead cover were measured along transects in five 50-m habitat study sections. SYMAP interpolation provided average values by square meter for each parameter. The same parameters were measured at the observed focal point location for fry, juvenile, and adult cutthroat trout. Probability-of-use curves were generated for each habitat parameter by fry and juvenile-adult fish. A habitat utilization model combined the quantity of habitat measurements and the probability-of-use curves to calculate quality of habitat indexes. Significant positive correlations were found between mean length and weight of adult cutthroat trout and quality of habitat indexes. Larger fish occupied the better habitat. A significant negative correlation was found between relative decreases in fry density after an August 1978 storm and the quality of habitat indexes. The better the habitat the fewer fry that were displaced. Depth, velocity, and instream cover proved to be the most important of the six parameters measured in relation to biomass and density of cutthroat trout.

The use of Bear Creek as a study area for timber removal was addressed considering the possible fluctuations in population and biomass related to stream flow necessary for sea-run spawning migrations.

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INTRODUCTION

In 1977 a study was begun on the Olympic Peninsula, Washington, to assess the effects of removal of the overhead forest canopy on resident and sea-run cutthroat trout in a headwater stream. This part of the study was initiated to provide baseline information on the life history of the cutthroat trout population during two summers and one winter prior to "canopy removal." The specific objectives were:

1) Describe the life history of cutthroat trout in Bear Creek;

2) Describe the population dynamics of cutthroat trout;

3) Quantify available cutthroat trout habitat and determine trout preferences for ranges of values for depth, flow velocity, substrate size, and proximity to cover.

4) Development of a habitat model that utilizes habitat measurements and fish preferences for particular ranges of habitat measurements to produce indexes of habitat quality which can be correlated to observed fish density.

Resident and anadromous salmonids utilize most of the coastal streams draining the Pacific Northwest. These streams include extremely varied fish habitats from precipitous mountain streams to low-gradient rivers. The ability of salmonids to survive in these varying habitats depends on adaptations in their life history characteristics. Alterations of the aquatic environment within specific habitats occurs with annual climatological events. Salmonids adapt to these annual events with behavioral responses (Armstrong 1971; Andrusak and Northcote 1971; Bustard and Narver 1975). Much of the recent research by salmonid fishery biologists deals with the effects of man-caused perturbations on salmonids in streams (Kraft 1968, Gibbons and Salo 1973, Moring and Lantz 1975, Aho 1976, Lestelle 1978). Most of these studies were concerned with detailing changes in density and biomass of fish. Little information was obtained on alterations of life history or behavioral responses which resulted in density and biomass changes.

Understanding response mechanisms of fish to alterations in their habitat is basic to the understanding of impacts caused by environmental perturbations. Accurately determining changes in life history patterns or behavioral responses of fish to man-caused habitat alterations requires some prior knowledge of how fish have adapted to yearly fluctuations in stream habitat. The important aspects of fish life history that need to be examined are adult spawning migration, spawning, incubation and emergence of fry, juvenile and adult rearing and anadromous outmigration. Behavioral responses such as yearly instream movement, feeding, habitat selection, and overwintering behavior should also be studied.

Numerous studies relating habitat parameters and life history characteristics of Pacific coast salmonids have been conducted (Reiser and Bjornn 1979). Upstream spawning migration has been related to temperature (Bell 1973), dissolved oxygen (Davis et al. 1963), turbidity

(Cordone and Kelley 1961), barriers (Chapman 1962) and streamflow (Thompson 1972). Spawning of salmonids has been associated with cover (Johnson et al. 1966, Giger 1973, Reiser and Wesche 1977), substrate composition (MacKinnon et al. 1961, Hunter 1973, depth (Smith 1973), and stream flow (Hooper 1973). Survival of incubating eggs is related to dissolved oxygen (Alderdice et al. 1958, Phillips and Campbell 1961), temperature (Combs 1965), intragravel flow (Coble 1961, Wickett 1962) and substrate size (Koski 1966, Phillips et al. 1975, Taggart 1976, McCuddin 1977). Juvenile salmonid rearing is dependent upon food production in streams (Gustason 1979, Chapman 1966, Giger 1973, Hooper 1973), temperature (Bell 1973, Moring 1975), suspended and deposited sediment (Bjornn et al. 1977), cover (Giger 1973, Chapman 1966, Chapman and Bjornn 1969, Everest 1969), stream flow (Thompson 1972, Nickelson 1976) and space (Chapman 1966, Bjornn et al. 1977). Elements of stream habitat have been shown to affect residence of adult salmonids (LeCren 1965, Lewis 1969, Moring 1975). Timing and abundance of downstream-migrating anadromous salmonids have been related to stream flow, temperature and photoperiod (Willis 1962, Sumner 1962, Gufler 1967, Armstrong 1971, Narver and Anderson 1974, Jones 1976, Garrison 1978). Most studies have concentrated on comparing the effects of one or two habitat parameters upon a certain life history phase. Few studies have described the general life history phases of salmonids in coastal streams in relation to stream habitat parameters (Fleener 1951, Wyatt 1959, Lavier 1963, Jones 1976).

DESCRIPTION OF STUDY AREA

Bear Creek is a remote tributary stream to the Bogachiel River, Clallam County, Washington (Fig. 1). The study area on Bear Creek is a third-order stream accessible only by hiking or helicopter. The stream gets little or no recreational use.

The climate is oceanic with heavy winter precipitation and relatively dry summers. Annual precipitation is 300 cm, occurring mostly as rain at elevations below 600 m (Phillips 1965). Peak precipitation occurs in December, decreasing into spring.

Bedrock within the Bear Creek study area consists of cretaceous sedimentary rock known as the Soleduck formation. The rocks are profoundly folded and consist of coarse-textured, thickly bedded graywacke interbedded with fine-textured, thinly bedded mudstone, siltstone, and argillite (Snyder et al. 1972). Hillside slopes range from 20% to over 40%. Physical characteristics of the study site are listed in Table 1.

The watershed is covered with dense climax forest consisting of western hemlock (*Tsuga heterophylla*), western red cedar (*Thuja plicata*) and Sitka spruce (*Picea sitchensis*) (Jones 1936). Red alder (*Alnus rubra*) occurs in clumps along the stream banks usually associated with unstable toeslopes. Other streamside woody vegetation are vine maple (*Acer circinatum*), salmonberry (*Rubus spectabilitis*, devil's club (*Oplopanax horridum*), salal (*Gaultheria shalion*), tall blue huckleberry (*Vaccium ovalifolium*) and red huckleberry (*V. parvifolium*).

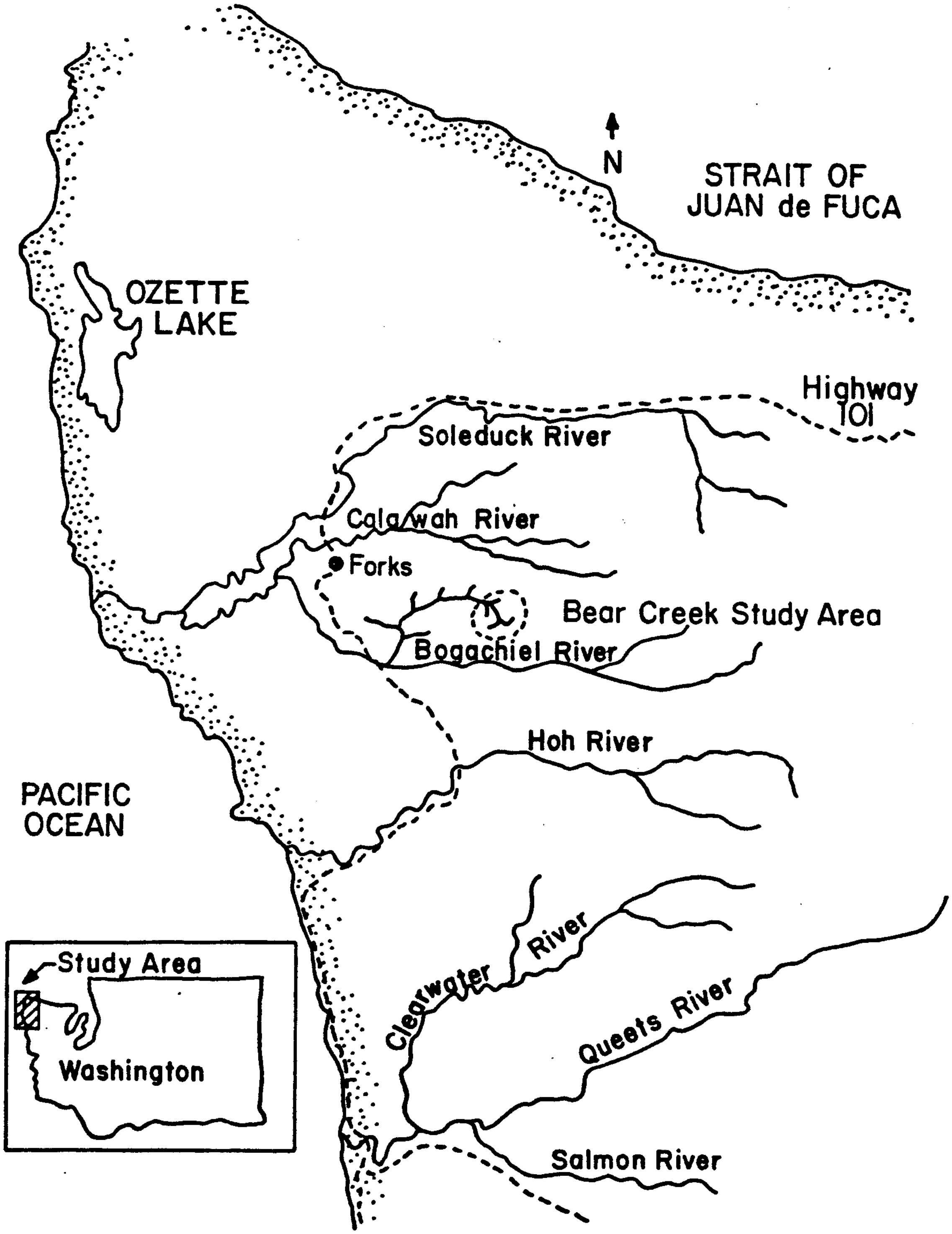


Fig. 1. Western Olympic Peninsula with location of Bear Creek study area.

Table 1. Physical characteristics of Bear Creek study area.

Length of study sections	1.2 km
Elevation at lower end of study section	184 m
Elevation at headwaters of study section	310 m
Gradient of study section	2.1%
Sinuosity of study section	1.2
Approximate watershed area of study section	230 ha
Stream aspect	Northwest
Approximate minimum discharge	0.01 m^3/s
Approximate maximum discharge	5.66 m^3/s
Minimum temperature (Jan.)	3.0°C
Maximum temperature (Aug.)	14.8°C
Water surface area at low flow (0.01 m^3/s)	3477 m^2
Percentage pool habitat at low flow (0.01 m^3/s)	64.8%

The study area contains native populations of prickly sculpin (*Cottus asper*) and cutthroat trout (*Salmo clarkii*). The cutthroat trout population has resident and sea-run components. A waterfall downstream from the study area restricts upstream migrations of larger adult anadromous salmonids such as coho salmon (*Oncorhynchus kisutch*) and steelhead trout (*Salmo gairdneri*).

The study section is 1.2 km in length. The downstream 1000 m is designated the experimental zone for future canopy removal. The upper 200 m is the control zone. Five fish-habitat study areas were located in the study area (Fig. 2). Each was 50 m in length. Two were located in the upper control zone and three in the experimental zone. Weirs and fish traps were located at the upper and lower ends of the study area. The entire study area was mapped and permanent stakes were positioned above the high flow-bank at 25 m intervals upstream from the lower weir. Each stake was labeled with the distance from the lower weir in meters.

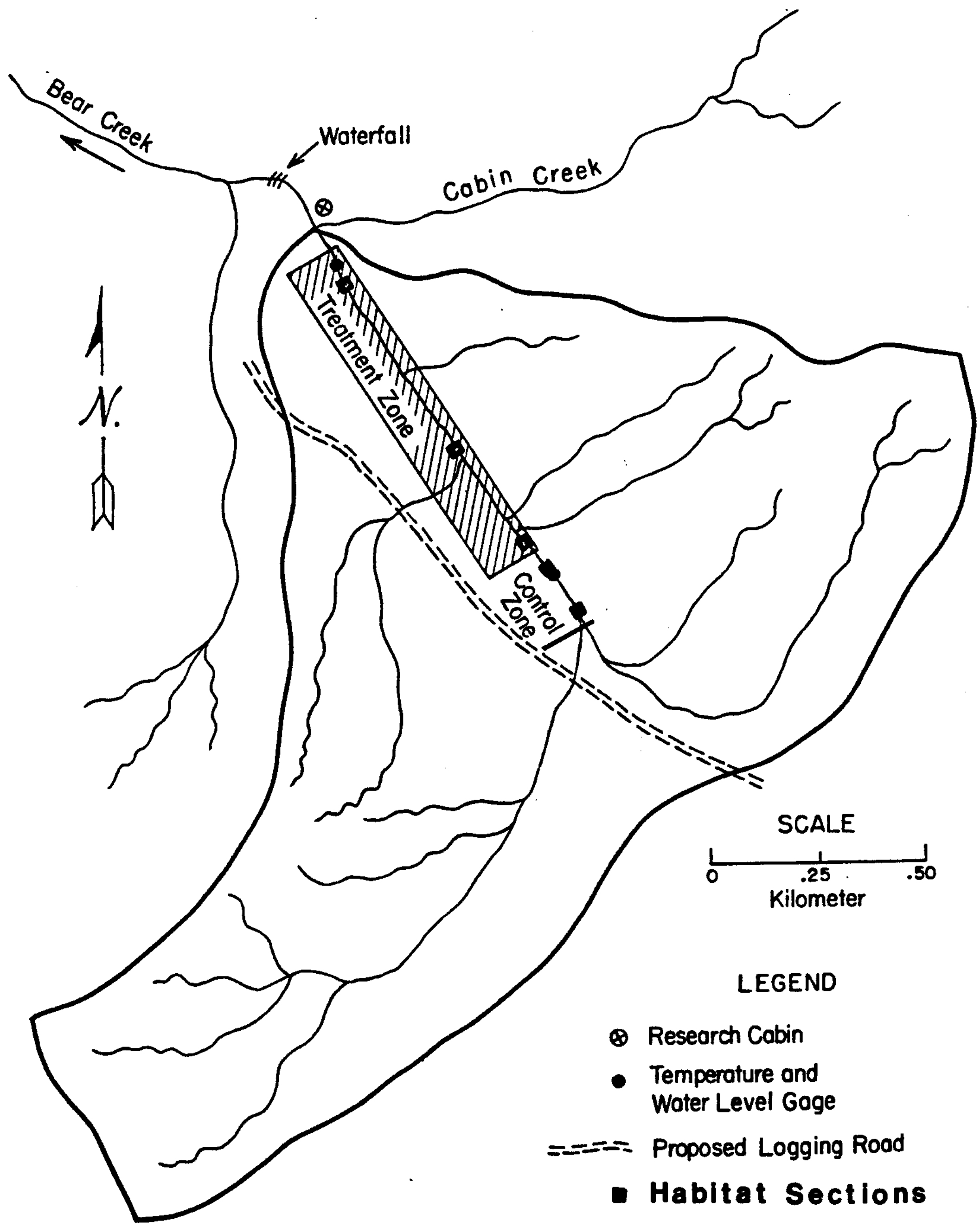


Fig. 2. The upper Bear Creek watershed and study area.

MATERIALS AND METHODS

The study was conducted from April 1977 to November 1978. The study was divided into life history description and habitat model development.

Life History Description

The life history of cutthroat trout was separated into 5 different phases: 1) upstream spawning migration; 2) spawning; 3) incubation of eggs and emergence of fry; 4) population dynamics; and 5) movement within and out of the study area.

Upstream Adult Spawning Migration

A fish trap was installed at the lower weir to capture upstream-migrating adult spawners. Heavy winter flows during December and January of 1978 prevented the operation of this trap. Timing and size of upstream-migrating spawners was estimated by bank observation during December through June of 1977 and 1978. The date, location, estimated size, and behavior of each fish was noted. Though inefficient in determining the numbers of upstream-migrating spawners, the bank observation did give some idea as to size and timing of migration.

Spawning

Redd surveys of the study section were conducted weekly between January and June. The banks were walked first upstream and then usually downstream. Redds were identified as areas of disturbed gravel. Each redd was located to the nearest meter upstream from the downstream weir (designated 0 meter). Notes were made giving the time, date of observation, and location of the redd as well as general descriptive information such as size, relation to banks or pools, and type of substrate. A numbered plastic flag was positioned on the nearest bank perpendicular to the redd to identify it from previous and subsequent sitings. The position and date of each redd was recorded on a scale map of the stream in the laboratory. The number and timing of redds constructed were determined.

Fry Incubation and Emergence

Fry surveys were done bi-weekly from April through July. Fry were observed from the banks by observers walking slowly upstream. The numbers and relative sizes of fry were recorded as well as location to the nearest meter within the stream relative to the downstream weir. Fry observations and redd locations were compared graphically through the length of the study section for each fry survey. Where peaks of observed fry were found within 1 to 5 m of a redd location, the dates of first sighting of the redd formation and first observation of fry were compared. Continuously recording thermographs allowed calculation of degree days between redd formation and emergence. The degree days to emergence measured in the field were compared to literature values for cutthroat trout determined in hatcheries. The value of using degree days to emergence to predict time of emergence was evaluated. The time from the first observation of emerged fry to the last observation of small, recently emerged fry was estimated in the study area.

Population Dynamics

Population Estimates. Estimates of population sizes were made five times during the study; July 1977, September 1977, April 1978, July 1978, and October 1978. A mark and recapture method was used for all estimates. Fish were collected with a battery-powered BP-3 electrofisher (Coffelt Elec- tronics Co, Inc.). Shocking began at the lower weir and moved upstream. Fish captured in each 25 linear meter section were held separately. Fish were marked with a small clip of a lobe of the caudal fin. Dorsal and ventral lobes were alternated for each sample date. All fish captured were measured to the nearest mm (fork length) and weighed to the nearest .1 g with an Ohaus dial balance. The location of capture of each fish was recorded relative to the lower weir and the upper end of the 25 m interval so that a fish in the interval 75 m to 100 m was recorded as being captured at 100 m. Scale samples were collected from fish through the range of lengths observed. After handling, all fish were returned to their approximate location of capture within their respective 25 m intervals. Four days separated the marking from the recapture. The upper and lower weir fish traps were used to enumerate any emigration and immigration between runs on most sample dates. The marking and recapture methods were similar except only the unmarked fish were weighed while all were measured.

Population estimates were calculated using the Chapman modification of the Peterson formula (Chapman 1951).

$$N = \frac{(m + 1)(c + 1)}{(r + 1)}$$

where N = estimate of the population

m = number of fish initially marked

c = the recapture run sample size, and

r = number of marked fish recaptured.

Confidence limits (95%) were calculated for each population estimate by computing the standard error of the estimate (Reiger and Robson 1971):

95% confidence limits = estimate $\pm$ 2 (standard error)

$$\text{where S.E. (N)} = N \frac{(N - m)(N - c)}{mc(N - 1)}$$

Population estimates were calculated for each year class of cutthroat. Year classes were determined by length frequency distributions for all fish captured and by scale analysis on a sample of fish collected on each sample date. Total population as well as numbers within each year class were estimated for fish in 100 m intervals of stream. Total population and year class estimates were calculated for the entire study area. Separate population estimates by year class were also calculated for each fish habitat study area.

Ages of fish are described mainly by year classes, i.e., 1975, 1976, and are designated as the year the fish emerged. Some reference to ages of fish were designated as age groups, i.e., 0^+, I^+, II^+, and refer to the number of winters a fish had experienced. The term $\geq III^+$ defines all fish having experienced three or more winters. Sculpin density was estimated in June 1978 using a two-pass removal method. Twelve 10 linear meter sections of stream were randomly selected. A random stratified transect method was used to calculate the population estimate (Cochran 1977).

Biomass. Biomass was calculated as the product of the mean weight of fish in a year class and the population estimate of that year class (Ricker 1975):

$$\hat{B} = \hat{\bar{W}} \hat{N}$$

where $\hat{B}$ = estimated biomass in grams,

$\hat{W}$ = estimated mean weight in grams, and

$\hat{N}$ = estimated population size.

Confidence limits (95%) for biomass estimates were calculated by computing the standard error of each estimate (Chapman 1971):

$$95\% \text{ confidence limits} = \text{estimate} \pm 2 \text{ (standard error)}$$

where $$\text{S.E. } (\hat{B}) = \sqrt{\hat{\bar{W}}^2 \hat{V}(\hat{N}) + \hat{N}^2 \hat{V}(\hat{\bar{W}})}$$

Biomass estimates were calculated by year class for each sample date for cutthroat trout. A similar method was used to calculate biomass of sculpins in June 1978; however, no attempt was made to separate the estimates by year class and confidence limits were not calculated.

Mortality. Mortality rates were defined as loss of fish between sample periods. During the winter and early spring months when the fish traps were not operating no distinction could be made between actual death of fish and emigration from the study area. Annual mortality rates (A) were calculated for the period July 1977 to July 1978 for year classes 1977, 1976, and 1975 cutthroat using the equation (Ricker 1975):

$$A = 1 - S$$

where $S = \frac{\hat{N}_2}{\hat{N}_2}$

$\hat{N}_1$, $\hat{N}_2$ = population estimates at times t_1 and t_2, respectively. Daily instantaneous mortality rates for each interval between sample dates and annual instantaneous mortality rates by year class for the July 1977 to July 1978 period were calculated using the formula (Ricker 1975):

$$Z = - \frac{(\log_e \hat{N}_2 - \log_e \hat{N}_1)}{\Delta t}$$

where Z = instantaneous mortality rate

$\hat{N}_1$, $\hat{N}_2$ = population estimates at times t_1 and t_2, respectively, and

t = time interval between sample dates.

Growth. Growth of cutthroat trout was calculated using three methods: 1) comparing observed mean weights by year class between sample dates; 2) measuring changes in mean weights of year classes from back calculated lengths at successive ages determined from scale analysis, and 3) observed changes in weight of individually tagged fish.

Instantaneous daily and sample interval growth rates were calculated for observed change in mean weight by year classes and individually tagged fish by the equation (Ricker 1975):

$$G = \frac{\log_e W_2 - \log_e W_1}{\Delta t}$$

where G = instantaneous growth rate,

W_1, W_2 = weights at time t_1 and t_2, respectively, and

t = number of days between sampling period. (t = 1 for interval rates.)

A weight-length relationship was calculated for each year class and sample date using observed lengths and weights of individual fish collected during population estimate sampling. Linear regression using natural logarithmic transformations was used to calculate (a) and (b) in the equation (Ricker 1975):

$$\log_e W = \log_e a + b\ (\log_e L)$$

where W = weight of fish in grams

a = constant

b = slope of weight-length regression line (weight-length exponent), and

L = length of fish in mm.

Yearly instantaneous growth rates by year class were determined from back calculated lengths from scale analysis converted to weights with the weight-length exponent (b) and the equation (Ricker 1975):

$$G = b\ (\log_e l_2 - \log_e\ l_1)$$

where G = instantaneous yearly growth rate

b = weight-length exponent, and

l_1, l_2 = mean lengths by year clases at age t_1 and age t_2, respectively.

Production. Production was estimated by year class for each sample interval. Total production in each interval was estimated by summing the individual year class production values. Total yearly production was calculated by summing all sample interval production values from July 1977 to July 1978. Production rates by year class, sample interval and year were calculated in grams per square meter of low flow water surface area per day. Production was calcualted using the equation (Ricker 1975):

$$P = G\ \bar{B}$$

where P = production in grams

G = instantaneous growth rate, and

$\bar{B}$ = mean of initial and final biomass in interval.

Confidence intervals for production estimates were not calculated.

Movement

Fry Movement. Dispersion of emergent fry from redd sites was estimated during fry emergence surveys. The study area stream bank was walked slowly and fry were counted by relative size, small (30 mm or less) or large, and location accurate to 1 m. Fry abundance in each linear meter of stream was summed in 5 m intervals and graphed against relative location in study area. Fry counts were relative abundances from survey to survey and not assumed to be absolute numbers or population estimates. Peaks above the horizontal axis on the graphs gave relative abundance and location of fry concentrations, compared with locations of known redd sites in the study area. Comparison of fry abundance and location curves between fry survey dates gave indications of rates and distances of dispersion from redd locations. Abundance of small fry assumed to be newly emerged fish, was compared with large fry abundance, assumed to be previously emerged fish, to determine possible effects of territoriality on dispersion of newly emerged fry.

Outmigration. A weir with a downstream migrant fish trap was operated between April 20 and September 25, 1977, and April 5 and July 10, 1978. During 1977, an inclined weir with a plane trap was used and during 1978, a vertical weir with a self-cleaning, rotating drum (Stevens Co.) trap was operated. All fish captured in the trap were identified to species, measured for length and weight, examined for brands, marks or tags, a scale sample removed, and then released downstream below the weir. The trap was checked on a daily basis when possible and the date and hour of checking recorded. Discharge values were taken from a staff gauge discharge rating curve. The age of each fish emigrating was determined from scale analysis as was yearly growth. The mean lengths and weights of each year class of emigrants was determined and compared with the population of cutthroat remaining in the study area.

Movement Within Study Area. Two methods were used to determine natural movement within the study area, tagging and branding. Cutthroat trout 120 mm and greater were tagged with 5 mm x 2.0 mm numbered plastic tags attached through the muscle tissue anteriorly to the dorsal fin with stretchable vinyl thread. Tags were attached to fish during the routine population estimation samples. The observation date, length, weight, location, and tag number of each fish was recorded and a scale sample collected for age determination. Similar data were recorded for tagged fish recaptured in later samples although scale samples were not taken. A computer program was written to analyze the data collected on tagged fish over the study period. Change in length, weight, and location of each fish recovered was calculated for each recapture and between initial and final capture. The days between each recapture were also determined. The total number of days between initial and final capture and changes in length and weight were used to calculate daily instantaneous growth rates in length and weight. Total movement between first and last capture was calculated as the sum of all movement regardless of direction between all recaptures for a single fish. Absolute movement was the relative change in location within the study area of the fish between the first and final capture. Correlation analysis was used to test if total or absolute movement was correlated with daily instantaneous growth in length or weight. Fish were divided into year classes and compared for significant differences in growth or movement with a one-way ANOVA. Fish were also divided into two groups; fish that had little or no movement (less than 50 m) and fish which moved at least 50 m.

All cutthroat in 5 habitat study sections (Fig. 2) were freeze-branded using the dry ice and acetone technique (Everest and Edmundson 1967). Fish from each habitat study section received a distinctive brand. Different brands were used during April and July 1978 sample dates. The lengths, weights, and 50 m habitat section from which each fish was captured were recorded. Fish were examined for brands upon recapture, and date, location, length, and weight were recorded. The numbers of fish moving upstream, downstream, and not moving were determined for each habitat section. The maximum upstream and downstream distance moved by any one fish in a section and mean distance moved by all fish branded in each section were calculated. Numbers of fish moving out of each section were correlated with habitat parameters measured in each section.

Habitat Analysis

Habitat analysis consisted of three phases: 1) quantifying ranges of values of important habitat parameters, 2) determining fish utilization for the ranges of values for each parameter, and 3) relating the combined effect of values of multiple habitat parameters on cutthroat trout utilization.

Quantifying Habitat

Many parameters within the stream environment combine to form stream habitat. Some of these parameters may become limiting to a fish population. Some habitat parameters become important seasonally or for a particular age of fish. Six parameters were chosen as primarily important to cutthroat trout in this study: 1) depth, 2) velocity, 3) bottom composition, 4) instream cover, 5) streamside cover, and 6) overhead cover. Cutthroat trout have been shown to have distinct microhabitat preferences within particular ranges of depth, velocity and bottom composition size (Thompson 1972; Hanson 1977). Instream cover has been shown to be extremely important to salmonids (Hoar et al. 1957; Hartman 1965; Chapman 1966; Everest 1969; Lestelle 1978). Streamside riparian vegetation has been shown to be an important aspect of cover for salmonids (Hooper 1973; Tebo 1974; Fox 1977). Shade provided by overhead cover can also be important to salmonids (Hartman 1965; Chapman 1966; Mundie 1969; Everest and Chapman 1972; Bustard and Narver 1975). Although other habitat parameters such as temperature, dissolved oxygen and food are also important in streams, these parameters were not thought to be limiting habitat use by cutthroat trout in Bear Creek, or thought likely to become limiting after canopy removal.

Depth, velocity, and bottom composition were measured using a transect method in each 50 m habitat study section. Each section had permanent wooden stakes positioned on opposite banks above the high flow area. The stakes were leveled from bank to bank and numbered. Each stake was surveyed and its location positioned on a map of the study area. Depth, velocity, and bottom composition were measured at 1/2 m intervals across each transect line on May 27 and May 28, 1978. Depth was recorded to the nearest 1 mm with a meter stick. Velocity was measured to the nearest 2 cm/sec at the substrate, mid-depth, and surface with a midget benzel current speedtube (Everest 1967) and the three velocity values averaged. Substrate size was visually categorized into one of five sizes: 1) silt, sand, or clay, 2) pea-sized gravel, 5-25 mm, 3) cobbles of 25 to 50 mm diameter, 4) small rocks of 50 to 100 mm diameter, and 5) large rock and bedrock over 100 mm diameter. Discharge in the five habitat study areas averaged 0.09 m^3/sec (3.0 ft^3/ sec) during sampling.

Field data for depth, velocity, and substrate size, along with the location of each transect stake, was utilized by a SYMAP (University of Massachusetts) program on a CDC 6400 computer to produce computer-drawn maps of each 50 m section with different symbols representing five ranges of values for each of the three parameters. Values between transect lines were interpolated by an individual point-determining algorithm utilizing polynomial approximation from actual data points provided as input. Data points and symbol representation were generated at 1 m intervals through the high bank surface area.

Depth profile maps for each section were taken into the field in August 1978 and areas of the three cover types were positioned on the maps. Instream cover was defined as any object that reduces velocity or offers shade and is below the water surface area up to high flow area. Streamside cover was any object along the stream bank from the water surface to 1/2 m above the water that provided shade cover. Overhead cover was defined as objects more than 1/2 m above the water surface that provided shade within the high flow bank area between 11:00 a.m. and 1:00 p.m. on August 2, 1978. These data were utilized by SYMAP to produce maps of each cover type with contour profiles of areas of stream at different distances from cover objects. A computer program was written to read the map matrix output from SYMAP and produce tables of square meter surface areas of each section having each of ten ranges of values for every parameter except bottom composition, which had five levels of values. Two of these tables were produced for each section. The first table gives actual areas within the wetted surface area at the time of measurement. The second table gives total square meter areas in the wetted surface and high bank areas for the range of values of bottom composition and the three cover types. This table gives potential areas available to the fish at high flows. Prediction of depth and velocity at high flows was not made. From each of these tables ranges of values were grouped, descriptive terms applied and total area represented determined for each section. For example, the ten categories of depth values would be grouped into riffle, run and pool and the total surface area in each group determined. Instream cover was divided into distances less than .1 m from objects, .1 to 2 m from objects and areas of stream greater than 2 m from any object of instream cover. Each habitat section was compared for areas within each group for each parameter and differences in habitat sections noted. Areas within each group were correlated with density, biomass, and fish movement within each habitat study section. A storm in August 1978 provided streamflows of winter intensity. Population estimates immediately preceding and shortly after the storm allowed correlation between changes in density and biomass of cutthroat trout and quantities of each habitat parameter in the 5 habitat sections.

Probability-of-Use Curves

Probability-of-use curves give the likelihood of a particular age and species of fish utilizing habitat with specific ranges of measured parameters. These curves can relate values measured for habitat parameters in the field to the likelihood of a certain species utilizing that area of stream (Bovee and Cochnauer 1977). Probability-of-use curves are based on three assumptions: 1) individuals of a species will select areas within a stream having the most favorable conditions, 2) they will utilize less favorable conditions, with the probability-of-use decreasing with diminishing favorability of one or more of the habitat parameters, and 3) that individuals will tend to leave an area when conditions become unfavorable.

Data for probability-of-use curves were collected by quietly observing individual or groups of cutthroat trout from the bank. The fish were observed for a minimum of 15 min while relative size of the fish and its focal point of activity was noted. The fish was then frightened away and the focal point marked with an anchored float. Depth, velocity, bottom composition and distances to nearest instream, streamside, and overhead shade cover were measured. Chi-square frequency analysis (Bovee and Cochnauer 1977) was used on the data collected to produce probability-of-use curves for each of the six habitat parameters for fry and juvenile-adult age groups. Curves were compared between age groups for significant differences.

Habitat Utilization Model

An index of the quality of fish habitat within a stream reach allows comparison of one reach to another or habitat changes within a single reach before and after a perturbation. It is important that such an index be related to the quality of habitat in terms of fish utilization and not the observer's objective opinion about what type of habitat is preferred fish habitat. Recently an incremental method model, HABITAT has been used to determine fish habitat quality in terms of depth, velocity, and substrate composition (Main 1978). The index of habitat quality calculated in habitat is called the "weighted usable area". Weighted usable area roughly equates an area of marginal fish habitat to an equivalent reduced area of optimal fish habitat throughout a subset of areas within a stream reach. These individual subsets of weighted usable areas are then summed to get the stream reach weighted usable area (Bovee and Cochnauer 1977). Habitat parameter measurements and probability-of-use curves are used as input to obtain weighted usable areas for specific species, life stages, and discharges. For a complete description of HABITAT, see Bovee and Cochnauer (1977) and Main (1978).

Weighted usable area values were calculated in this model as quality of habitat indicators. Six previously described habitat parameters were used to relate fish habitat utilization to measured stream habitat and determine fish habitat quality. Values for these parameters were measured as previously described. SYMAP produced a matrix of observed and interpolated values in square meter intervals through each of the 5 50-m habitat study sections. Probability-of-use curves were also generated for the range of values observed for each parameter by fry and juvenile-adult age groups as previously described. The model calculated weighted usable area values using habitat parameter matrices and probability-of-use curves by the following procedure.

The matrix containing depth values was used to determine the wetted surface area within each one square meter subarea of the reach. Those areas with no water were eliminated from further calculations. The one square meter intervals for values of each parameter allowed up to four values to be averaged for each square area of stream, i.e., four corner points defining a square meter of area. Only values of parameters that had wetted surfaces at those points were averaged. The average value of each parameter was then compared with its specific probability-of-use curve for the age of fish of interest and the corresponding probability-of-use value was obtained. The probability-of-use values for each of the six parameters were multiplied together to get a composite probability-of-use value for each square meter of stream. This value was then multiplied by the wetted surface area within that square meter area to get the weighted usable area. Finally, the weighted usable areas within all of the individual square meter areas within the stream reach were summed to get the weighted usable area of the total stream reach. Weighted usable areas were divided by the actually wetted surface area in each section to get comparable quality of habitat indices. Indices were calculated for each habitat section for fry and juvenile-adult cutthroat, using all 6 habitat parameters and only 3 parameters (depth, velocity, and instream cover). These quality of habitat indices were correlated with density, biomass, and mean weight by age group of cutthroat for each habitat section and changes in density, biomass, and mean weight between sample dates. All percentage and ratio values were transformed with an arcsine function (Zar 1974).

RESULTS

Life History Description

Upstream Adult Spawning Migration

High flows in December through March of 1978 prevented efficient operation of the upstream fish trap at the lower weir. No fish were caught in the upstream trap during either year. High flows over the weir during storm events allowed upstream movement past the weir and trap. Though the exact timing of initial migration of sea-run and resident cutthroat trout into the study area could not be precisely determined, sea-run cutthroat were observed in the study area during redd surveys. They were longer (300 to 400 mm total length) than the residents. No sea-run adults were observed in the study area during 1977. Low flows during the winter of 1976-77 probably reduced or blocked upstream migration past the waterfall below the study section. A large, 400 mm cutthroat was observed 500 m upstream of the weir on January 19, 1978 and a redd was observed 10 m downstream indicating that the fish may have been in the area for some time. Two cutthroat (400 mm or greater in length) were observed 5 m above the lower weir on February 22, 1978, and two more cutthroat, (approximately 350 mm in length) were observed at 70 m on March 8, 1978. Though surveys were conducted during all daylight hours, most observations were made during early mornings or late evenings indicating probable nighttime migration. On April 4, 1978, 500 m of the study section were sampled for the presence of adult sea-run cutthroat but none were found. Thus sea-run cutthroat adults entered the Bear Creek study area as early as January and had completed spawning and migrated out by April 4, 1978.

Spawning

Bi-weekly redd surveys were conducted from January through June of 1977. Two cutthroat trout redds were observed on 14 May 1977 at 852 and 880 m above the lower weir. No other redds were observed in 1977.

Ten cutthroat trout redds were observed in the study section between January and June during weekly surveys in 1978 (Table 2). The first redds were observed on 19 January 1978 at 500 and 853 m. Nine redds were found through 7 March 1978. One additional redd was observed 63 days after March on 10 May 1978 at 485 m. This redd was assumed to be a resident cutthroat redd because no sea-run fish had been captured in the April 1978 population estimate sample.

Six of the redds observed in 1978 were located in pool tailout areas, two in run areas, and two in strictly riffle areas. Five of the redds were measured for length, width, water depth, and substrate size (Table 2). The four redds observed prior to March 8 had an average area of .68 m^2, average depth of 15 cm and were in substrate ranging from 2 to 5 cm in diameter. The resident redd observed on 10 May 1978 was .15 m^2, 15 cm deep, and was in substrate 1-2 cm in diameter.

Scales were collected from 348 cutthroat trout of which 189 were readable. Nine had definite spawning marks. Five had spawned at age 2 just after forming an annulus at a mean length of 122.5 mm. Four spawned at age 3 at a mean length of 144.2 mm (Appendix A).

Table 2. Location, date, size, substrate composition and estimated timing of emergence for ten cutthroat trout redds observed in Bear Creek during 1978.

Date observed	Location in meters from lower weir	Description of location	Length (m)	Width (m)	Water depth (cm)	Substrate size (cm)	Date of emergence	
							Predicted	Observed
1/19/78	500	Riffle	--	--	--	--	3/28-4/16	5/9
1/19/78	853	Pool tailout	--	--	--	--	3/28-4/16	4/28
2/22/78	380	Pool tailout	1.2	0.4	10	2-5	4/30-5/17	5/9
2/22/78	550	Riffle	--	--	--	--	4/30-5/17	5/25
2/22/78	723	Pool tailout	1.0	0.6	15	2-5	4/30-5/17	4/28
3/4/78	1,150	Pool tailout	0.9	0.5	14	2-5	5/10-5/25	4/28
3/8/78	70	Run	--	--	--	--	5/12-5/27	6/8
3/8/78	100	Pool tailout	--	--	--	--	5/12-5/27	6/8
3/8/78	777	Run	1.5	0.8	20	2-5	5/12-5/27	5/25
5/10/78	485	Pool tailout	0.5	0.3	15	1-2	6/27-7/9	7/6

Analysis of tagged fish over 120 mm showed a significant difference (t-test 0.02516) in mean length (t-test, sig. = .02), between ripe males and nonripe fish that were not sexed (173.8 vs 146.5 mm). Ripe males weighed more than the nonripe fish, (t-test, sig. = .01), 25.5 g versus 14.7 g. Forty-three tagged fish were not ripe when captured and 4 were ripe. All ripe fish were males.

Incubation and Emergence

Temperature is one of the most important factors influencing the timing of ontogenetic events during fish egg incubation (Bagenal and Braum 1971). Degree-days, the product of temperature and number of days, have been shown to be linearly related to time of hatching when temperature is constant (Blaxter 1969). In natural streams where temperature fluctuations can be extreme the relationship is exponential. Between 350 and 460 degree-day temperature units are required for the hatching of cutthroat trout held at constant temperatures (Merriman 1935). An additional 20% of the temperature units to hatching are required for emergence (E. Brannon, personal communication). A range of temperature units from 430 to 560 degree-days was estimated for egg deposition to emergence for cutthroat trout in Bear Creek. The cumulative degree-days between January and July in 1978 are shown in Fig. 3. The date of redd deposition is found on the x axis and the degree-day units accumulated up to that time are read from the curve. The lower value and upper value of degree-days required to emergence are added to the degree-day units previously accumulated and the new values located

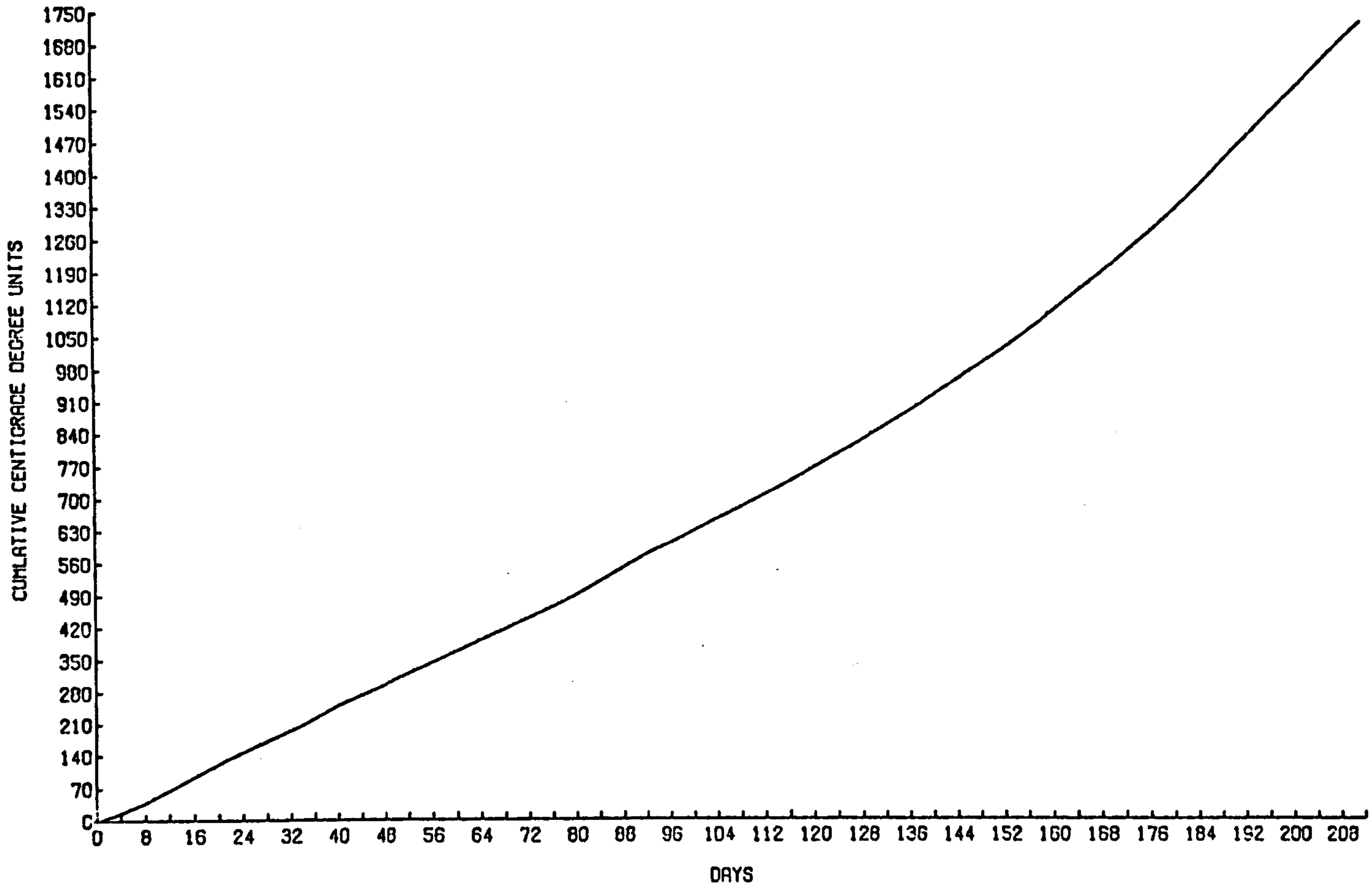


Fig. 3. Cumulative degree-days between January 1 and July 31, 1978 in Bear Creek.

on the curve. These values correspond to the predicted dates of earliest and latest emergence. The earliest predicted emergence for cutthroat in Bear Creek was 28 March for two redds deposited about January 19 in 1978 (Table 2). The latest predicted date of emergence was 9 July for the redd deposited on 10 May.

Fry surveys gave approximate times of first emergence in the study section (Fig. 4). The first emergence of fry was observed on April 28. Fry were observed in small numbers within 50 m of 3 redd sites, completed on January 19, February 22, and March 4 (Fig. 4). The predicted time of emergence differed from the estimated time of actual emergence in 7 out of 10 known redds. The difference ranged from 2 to 23 days (Table 2). Emergence was observed after the predicted date in 5 cases and before the predicted date for 2 redds.

The range of degree-day units to the observed emergence was calculated as the degree-days to the date of fry observation as the upper range and the date of the previous fry survey as the lower range. The observed mean range for all ten redds was 475 to 601 degree-day units.

There were two dates of peak fry emergence. The first occurred between May 9 and May 25 and the second just prior to July 6 (Fig. 4).

It is very possible that observed fry attributed to recent emergence from known redd locations were due to fry migrations from known or unknown redds.

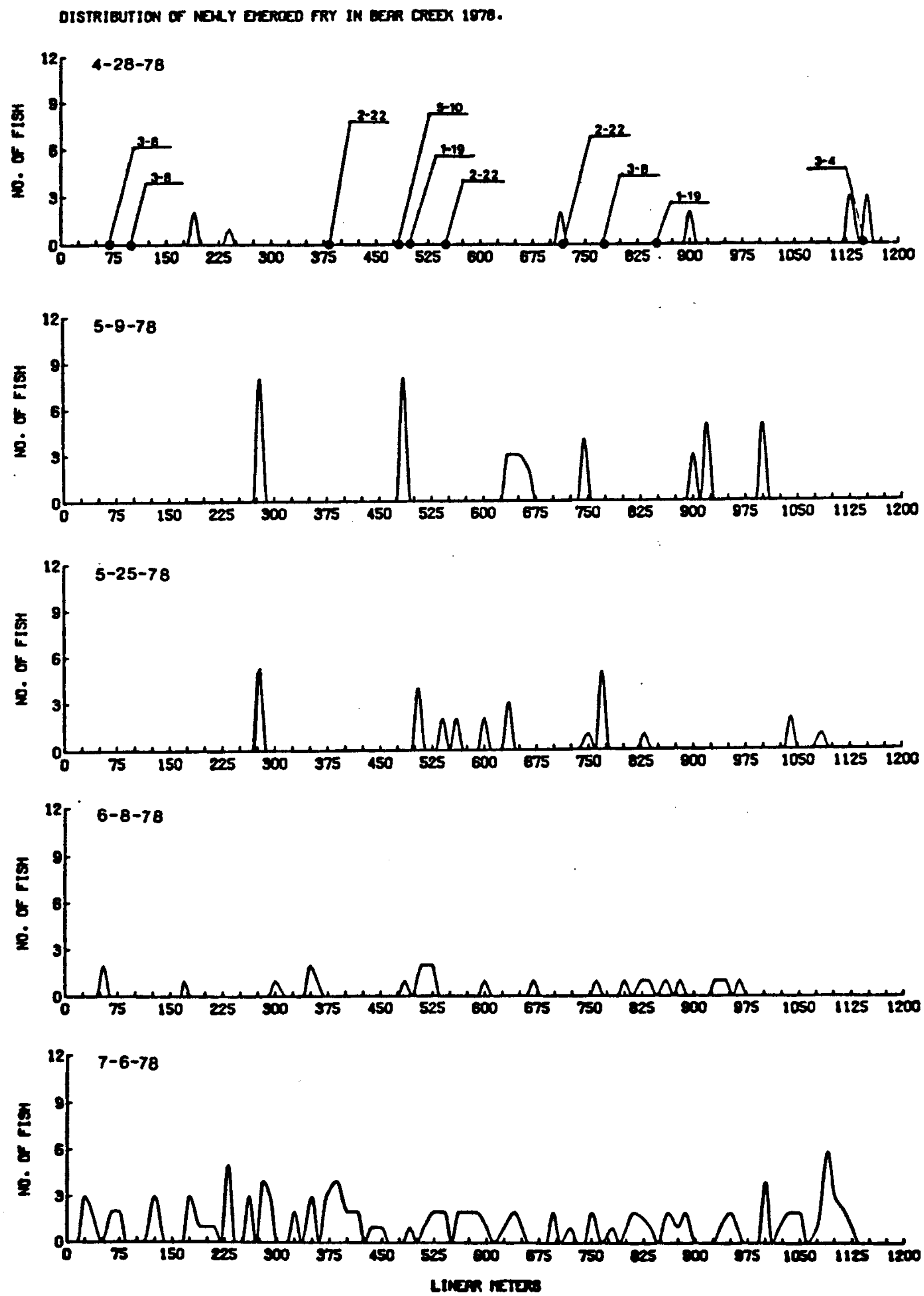


Fig. 4. Location, date of deposition and observation of fry for ten cutthroat trout redds in Bear Creek during 1978.

Population Dynamics

Population Estimates. Four age groups of cutthroat trout were identified for population estimates in 1977 and 1978: 0, I, II, and $\geq$III. In September 1977, estimated numbers of age group 0+ fish (1977 year class) were lower than age group 1+ (1976 year class) cutthroat, 295 and 427, respectively (Table 3). Poor recruitment in the 1977 year class due to the drought of winter 1976-77 appeared to cause this discrepancy. In 1978, an average water year, age 0 fish dominated, accounting for 62% of the total population estimate in October. The estimate of age group I+ (1977 year class) fish increased 100% between April 1978 and July 1978 samples (Table 3). This increase was attributed to an upstream feeding migration from an over wintering area between the lower end of the study section and the waterfall below the study area. Age II+ (1975 year class) estimated abundance decreased by 57 % during the same time period and was attributed to downstream migration of sea-run juveniles during May and June.

Densities of cutthroat trout ranged from .131 fish/m^2 in April 1978 to .397 fish/m^2 in July 1978 after the 1978 year class emergence (Table 4). Changes in estimated absolute abundance and density are shown in Figs. 5 and 6.

Sculpin standing stock was estimated to be .72 fish/m^2 in June 1978.

Table 3. Numbers and 95% confidence intervals for cutthroat trout estimated in Bear Creek, 1977-1978. Age groups in parentheses.

Sample date	Year class					Total
	≥ 1974	1975	1976	1977	1978	
	(≥ III+)	(II+)	(I+)	(0+)		
7/20/77	24 ± 14[1]	36 ± 12[1]	476 ± 59[1]	280 ± 49[1]		822 ± 80[1]
	(≥ III+)	(II+)	(I+)	(0+)		
9/7/77	22 ± 12[1]	28 ± 4[1]	427 ± 55[1]	295 ± 61[1]		761 ± 76[1]
		(≥ III)	(II)	(I)		
4/28/78		50 ± 39[1]	204 ± 74[1]	154 ± 47[1]		407 ± 98[1]
		56 ± 39[2]	214 ± 74[2]	183 ± 47[2]		457 ± 98[2]
		(≥ III+)	(II+)	(I+)	(0+)	
7/11/78		39 ± 12[1]	63 ± 20[1]	324 ± 27[1]	846 ± 74[1]	1258 ± 78[1]
		39 ± 12[2]	70 ± 20[2]	371 ± 27[2]	916 ± 74[2]	1381 ± 78[2]
		(≥ III+)	(II+)	(I+)	(0+)	
10/5/78		28 ± 6[1]	39 ± 16[1]	273 ± 33[1]	523 ± 73[1]	868 ± 76[1]
		28 ± 6[2]	44 ± 16[2]	310 ± 33[2]	579 ± 73[2]	950 ± 76[2]

[1] 3,136 m^2 sampled.
[2] 3,477 m^2 sampled.

Table 4. Density (fish/m^2 low flow) and 95% confidence intervals for cutthroat trout estimated in Bear Creek, 1977-78. Age group in parentheses.

Sampling date	Year class ≥ 1974	1975	1976	1977	1978	Total
7/20/77[1]	(≥ III+)	(II+)	(I+)	(0+)		
	0.008 ± 0.004	0.011 ± 0.004	0.152 ± 0.019	0.089 ± 0.016		0.262 ± 0.026
9/7/77[1]	(≥ III+)	(II+)	(I+)	(0+)		
	0.007 ± 0.004	0.009 ± 0.001	0.136 ± 0.018	0.094 ± 0.019		0.243 ± 0.024
4/28/78[2]		(≥ III)	(II)	(I)		
		0.016 ± 0.011	0.062 ± 0.021	0.053 ± 0.014		0.131 ± 0.028
7/11/78[2]		(≥ III+)	(II+)	(I+)	(0+)	
		0.011 ± 0.003	0.020 ± 0.006	0.107 ± 0.008	0.263 ± 0.021	0.397 ± 0.022
10/5/78[2]		(≥ III+)	(II+)	(I+)	(0+)	
		0.008 ± 0.002	0.013 ± 0.005	0.089 ± 0.009	0.167 ± 0.021	0.273 ± 0.022

[1] 3,136 m^2 sampled.
[2] 3,477 m^2 sampled.

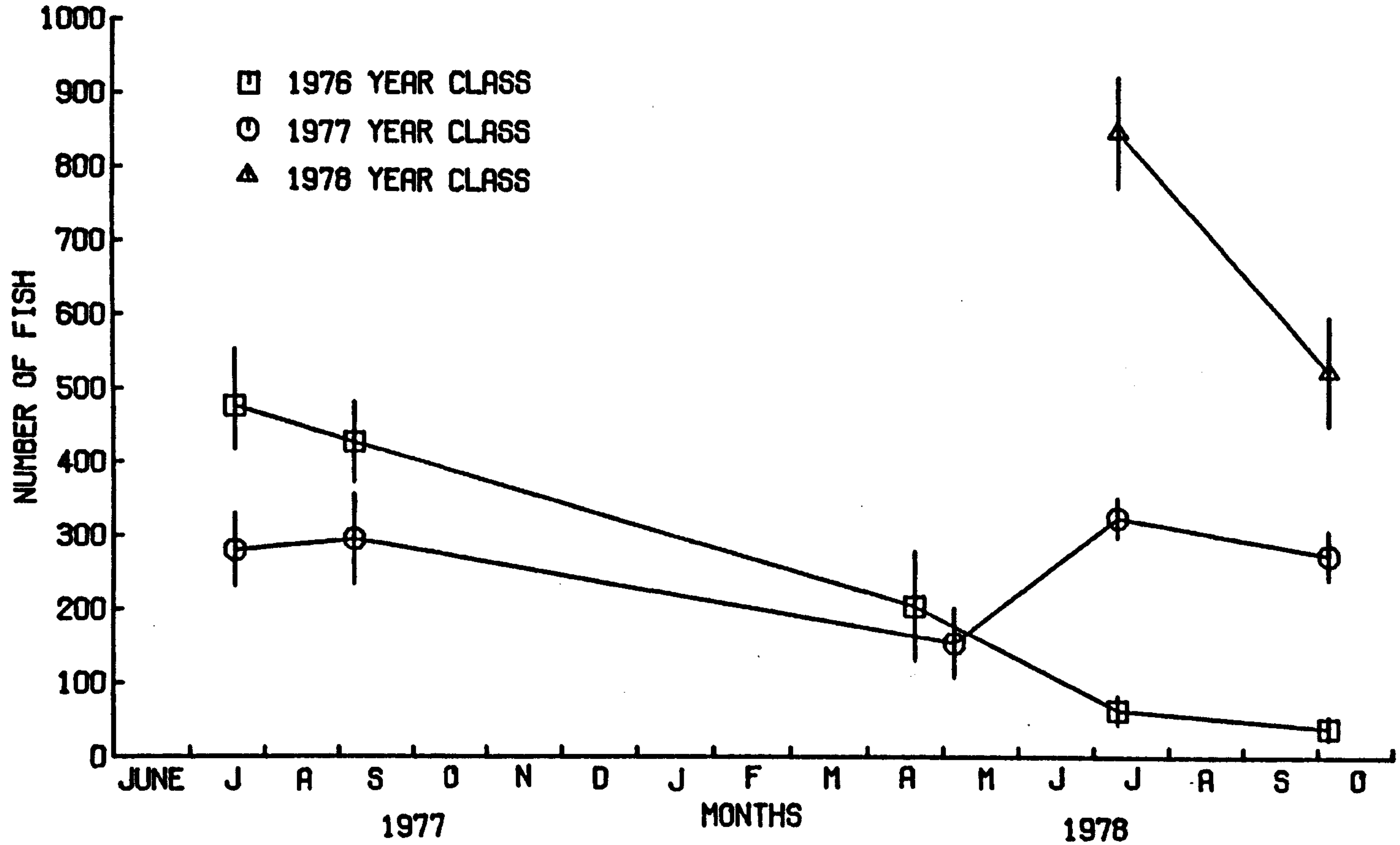


Fig. 5. Absolute abundance of three year classes of cutthroat trout in Bear Creek during 1977-78. 95% confidence bars on data point symbols.

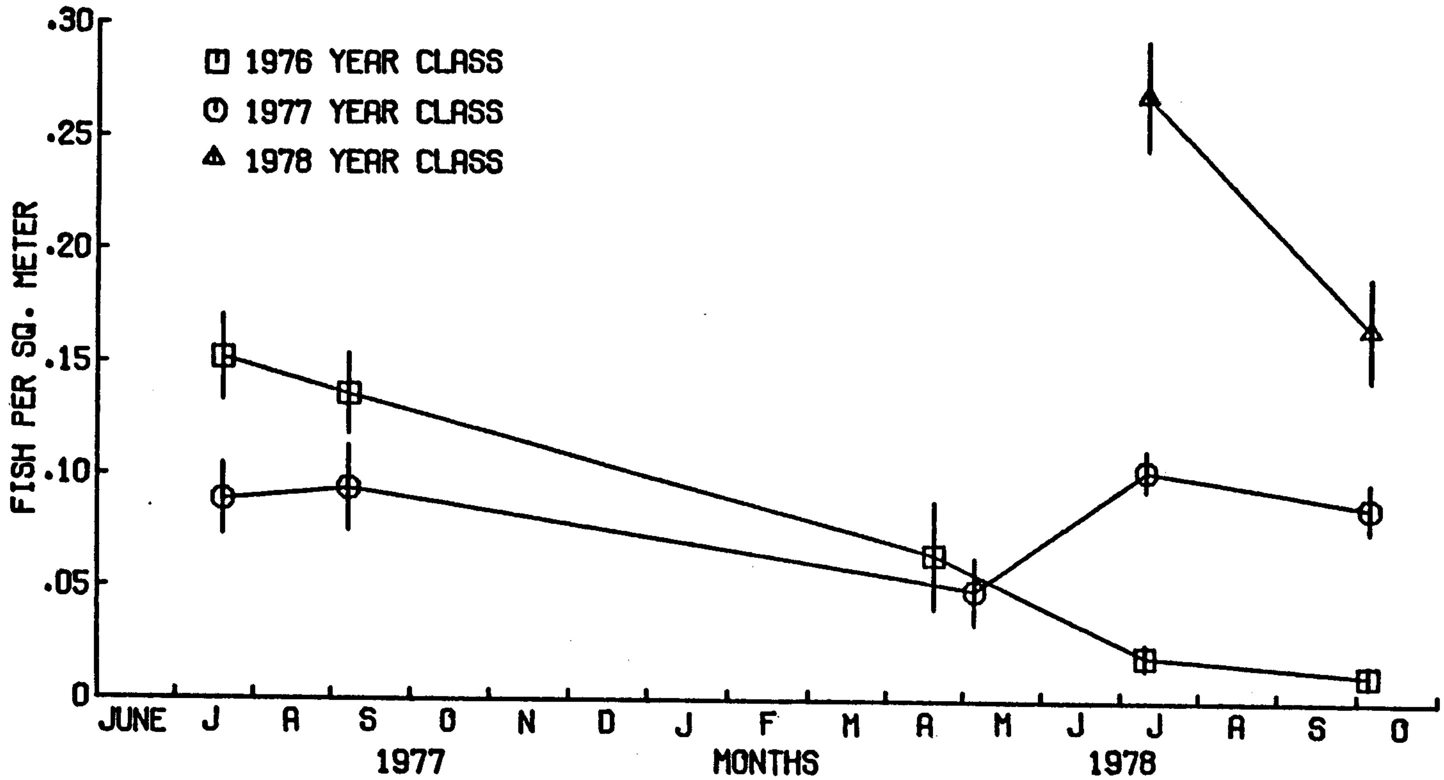


Fig. 6. Density (numbers of fish per square meter low flow surface area) of three year classes of cutthroat trout in Bear Creek during 1977-78. 95% confidence interval bars on data point symbols.

Biomass. Relative biomass estimates for all age groups combined ranged from 1.62 g/m^2 in April 1978 to 2.29 g/m^2 in July 1978 (Table 5). Trends within year classes and between sample dates were similar to those found with abundance. Age 0+ (1977 year class) cutthroat trout accounted for 11% of the total biomass in September 1977 while age 0+ (1978 year class) made up to 25% of the total biomass in October 1978. The decrease in relative biomass of the 1976 year class between April and July of 1978 was attributed to outmigration during May and June (Fig. 7). The greatest increase in biomass in age groups I+ and older fish occurred between April and July. Age 0+ fish increased in relative biomass from emergence through October.

Relative biomass of sculpins was estimated to be 2.16 g/m^2 in June 1978.

Mortality. Daily instantaneous mortality rates were comparable among age groups between sample dates July to September 1977 and July to October 1978 (Table 6). The highest mortality rate occurred between April and July 1978 for the age group II+ (1976 year class) cutthroat due to outmigration, however, heavy spring flows prevented efficient downstream trapping and enumeration of the outmigrant portion of the total mortality. The effect of age group II+ outmigration was also found in the annual instantaneous and annual mortality rate, 1.92 and .85, respectively (Table 7). Mortality rates were lower for age groups 0 to I+ and II+ to $\geq$III+ than the I+ to II+ age group.

Table 5. Absolute and relative biomass and 95% confidence intervals estimated for cutthroat trout by year class and sample date in Bear Creek, 1977-78. Age classes in parentheses.

Sample date	Year Class: 1974+	1975	1976	1977	1978	Total
7/20/77[1]	(III+) 1259g ±53 0.40g/m² ±0.02	(II+) 749g ±31 0.24g/m² ±0.01	(I+) 4232g ±74 1.35g/m² ±0.87	(0+) 305g ± 24 0.10g/m² ± 0.01	--	6545g ±99 2.09g/m² ±0.03
9/7/77[1]	(III+) 1194g ±49 0.38g/m² ±0.02	(II+) 604g ±21 0.19g/m² ±0.01	(I+) 4227g ±71 1.35g/m² ±0.02	(0+) 735g ±33 0.23g/m² ±0.18	--	6760g ±95 2.16g/m² ±0.03
4/28/78[2]		(III) 2205g ±72 0.63g/m² ±0.02	(II) 2600g ±60 0.75g/m² ±0.51	(I) 825g ±34 0.24g/m² ±0.01	--	5630g ±99 1.62g/m² ±0.03
7/11/78[2]		(III+) 1762g ±60 0.51g/m² ±0.02	(II+) 1360g ±34 0.39g/m² ±0.01	(I+) 3142g ±67 0.90g/m² ±0.65	(0+) 1630g ±53 0.47g/m² ±0.02	7894g ±110 2.29g/m² ±0.03
10/5/78		(III+) 1375g ±54 0.40g/m² ±0.02	(II+) 998g ±30 0.29g/m² ±0.01	(I+) 3317g ±66 0.95g/m² ±0.02	(0+) 1905g ±48 0.55g/m² ±0.01	7595g ±102 2.18g/m² ±0.03

[1]Based on 3,163 m^2 sampled.

[2]Based on 3,477 m^2 sampled.

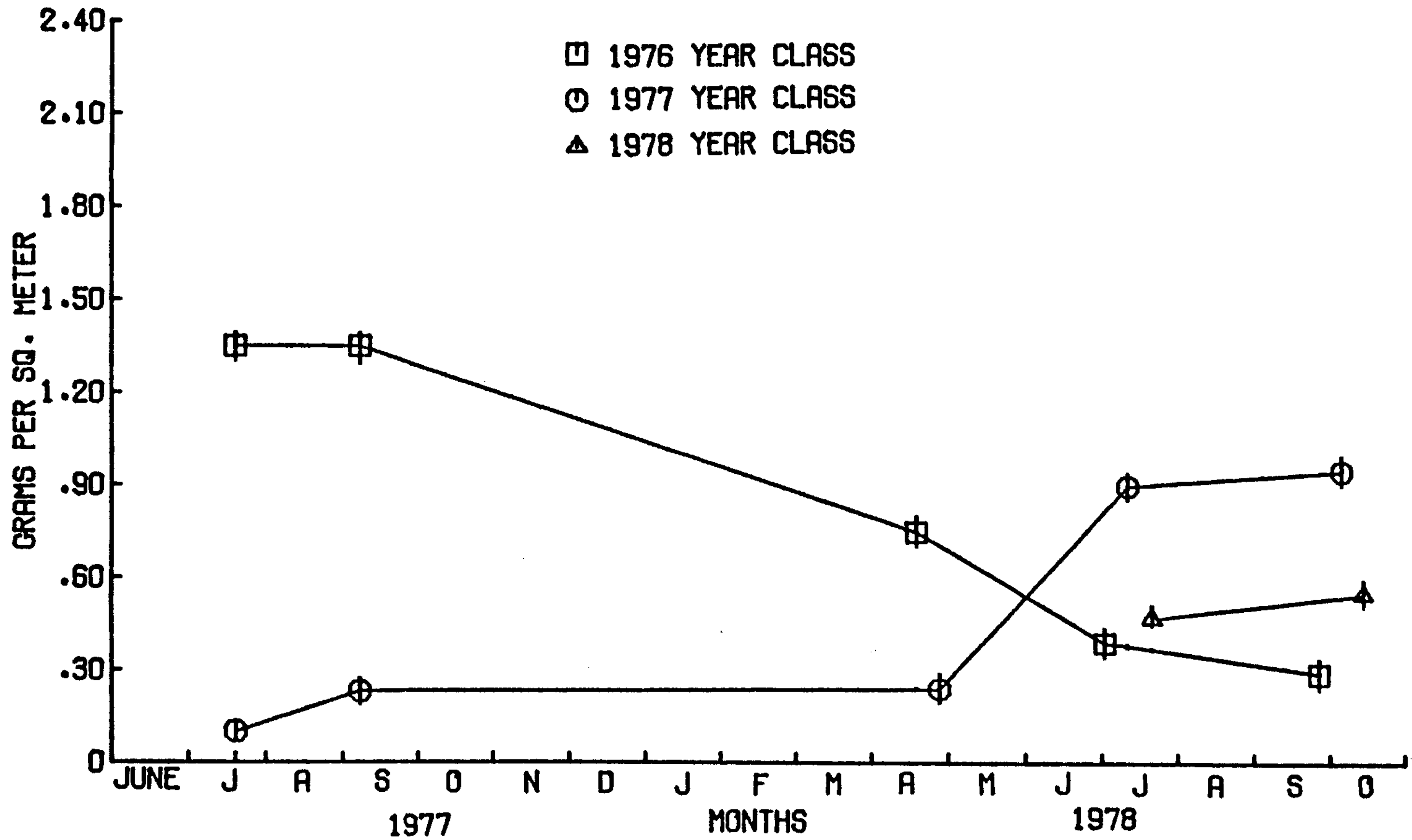


Fig. 7. Relative biomass (grams per square meter low flow surface area) of three year classes of cutthroat trout in Bear Creek during 1977-78. 95% confidence interval bars on data point symbols.

Table 6. Daily instantaneous mortality rates estimated by year class and sample period for cutthroat trout in Bear Creek, 1977-1978. Age groups in parentheses.

Sample period Days	Year class 1978	1977	1976	1975	1974>
July - Sept. 1977		(0+)	(I+)	(II+)	(III+>)
49 days	--	--[1]	0.0022	0.0051	0.0018
Sept. 1977-April 1978		(0+)	(I+)	(II+)	(III+>)
233 days	--	0.0032	0.0028	--[2]	0.0000
April - July 1978		(I+)	(II+)	(III+>)	--
74 days	--	--[1]	0.0151	0.0049	
July - Oct. 1978	(0+)	(I+)	(II+)	(III+>)	
80 days	0.0025	0.0022	0.0058	0.0018	
Sept.1977-Oct.1978		(0+-I+)	(I+-II+)	(II+-III+>)	
365 days	--	--[1]	0.0066	0.0016	

[1]Increase in population.

[2]Age II and III> fish combined.

Table 7. Annual instantaneous mortality rate (Z) and annual mortality rate (A) by year class for cutthroat trout from July, 1977 to July, 1978 in Bear Creek. Age groups in parentheses.

Year Class (Age Group)	Z	A
1977 (0+ to I+)	0.43	0.35
1976 (I+ to II+)	1.92	0.85
1975 (II+ to III+>)	0.43	0.35

Growth. Growth rates were determined from observed changes in mean length and weight by year class, from length at age back-calculated from scale analysis and from changes in length and weight observed on individual tagged fish.

The mean lengths of age 0+ cutthroat trout differed significantly ($p \leq .05$, t-test) between July 1977, 47.4 mm, and July 1978, 55.6 mm (Table 8). This difference was probably due to increased numbers of earlier emerging, therefore larger sea-run fry in 1978. A significant difference also occurred between September 1977 and October 1978 for 0+ fish. This difference may be due to the almost one month difference between the September 7, 1977 and October 5, 1978 samples, however, scale analysis indicated little growth occurring after August. Mean lengths between older age groups were not significantly different between any of the sample periods. Change in mean length for each identifiable year class over all sample periods is shown in Fig. 8.

Significant differences in mean weight were found for age 0+ and age I+ fish between July 1977 and July 1978 and September 1977 and October 1978 (Table 9). Cutthroat in both age classes were heavier in 1978 than 1977 (Fig. 9).

Instantaneous interval and daily growth rates calculated by observed changes in weight between sample dates were highest for each age group between April and July than in other time intervals (Table 10).

Table 8. Mean length in millimeters, 95% confidence interval and sample size (N), for identifiable year classes by sample date for cutthroat trout from Bear Creek collected in 1977 and 1978. Age class in parentheses.

Sampling date	Year class 1974+>	1975>	1976	1977	1978
July 77	(III+>) 170.9 ± 14.8 N=15	(II+) 127.6 ± 2.4 N=25	(I+) 94.7 ± 1.1 N=318	(O+) 47.4 ± 1.0 N=184	--
Sept. 77	(III+>) 174.1 ± 14.6 N=14	(II+) 130.1 ± 2.2 N=25	(I+) 99.0 ± 1.1 N=290	(O+) 61.5 ± 1.0 N=177	--
April 78	--	(III>) 157.8 ± 9.8 N=25	(II) 106.3 ± 1.8 N=102	(I) 75.5 ± 1.3 N=107	--
July 78	--	(III+>) 163.7 ± 9.4 N=28	(II+) 126.3 ± 1.7 N=50	(I+) 95.5 ± 1.2 N=303	(O+) 55.6 ± 0.6 N=648
Oct 78		(III+>) 166.2 ± 10.0 N=23	(II+) 133.5 ± 2.1 N=30	(I+) 103.9 ± 1.4 N=233	(O+) 68.5 ± 0.8 N=371

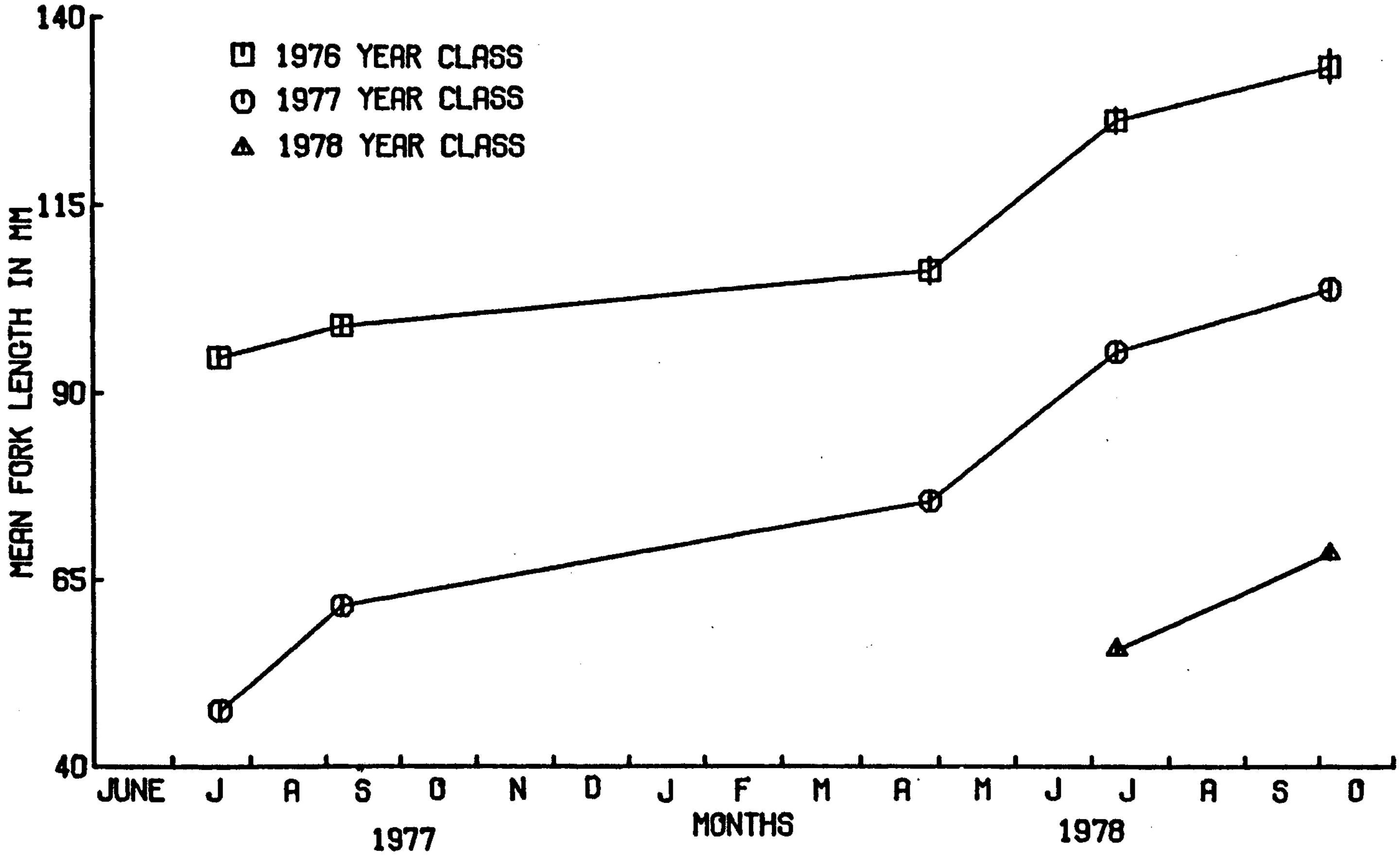


Fig. 8. Mean lengths of three year classes of cutthroat trout measured in Bear Creek during 1977-78. 95% confidence interval bars on data point symbols.

Table 9. Mean weight in grams, 95% confidence interval and sample size by year class and sample date for cutthroat trout from Bear Creek, collected during 1977 and 1978. Age class in parentheses.

Sampling date	Year class				
	1974+>	1975>	1976	1977	1978
July 77	(III+>) 52.47 ± 14.3 N=15	(II+) 20.81 ± 1.55 N=25	(I+) 8.89 ± 0.32 N=318	(O+) 1.09 ± 0.08 N=184	--
Sept. 77	(III+>) 54.29 ± 13.83 N=14	(II+) 21.56 ± 1.53 N=25	(I+) 9.90 ± 0.33 N=290	(O+) 2.49 ± 0.14 N=177	--
April 78	--	(III+>) 39.38 ± 7.84 N=25	(II) 12.15 ± 0.72 N=102	(I) 4.51 ± 0.28 N=107	--
July 78	--	(III+>) 45.18 ± 8.67 N=28	(II+) 19.43 ± 0.87 N=50	(I+) 8.47 ± 0.35 N=303	(O+) 1.78 ± 0.06 N=648
Oct 78	--	(III+>) 49.11 ± 11.12 N=23	(II+) 22.68 ± 1.21 N=30	(I+) 10.70 ± 0.45 N=233	(O+) 3.29 ± 0.10 N=371

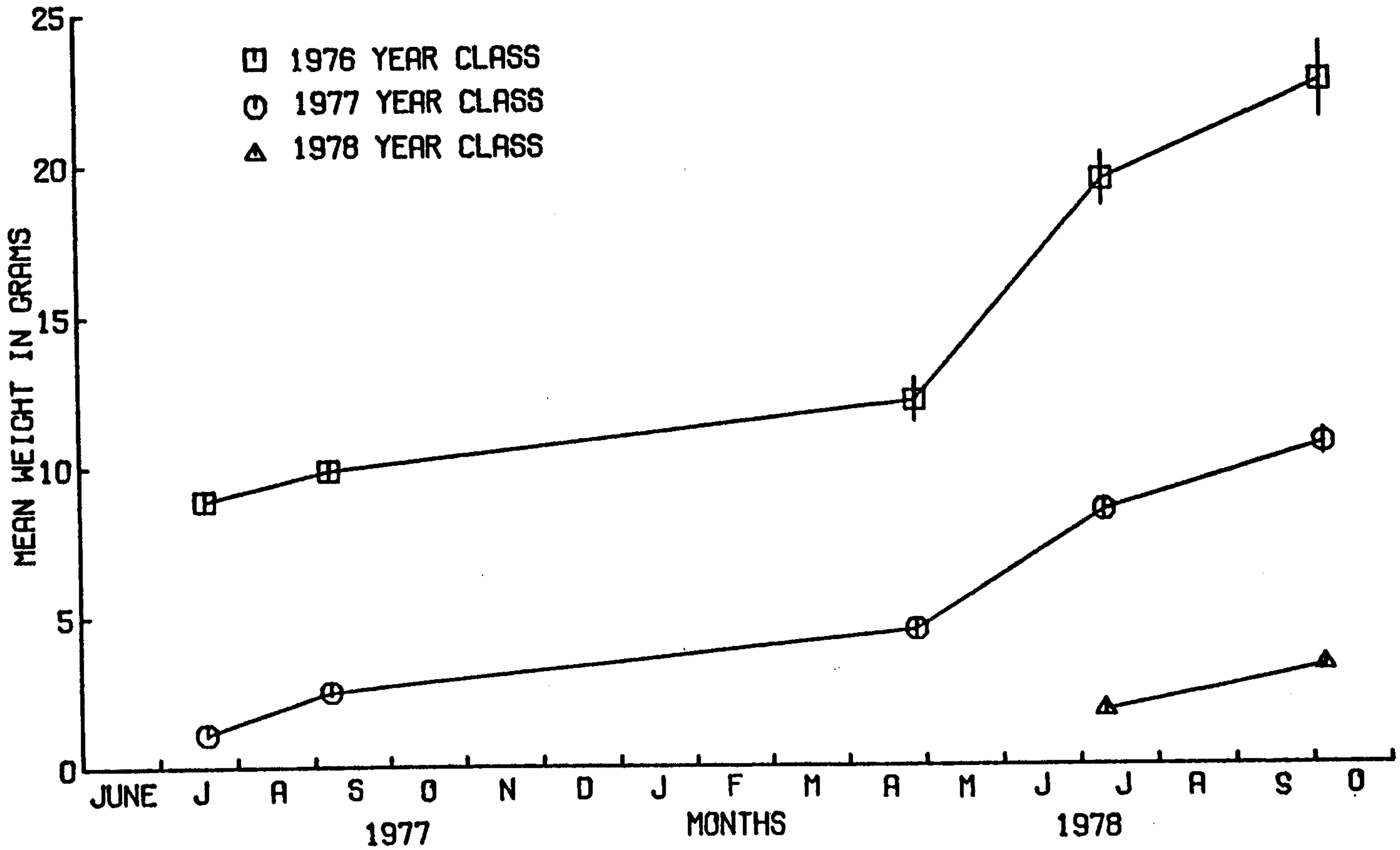


Fig. 9. Mean weights of three year classes of cutthroat trout weighed in Bear Creek during 1977-78. 95% confidence interval bars on data point symbols.

Table 10. Estimated instantaneous interval growth rates by weight in grams for age class and sample interval for cutthroat trout in Bear Creek from July 1977 to October 1978. Daily instantaneous growth rates in parentheses.

Sample period Days	Year class 1974+>	 1975	 1976	 1977	 1978
July 77 to Sept 77 49 days	III+> 0.034 (0.0007)	II+ 0.035 (0.0007)	I+ 0.108 (0.0022)	0+ 0.826 (0.0169)	--
Sept 77 to April 78 233 days	--	II+[1] 0.167 (0.0007)	I+ 0.205 (0.0009)	0+ 0.594 (0.0025)	--
April 78 to July 78 74 days	--	III> 0.137 (0.0019)	II 0.469 (0.0063)	I 0.630 (0.0085)	0+ 3.390[2] (0.0462)
July 78 to Oct 78 80 days	--	III+> 0.083 (0.0010)	II+ 0.155 (0.0019)	I+ 0.234 (0.0029)	0+ 0.614 (0.0017)
July 77 to July 78 365 days		II to III+ 0.775 (0.0021)	I to II+ 0.782 (0.0021)	0+ to I+ 2.050 (0.0056)	

[1]Estimated from age II and III combined.

[2]Estimated weight at emergence 0.06 grams.

Instantaneous growth rates were higher in the 0+ age group in every sample period. Interval and daily instantaneous growth rates for the year beginning and ending in April were calculated for age group 0 to I and I to II year old fish by comparing successive mean weights observed in each age group in April 1978. Age group 0 to I had a yearly interval instantaneous growth rate of 4.320 and a daily growth rate of .046. Age group I to II had an interval rate of .991 and a daily rate of .003.

Scale analysis indicated that yearly annulus marks were formed in March and April of each year. Back-calculated mean lengths at each age from scale analysis were slightly larger than those observed in the actual population sampling for age I and II fish (Tables 11 and 12). The differences were not statistically significant for any age group. Yearly instantaneous interval growth rates for each age group were similar between observed and scale analysis data (Tables 11 and 12).

Growth rates for cutthroat trout greater than 120 mm and usually older than age II were determined from observed changes in length and weight in tagged fish. Of 79 fish tagged during the study, 47 were recaptured at least once. Mean daily instantaneous growth rates in weight .00099, and length, .00029, were negligible (Appendix B). Growth rates did not differ significantly between age II+, III+, and >III+ groups (one-way ANOVA .05 level) between mature and immature fish (t-test,.05 level) or by moving versus nonmoving fish (t-test, .05 level).

Table 11. Estimated lengths at age and instantaneous interval growth rates between ages based on scale analysis for cutthroat trout from Bear Creek, 1977-1978. Lengths in mm at age.

Age group observed	Number of fish	Length at capture	Calculated length at age I	II	III	IV
IV	5	214.8	73.8	114.0	142.9	170.5
III	7	159.3	77.1	116.3	145.9	
II	33	126.4	79.0	114.7		
I	79	96.9	79.1			
Total	124	Average	78.8	114.9	144.6	170.5
		Number	124	45	12	5
		Length interval	78.8	36.1	29.7	25.9
		Std. Dev.	4.339	4.009	6.174	3.413

Interval instantaneous growth rates (based on weight calculated from length)

Age interval	Between year classes	Within year classes
0-I	4.659	4.659
I-II	1.151	1.154
II-III	0.721	0.682
III-IV	0.469	0.530

Table 12. A comparison of mean length at each age and yearly instantaneous growth rates by weight calculated from observed data and derived from scale analysis for cutthroat trout from Bear Creek, 1977-1978.

Age interval April to April	Mean length at age, mm	
	Observed data	Scale analysis
0 - I	75.5	78.8
I - II	106.3	114.9
II - III	157.8	144.6
III - IV	--[1]	170.5

Age interval	Yearly instantaneous growth rates	
	Observed data	Scale analysis
0 - I	4.320[2]	4.659[3]
I - II	0.991	1.154
II - III	0.778	0.682
III - IV	--[1]	0.530

[1]Age group not identifiable.

[2]Assumed weight at emergence 0.06 g (Merriman 1935).

[3]Assumed length at emergence 21.0 mm (Brannon, pers. comm.).

Observed lengths and weights for all ages and all sample dates yielded a constant and slope in the length-to-weight relationship of -4.9436 and 2.9655, respectively. The linear regression equation had an r^2 of .9695 and was based on 2,968 fish. Length-weight relations for each year class by sample date and for all sample dates combined are given in Appendix Table C.

Production. Production for all year classes of cutthroat between July 1977 and July 1978 was 6,662 g or 1.97 g/m^2 low-flow area. This equated to a production rate of .0054 $g/m^2/day$ (Table 13). Production values in July 1977 showed similar trends as density and biomass values with the 1976 year class, age I+, accounting for more production than the 1977 year class, age 0+ fish. This was reversed in 1978 with the 0+ age group production larger than the I+ age group. Most production occurred between April and July.

Movement

Fry Movement. Cutthroat trout fry were collected in the downstream trap at the lower weir in 1977. The first fry were observed on May 26 and 27 though the peak of fry capture occurred between June 21 and June 30 (Fig. 10). A total of 81 fry were captured with a mean length of 27.8 mm (range 25 to 40 mm) and a mean weight of .42 g (range .20 to .55 g). Fry in the 27 to 30 mm length interval accounted for 84% of the total (Fig. 11). All age groups of cutthroat trout including fry seemed

Table 13. Total production in grams and rate of production in g/m^2/day of cutthroat trout by year class and sample date in Bear Creek during 1977-1978. Age groups in parentheses.

Sample interval	Year class 1974+>	1975>	1976	1977	1978	Total
July 77 to Sept 77[1] 49 days	(III+>) 41.7 g 0.0003 g/m^2/day	(II+) 23.7 g 0.0002 g/m^2/day	(I+) 456.8 g 0.003 g/m^2/day	(0+) 429.5 g 0.0028 g/m^2/day	--	952 g 0.0062 g/m^2/day
Sept 77 to April 78[1] 233 days	--	(III>) 479.0 0.0007	(II) 687.3 0.0009	(0+) 630.9 0.0009	--	1797 0.0025
April 78 to July 78[2] 74 days	--	(III+>) 271.7 0.0011	(II+) 928.6 0.0036	(I+) 1221.3 0.0047	(0+) 1491.9 0.0051	3914 0.0152
July 78 to Oct 78[2] 80 days	--	(III+>) 130.2 0.0005	(II+) 182.7 0.0007	(I+) 755.7 0.0027	(0+) 1085.2 0.0039	2154 0.0077
July 77 to July 78[1] 365 days		816.1 0.0007	2072.7 0.0017	2281.7 0.0018	1491.9 0.0012	6662 0.0054

[1]Based on 3136 m^2 sampled.

[2]Based on 3477 m^2 sampled.

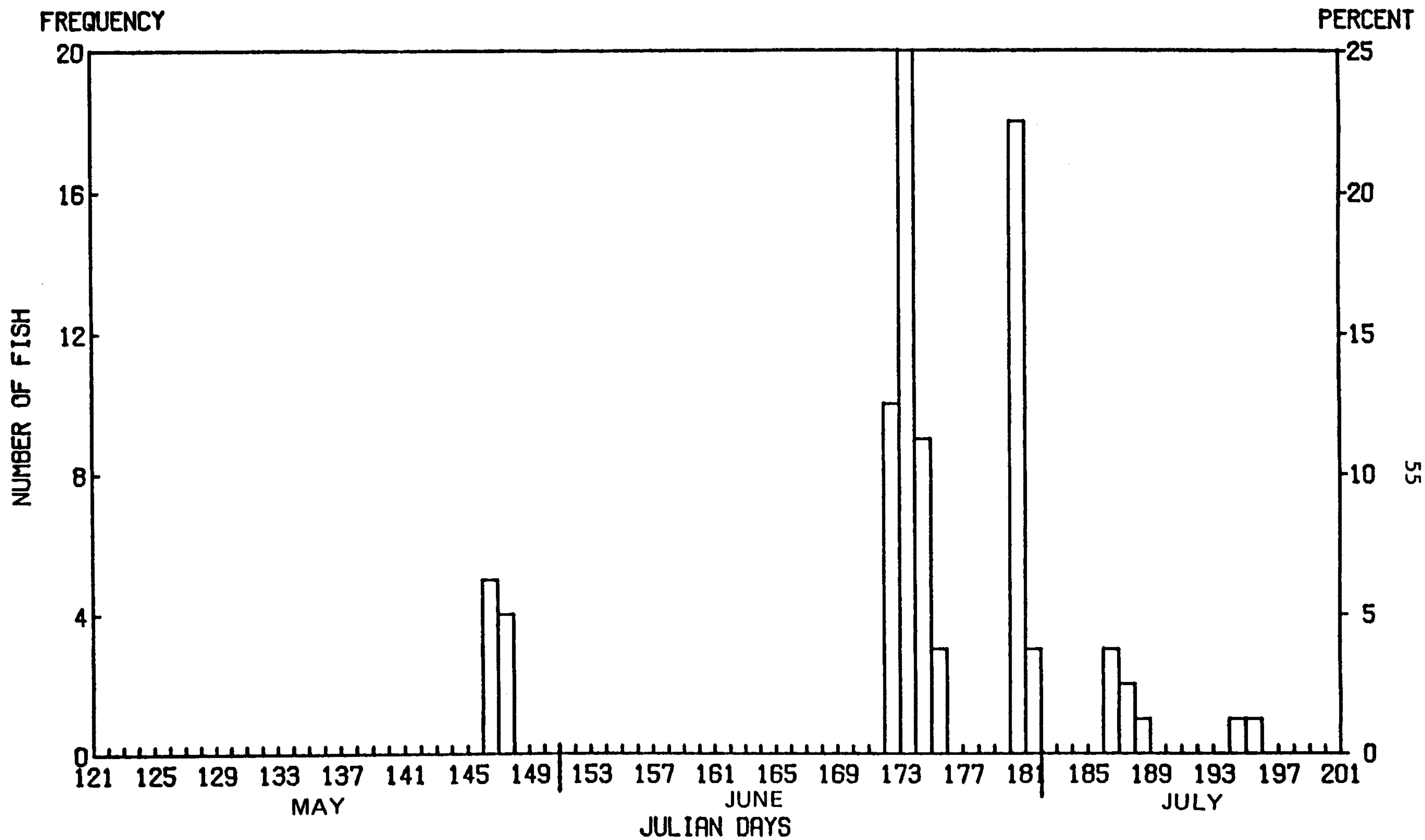
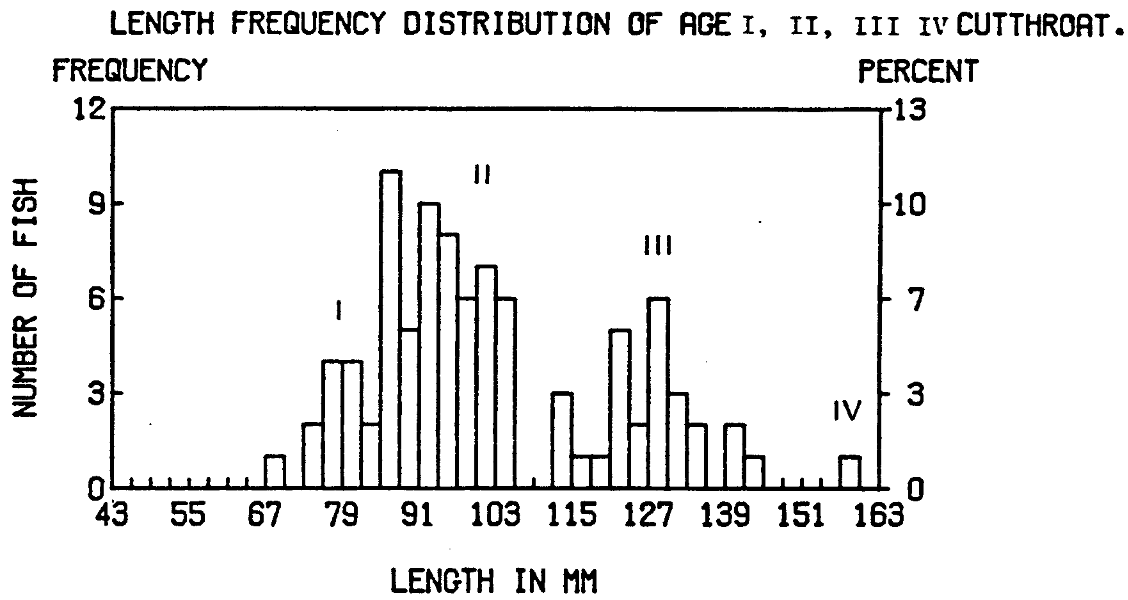


Fig. 10. Numbers and dates of cutthroat trout fry captured in the lower weir downstream fish trap from May through July 1977 in Bear Creek.



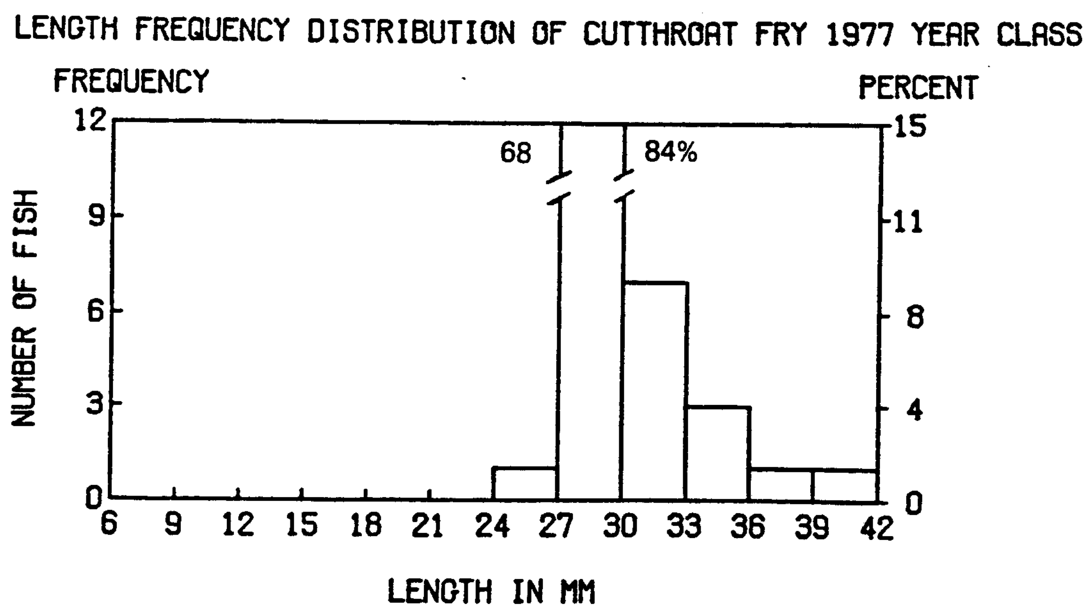


Fig. 11. Length frequency distributions for cutthroat trout fry and older age groups captured in the lower weir downstream fish trap during May through July 1977 in Bear Creek.

to migrate downstream out of the study section during periods of decreased flows after spring rainstorms (Fig. 12). Fry may have been displaced downstream by these higher flows. Fry movement out of the study section accounted for 22% of the total population estimate for the 1977 year class in July 1977.

Fry movement from the ten known redd sites was studied from April 28 until July 6, 1978. Newly hatched fry, less than 30 mm, appeared to remain in the redd area for at least 1 to 2 weeks after emergence (Fig. 4). Distributions of fry in the May 25 survey, 2 to 3 weeks after emergence and greater than 30 mm, indicated a general downstream movement of 25 to 100 m from the redd location (Fig. 13). Fry seemed to remain in groups during movement and appeared to settle into the margins of pools below the redd sites. It is very possible that observations of fry attributed to downstream movement from known redd sites were actually fry from unknown redds.

Distributions of all sizes of fry on June 8 and July 6, 1978 show an even distribution of fry throughout the study area (Fig. 14). Fry generally remain clumped for 1 to 2 weeks after emergence with a downstream movement and even distribution in 3 to 6 weeks after emergence.

Outmigration. Fish were captured in a downstream fish trap at the lower weir in 1977 and 1978. A total of 172 cutthroat were caught in 1977, of which 47% were age group 0, 1977 year class (Table 14).

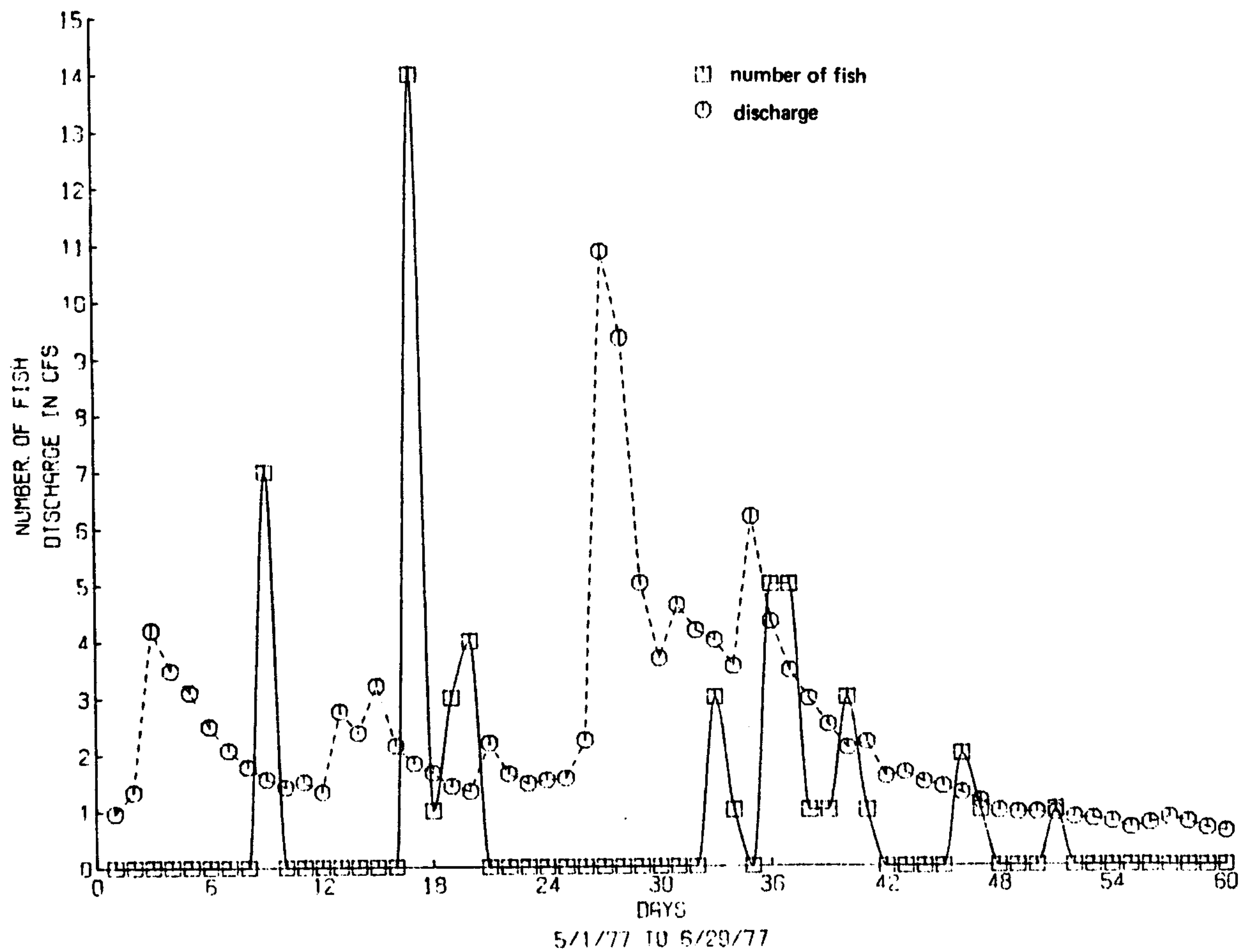


Fig. 12. Numbers and dates of cutthroat trout (all year classes) captured in the lower weir downstream fish trap versus discharge in cubic feet per second during May through July 1977 in Bear Creek.

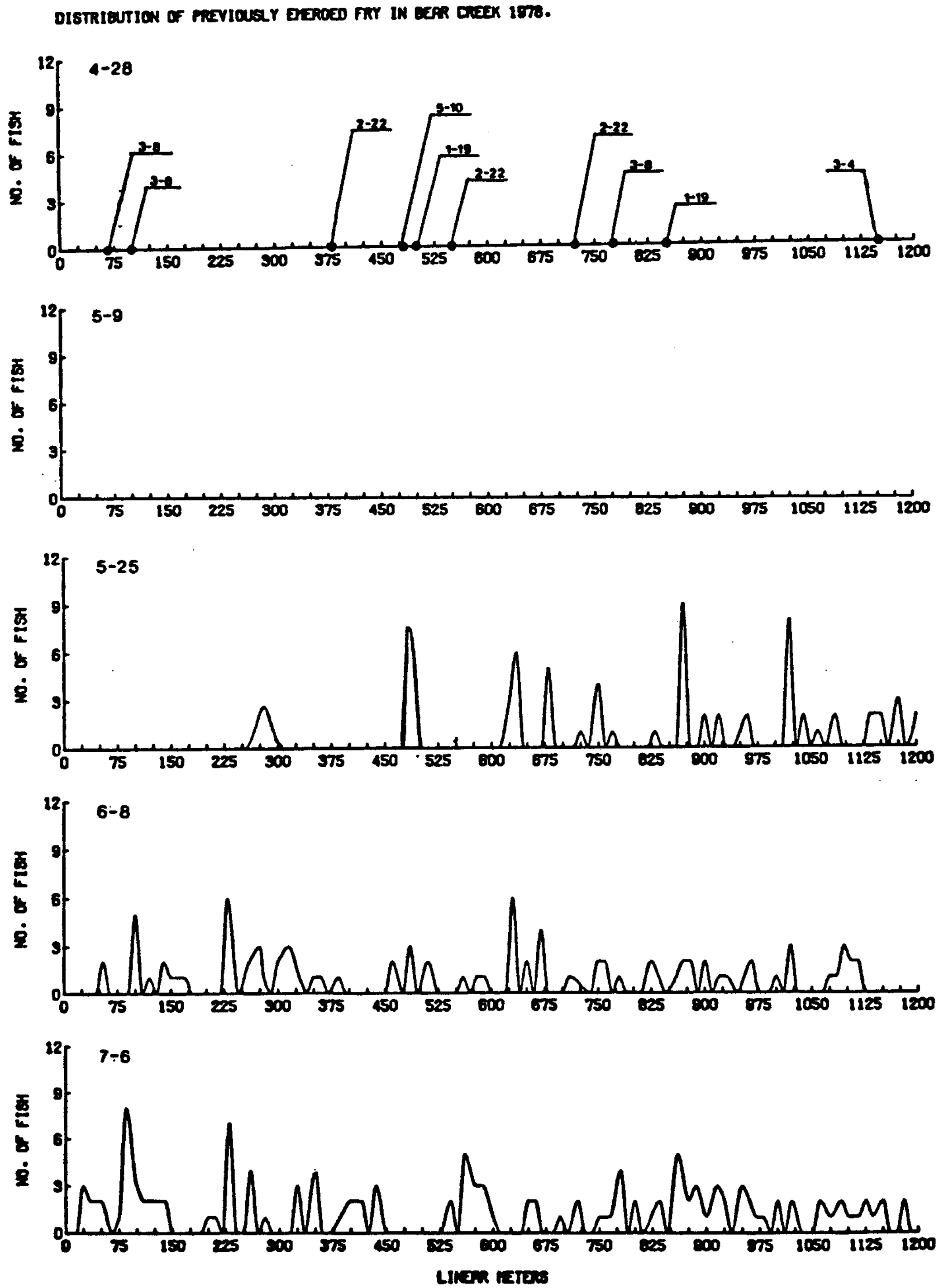


Fig. 13. Distribution of cutthroat trout fry approximately 30 mm and greater in length observed on five sample dates in Bear Creek during 1978.

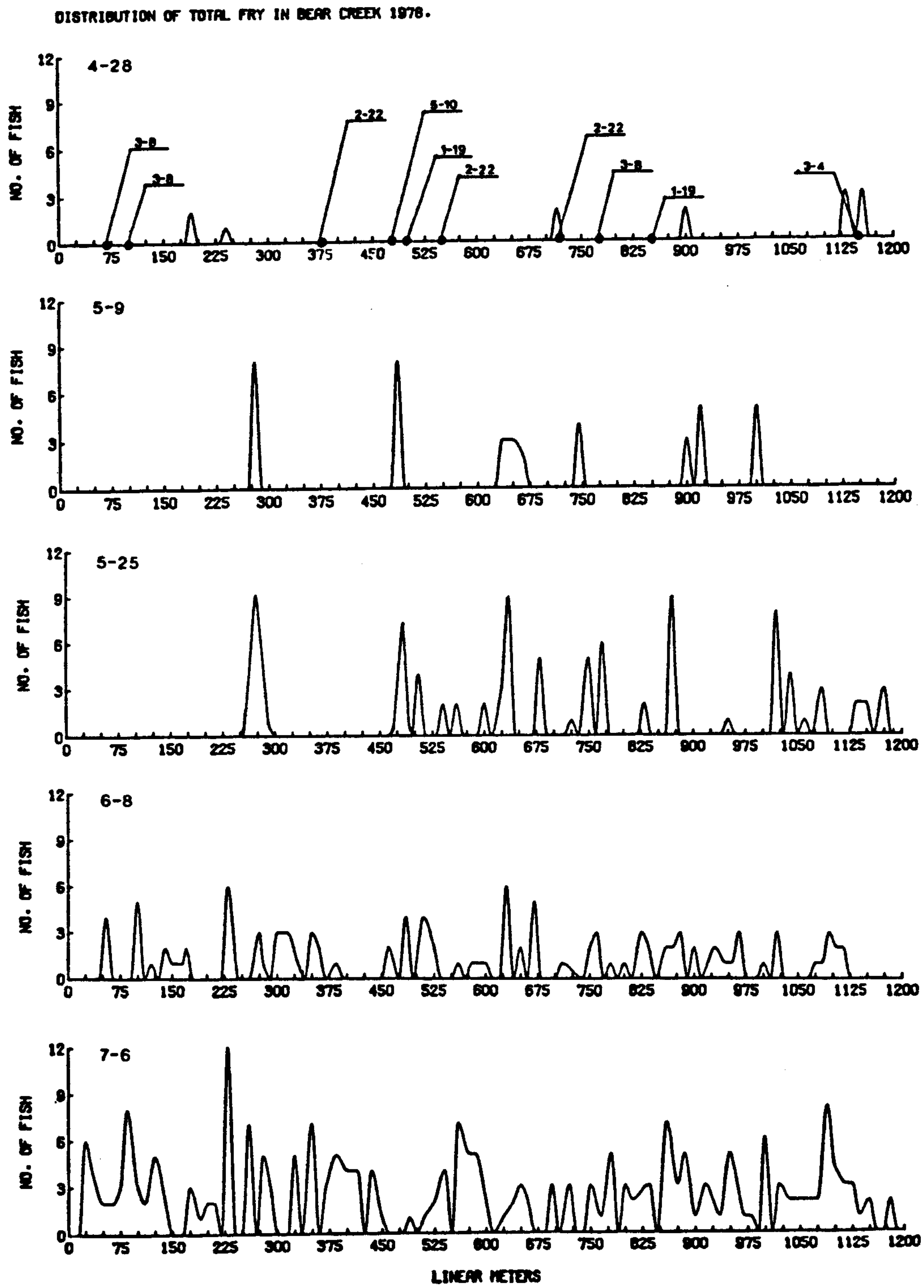


Fig. 14. Distribution of all sizes of cutthroat trout fry observed on five sample dates in Bear Creek during 1978.

Table 14. Number, age, mean length, mean weight and 95% confidence intervals of cutthroat trout captured in the downstream trap on the lower weir Bear Creek during spring 1977.

Age group	Mean date of capture (Julian day)	Mean length in mm	Mean weight in grams	No. captured	% total
0	June 22 (173)	27.8 ± 0.5	.42 ± 0.12	81	47
I	May 24 (144)	77.5 ± 2.2	5.15 ± 0.66	12	7
II	May 25 (145)	95.1 ± 2.0	8.72 ± 0.63	55	32
III	May 20 (140)	128.3 ± 3.0	18.28 ± 1.48	23	13
IV	May 14 (134)	157.0 —	32.01 —	1	> 1

Outmigration of all age groups was related to discharge (Fig. 12). Larger, older fish tended to migrate earlier than younger fish (Table 12) with peak outmigration for I, II, III and >III+ late in May (Fig. 15). Lengths and weights of outmigrants in 1977 (Fig. 11) were not significantly differ- ent from observed values for the same age groups in the total study area population in April 1978 (Tables 6 and 7). High flows in spring of 1978 prevented efficient downstream trapping of outmigrants. A total of 13 fish was captured between April 28 and August 1, 1978. Peak outmigration occurred between June 15 and July 6, 1978, and apparent differences existed between age group structure, and mean weights, and lengths compared with 1977 outmigrants, although the small 1978 sample size prevented statistical analysis (Appendix Table D).

Movement Within the Study Area. Numbered tags were placed on 79 cutthroat trout over 120 mm during the study period. A total of 158 recaptures were made on 47 fish ranging from 2 to 8 recaptures per fish with a mean of 3.4. The intervals ranged from 4 to 221 days with a mean of 91. The fish ranged in length from 122 to 206 mm with a mean of 148.8 mm. Their mean weight was 33.3 g and ranged from 16.2 to 83.9 g.

Thirty fish out of the 47 recaptured had moved at least 25 m. Thirteen moved downstream while 17 moved upstream. Total movement, defined as the relative change in position between initial and final capture location, averaged -3.7 m (95% conf. is ± 51.5 m), with a range

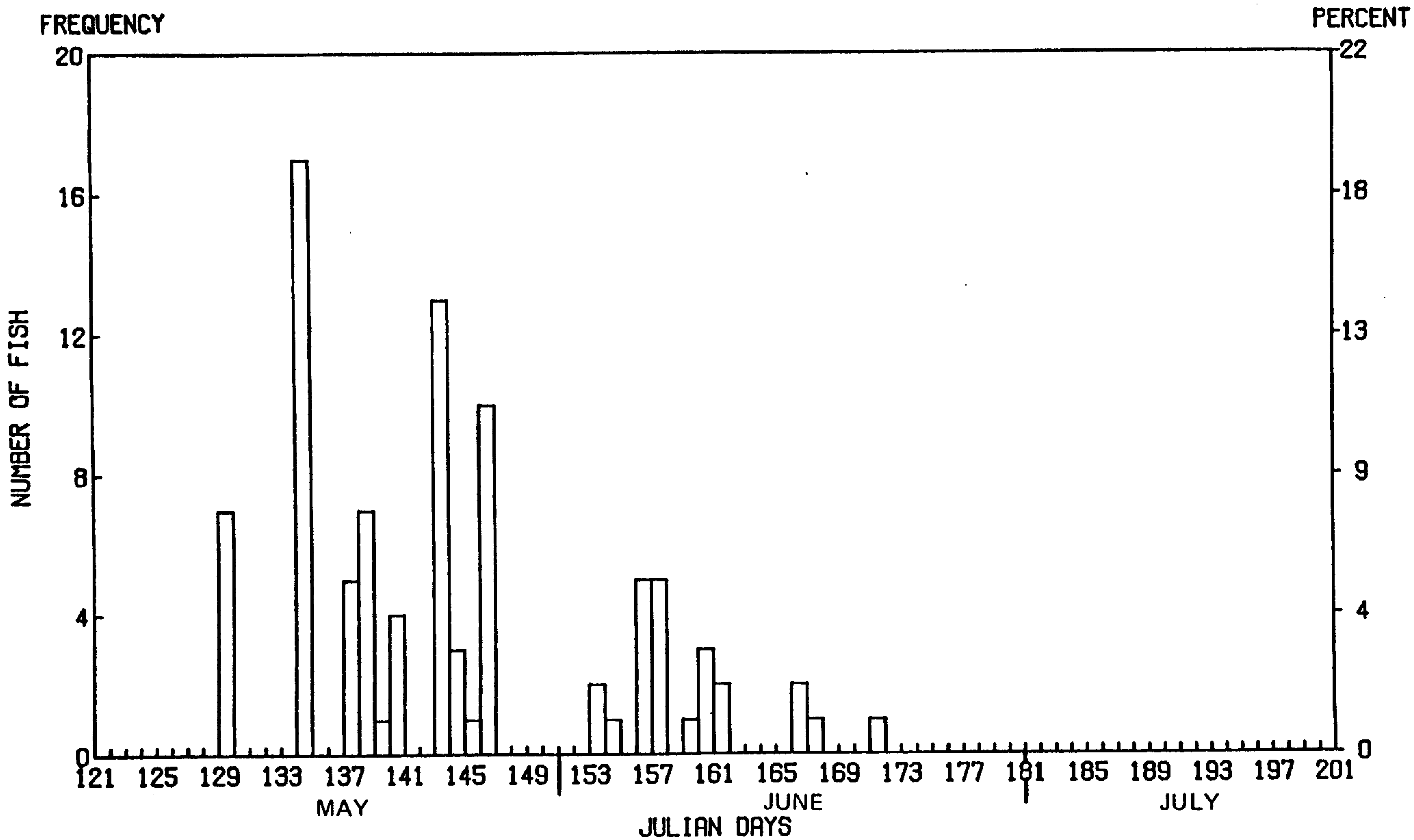


Fig. 15. Numbers and dates of capture of age groups I, II, III and older cutthroat trout collected in the lower weir downstream fish trap during May through July 1977 in Bear Creek.

of -875 to 425 m (Fig. 16). Absolute movement, defined as the sum of changes in location during all recaptures, averaged 115.4 m (95% confidence is ± 53.9 m), with a range of 0 to 875 m (Fig. 17).

Ripe males were found to have significantly greater (t-test p = .002) absolute movement, 375 m, than nonripe unsexed fish, 91 m. Upstream-moving fish came from the lower part of the study area (270 m) than downstream-moving fish which tended to come from the upper area, (560 m), (t-test, SIG. = .017).

Fish were grouped by upstream, downstream, and no movement and one-way ANOVA's used to test for significant difference in length, weight, total movement and absolute movement (Table 15). Larger fish tended to move upstream while the smaller fish stayed in a single location. There was a significant difference in both total and absolute movement between the groups with downstream-moving fish showing not all movement was directed in a downstream direction, though the final location of capture was downstream from initial capture. Total movement, 102.9 m, and absolute movement, 138.2 m for upstream-moving fish showed more movement in a single direction.

Cutthroat trout were freeze-branded in five 50-m habitat study sections in April and July 1978. Of 33 fish branded in April, 19 or 58% were recaptured by November 1978. Five fish moved upstream an average of 69.0 m, 4 fish moved downstream an average of -168.8 m and 10 fish did not move a detectable distance (Table 16). One habitat section had no recaptures, 2 sections showed average upstream movement, and 3

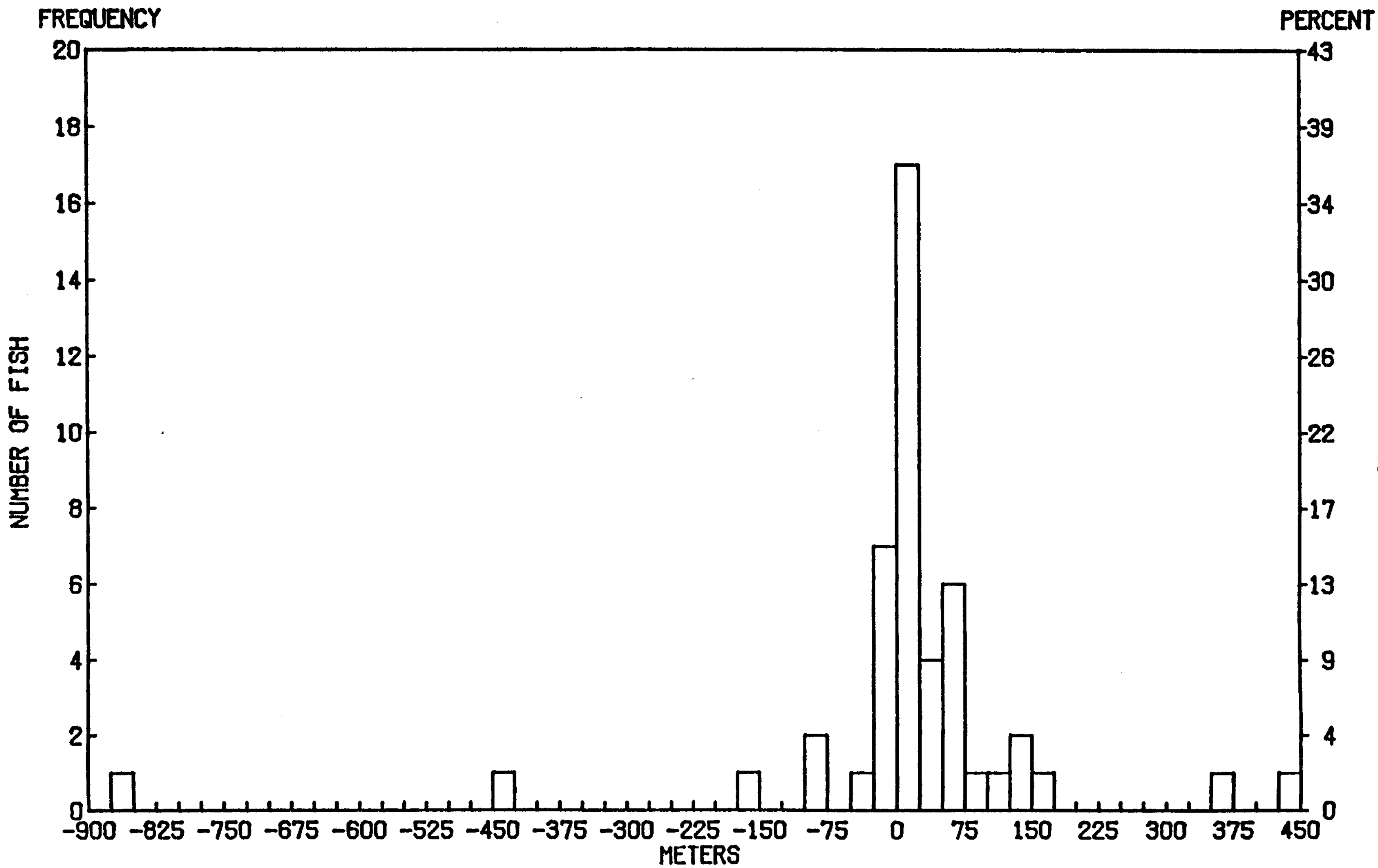


Fig. 16. Total movement (difference in position between initial and final capture) for tagged cutthroat trout during 1977-78 in Bear Creek.

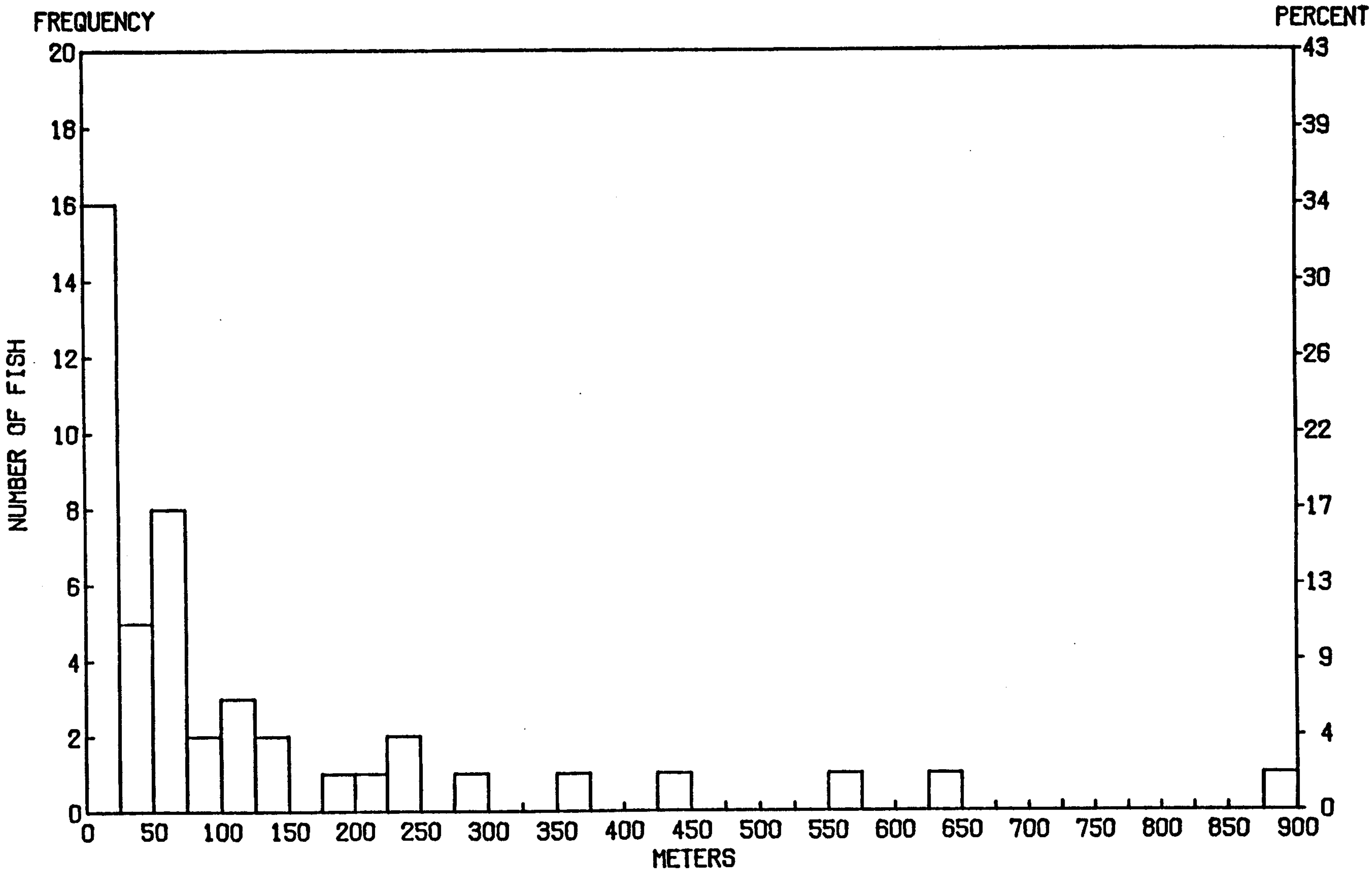


Fig. 17. Absolute movement (combined distances traveled between all recaptures) for tagged cutthroat trout during 1977-78 in Bear Creek.

Table 15. Significant differences in lengths, weights, total distance moved and absolute distance moved of cutthroat grouped by direction of movement in Bear Creek during 1977-1978.

Variable	Group	Mean	F value	Sig.
Length	No movement	136.1 mm		
	Upstream	160.9 mm	6.08	.005
	Downstream	149.7 mm		
Weight	No movement	24.5 g		
	Upstream	40.9 g	4.86	.012
	Downstream	34.8 g		
Total movement	No movement	0 m		
	Upstream	102.9 m	10.75	.0002
	Downstream	-148.1 m		
Absolute movement	No movement	2.9 m		
	Upstream	138.2 m	7.69	.0014
	Downstream	232.7 m		

Table 16. Movement of branded cutthroat trout in five habitat study sections of Bear Creek from April 28 to November 11, 1978.

Habitat study section	No. fish tagged	No. fish recaptured	No. of observations	No. moving upstream	Mean dist. upstream	No. moving downstream	Mean dist. downstream	No. not moving	Average movement per observation
75- 125 m	6	4	8	0	0	2	-37.5 m	2	-9.4 m
550- 600 m	2	0	0	NO RECAPTURES					
900- 950 m	9	6	9	4	80.0 m	1	-25.0 m	1	41.7 m
1000-1050 m	4	2	3	0	0	1	-575.0 m	1	-191.7 m
1125-1175 m	12	7	9	1	25.0 m	0	0	6	-2.8 m
Total	33	19	29	5	69.0 m	4	-168.8 m	10	-8.6 m

sections had an average downstream movement (Table 16). One fish branded in section 1000-1050 m moved -575 m. The next greatest amount of movement was 125 m upstream by a fish in section 900-950 m. No significant relationships existed between amount or number of fish moving out of a section and habitat within the section such as riffle or pool area, percent shade area, surface area or average depth (bivariate correlation analysis).

Fish in each 50-m section were rebranded in July 1978 and movement monitored through November 1978. Eighty cutthroat were branded and 41 were recaptured with no movement detected from any fish. One fish branded in April moved -25 m from section 900-950 m between July and November 1978.

Overall movement of all fish recaptured prior to July 1978 averaged -20.0 m. However, if the single fish from section 1000-1050 that moved -575 m is removed from the calculations the mean movement is +20.0 m. Average movement of all fish branded and recaptured after July 1978 was -.5 m.

Habitat Analysis

Quantifying Habitat

Habitat section one, 75 to 125 m, had the largest full-flow bank area, 497 m^2, the highest spring low-flow surface area, 318 m^2, and the highest percentage of surface area in pools and runs, 37% (Table 17). Section 3, 900 to 950 m, had the highest percentage of riffle area, 93%,

Table 17. Full bank area, wetted surface area, and percent of wetted surface area of three ranges of depth and velocity measured in five habitat study areas of Bear Creek in April 1978.

Section	Full flow area	Spring flow wetted area	Depth			Velocity		
			Riffle 0 to 20 cm	Run 20-40 cm	Pool >40 cm	Slow $\leq$60 cm/s	Medium 6-20 cm/s	Fast $\geq$20 cm/s
75- 125 m	497 m^2	318 m^2	63%	30%	7%	48%	15%	37%
550- 600 m	328 m^2	244 m^2	83%	17%	>1%	43%	14%	42%
900- 950 m	335 m^2	210 m^2	93%	7%	>1%	55%	13%	32%
1000-1050 m	344 m^2	264 m^2	76%	17%	7%	50%	14%	36%
1125-1175 m	418 m^2	237 m^2	91%	7%	2%	57%	13%	30%

but had the second-lowest percentage of fast velocity water, 32% (Table 17). All sections were similar in percentage of spring low-flow surface area in both depth and velocity. All sections were also similar in bottom composition, with most of the bottom of cobble or small rock size and little area in sand-silt or bedrock (Table 18). Section 3, 900-950 m, had lower percentages of areas of instream and streamside cover than the rest of the sections and was second lowest in overhead cover. There was a wide range of area shaded by overhead cover in the 5 sections ranging from 81% in section 4 to 49% in section 1 (Table 18).

Contour maps were drawn for 5 ranges of values for each habitat variable for each section. An example of a symbol contour map for bottom composition in habitat section 4, 1000-1050 m is shown in Fig. 18. These series of maps for each section will be compared with those for the same sections after canopy removal to detail areas of habitat variable changes.

The habitat utilization model also produced tables of surface area represented in ten intervals of depth, velocity, and distances to 3 types of cover. Bottom composition was separated into 5 categories. These tables were calculated from values obtained from the SYMAP output and processed for actual usable areas, or areas submerged by water at mean spring flow, and potential usable areas, or areas of variable ranges potentially available at mean high flows. Examples of these tables are shown for section 4, 1000-1050 m (Table 19). Values from these tables can be used for pre- to post-canopy removal habitat alteration comparisons.

Table 18: Percent of wetted surface area with five ranges of substrate diameter and three types of cover in five habitat study sections of Bear Creek in April 1978.

Section	1 Sand silt	2 Gravel 5-25 mm	3 Cobble 25-50 mm	4 Sm. rock 50 mm-100 mm	5 Lg. rock >100 mm	Cover: Instream (submerged)	Cover: Streamside (≤.5 m above surface)	Cover: Overhead (>.5 m above surface)
75- 125 m	5.8%	17.9%	35.3%	25.6%	12.9%	20%	29%	49%
550- 600 m	5.0%	2.8%	30.9%	52.3%	9.1%	18%	28%	61%
900- 950 m	5.2%	9.4%	40.7%	42.0%	2.6%	9%	16%	59%
1000-1050 m	1.7%	10.6%	31.4%	54.8%	1.4%	24%	25%	81%
1125-1175 m	16.6%	11.6%	31.0%	25.0%	15.7%	21%	29%	70%

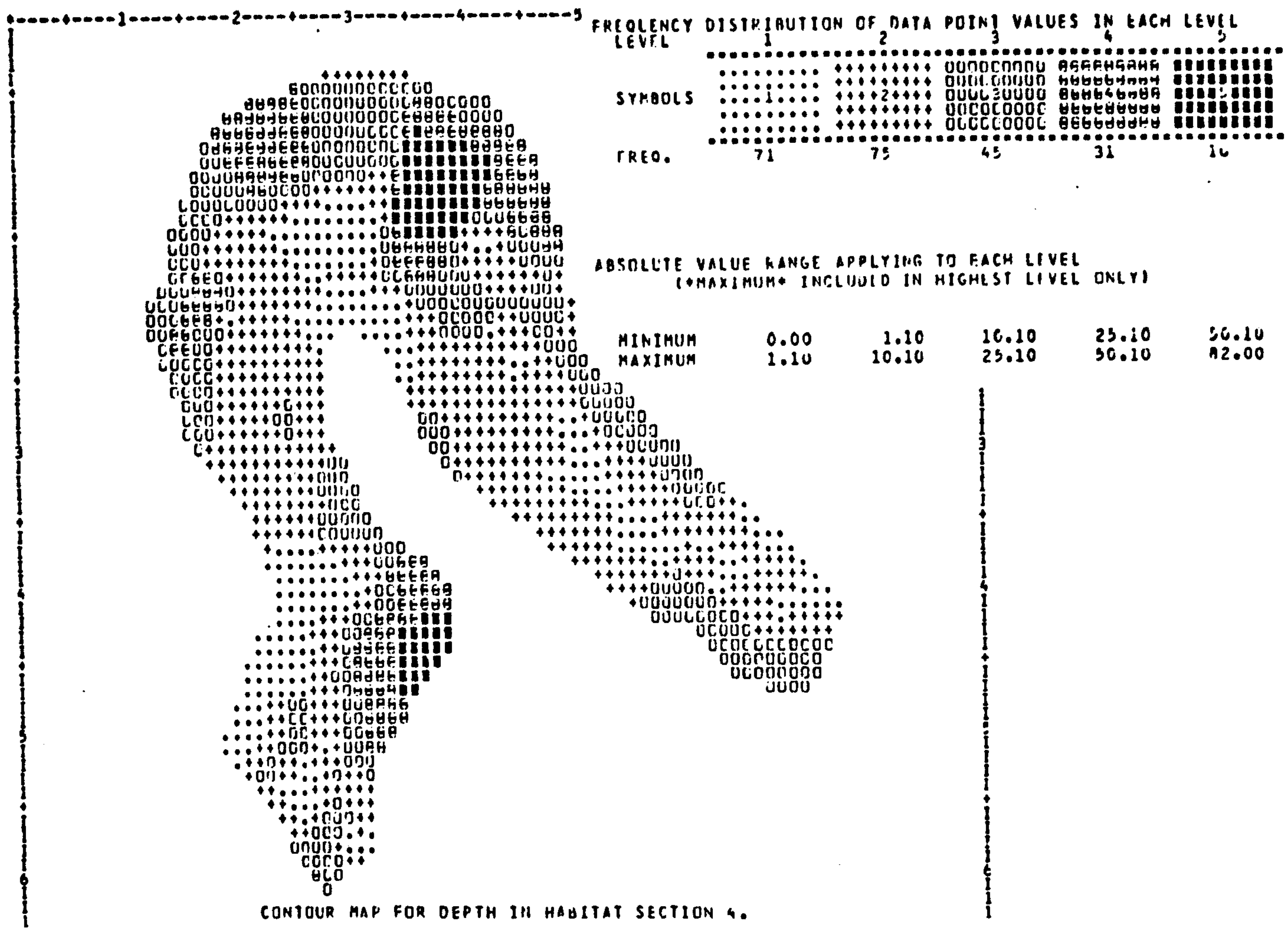


Fig. 18. SYMAP produced contour map of depth in habitat section 4 measured in spring 1978 in Bear Creek.

Table 19. Actual and potential (in parentheses) useable stream areas estimated for ten intervals of values of six habitat parameters in habitat study section 4 of Bear Creek in April 1978.

Variable	Interval range area 1	2	3	4	5	6	7	8	9	10
Depth	0-1 cm 9.3 m^2	1-6 56.0	6-10 70.5	10-20 65.8	20-25 14.5	25-30 12.5	30-40 17.5	40-55 10.3	55-70 5.8	>70 2.0
Velocity	0-3 cm/s 18.3 m^2	3-5 18.0	5-6 10.0	6-9 29.3	9-12 31.3	12-14 10.5	14-16 15.3	16-18 17.3	18-21 18.5	>21 95.8
Bottom composition	silt/sand 4.5 m^2 (8.0 m^2)	5-25 mm 28.0 (31.8)	25-50 83.0 (89.0)	50-100 144.7 (155.3)	>100 3.8 (4.0)					
Distance to instream cover	0-.4 m 63.8 m^2 (67.3 m^2	.4-.6 9.5 (10.0)	.6-.75 19.0 (19.0)	.75-1.0 21.5 (23.3)	1.0-1.3 21.5 (21.8)	1.3-1.5 21.3 (21.3)	1.5-1.7 10.3 (12.0)	1.7-2.3 49.5 (55.3)	2.3-2.8 29.5 (34.5)	>2.8 18.3 (23.8)
Distance to streamside cover	0-.3 m 67.0 m^2 (70.8 m^2)	.3-.5 28.3 (29.3)	.5-.7 17.0 (17.8)	.7-.85 15.3 (16.0)	.85-1.1 17.5 (18.3)	1.1-1.3 15.3 (16.0)	1.3-1.8 27.8 (30.0)	1.8-2.3 36.0 (42.3)	2.3-2.5 9.8 (10.8)	>2.5 30.3 (37.0)
Distance to overhead cover	0-.05 m 213.3 m^2 (235.3 m^2)	.05-.15 12.5 (13.5)	.15-.25 7.8 (8.3)	.25-.4 5.8 (5.8)	.4-.5 3.8 (3.8)	.5-.8 6.5 (6.8)	.8-1.0 4.0 (4.3)	1.0-1.3 3.5 (3.5)	1.3-1.5 0 (0)	>1.5 7.0 (7.0)

Probability-of-Use Curves

Observations of 88 cutthroat trout from April through June 1978 were used to calculate probability-of-use curves for depth, velocity, bottom composition and distances from three types of cover. Thirty small fry were observed, 34 large fry, fourteen 1 or 2-year old fish and 10 fish large enough to be greater than 2 years old. One-way ANOVA analysis found no significant differences between values of habitat variables measured for small and large fry. Similar results were found for fish 1 to 2 years old and fish greater than 2 years old. Small and large fry were grouped as were 1-year-old and older fish, and mean values of variables retested. Significant differences between fry (age 0 fish) and juvenile to adult (I+ older fish) were found in water depth, velocity, and bottom composition (Table 20). No differences were found in distance to the three cover types or depth of the fish. All variables where significant differences were found were retested with a nonparameteric Kruskal-Wallis one-way ANOVA and all were still found to have significant differences.

Separate probability-of-use curves for fry and juvenile-adult fish were calculated for those variables where significant differences were found between the two fish groups. Fry had a greater probability of being found in shallow depth, less than 25 cm, while the juvenile-adult group were more likely to be found in deeper water, greater than 60 cm (Fig. 19). Adult and juvenile fish had a narrower range of velocities, between 2 and 6 cm/sec, with high probability-of-use than fry which had high probabilities from 6 to 14 cm/sec (Fig. 20). Fry had a greater

Table 20. Analysis of differences in habitat variables measured at location of cutthroat trout grouped as fry (age 0) and juvenile-adult (age I and older) in Bear Creek, spring 1978.

Variable	Mean value for fry	Mean value for juvenile-adult	One-way ANOVA F value	Sig.
Depth of water	24.8 cm	47.7 cm	12.289	.0001
Depth of fish from bottom	7.7 cm	9.0 cm	.916	.4370
Velocity at fish position	8.2 cm/s	4.6 cm/s	4.425	.0061
Surface velocity	11.4 cm/s	6.6 cm/s	4.376	.0065
Mid-depth velocity	9.4 cm/s	5.3 cm/s	3.749	.0140
Bottom velocity	6.1 cm/s	3.0 cm/s	3.664	.0155
Average velocity	9.0 cm/s	5.0 cm/s	4.443	.0060
Bottom composition	3.2	3.9	5.030[1]	.0238[1]
Distance to instream cover	.69 m	.93 m	1.034	.3819
Distance to streamside cover	.85 m	.92 m	.570	.6363
Distance to overhead cover	.81 m	.27 m	1.360	.2608

[1]Chi-squared value and level of significance from 2x2 contingency table of nominal data.

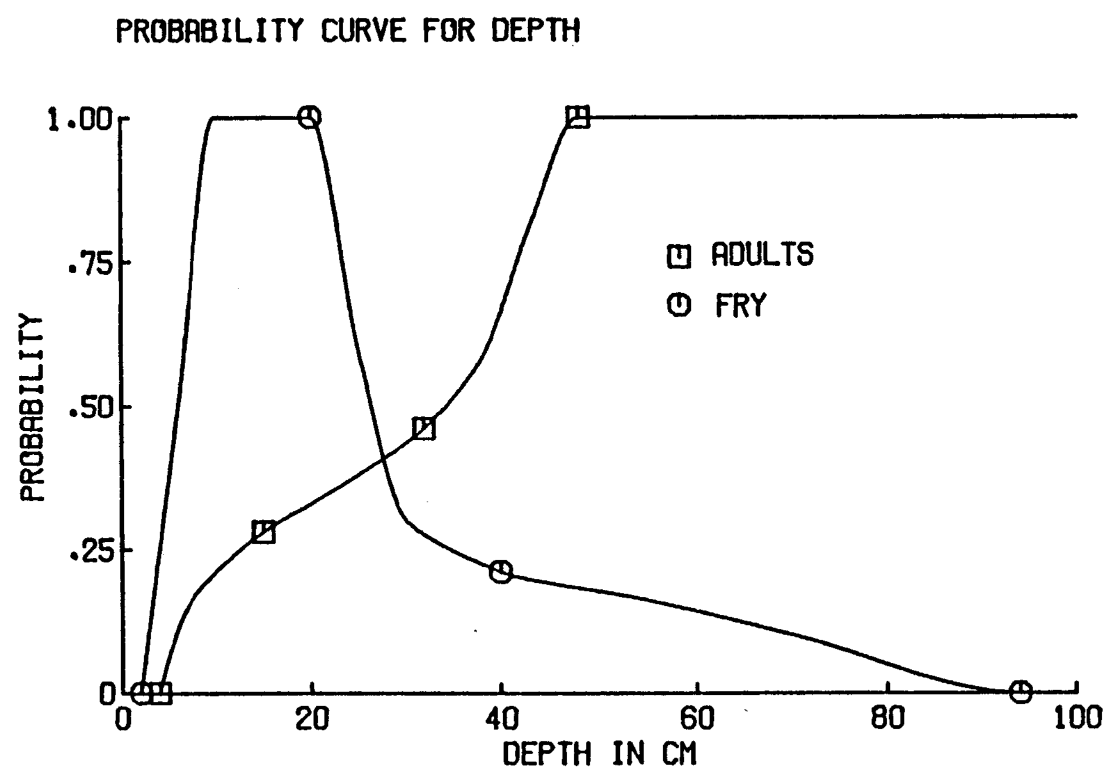


Fig. 19. Probability-of-use curves for depth by fry and juvenile-adult cutthroat trout during spring 1978 in Bear Creek.

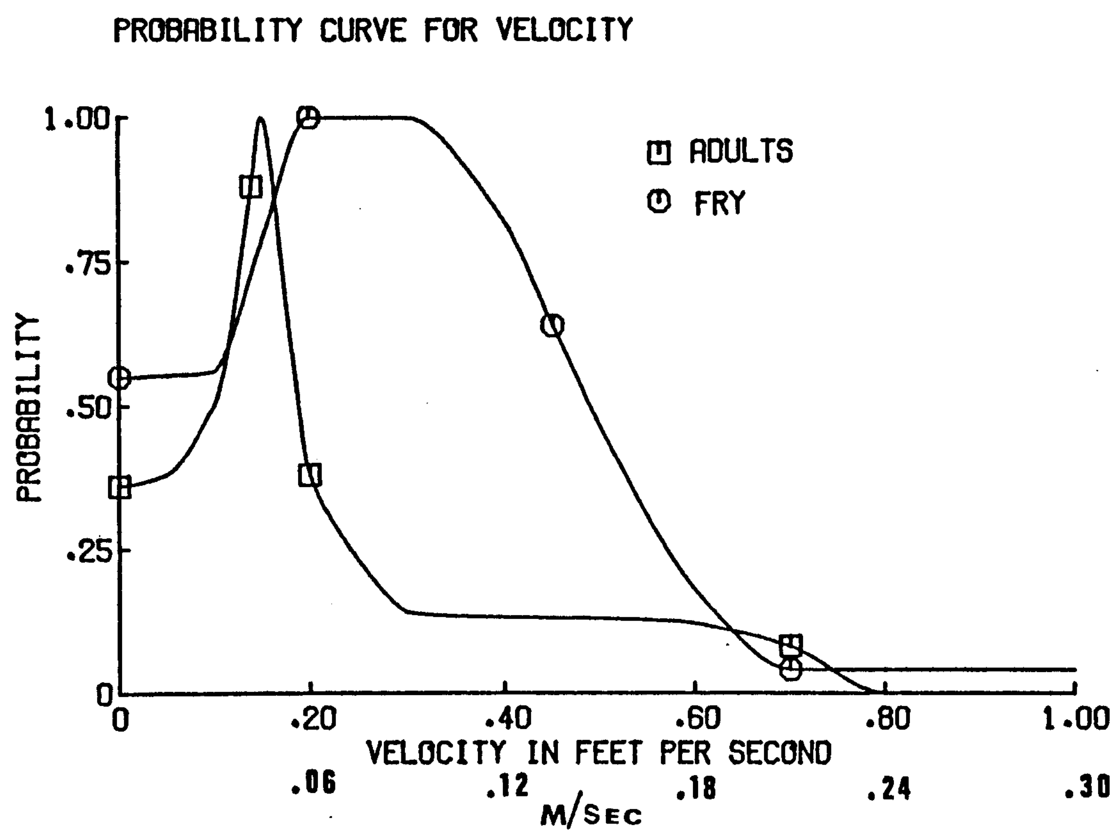


Fig. 20. Probability-of-use curves for water velocity of fry and juvenile-adult cutthroat trout in Bear Creek during spring 1978.

probability of being found over smaller-sized substrate, cobbles 25-50 mm diameter. Adults and juveniles had greater probability of being positioned over larger substrate, small rock 50-100 mm diameter (Fig. 21). All fish were combined in the probability-of-use curves for distances to the three types of cover. Fish had a high probability of being within .3 m of instream, streamside, and overhead cover. Probability curves for the three types of cover were very similar through all distances (Fig. 22).

Habitat Utilization Model

Habitat section 4, 1000 to 1050 m, had the highest 3 and 6-parameter quality of habitat indices for adult and juvenile cutthroat trout, 4.1% and 1.2% of spring wetted area, respectively (Table 21). Section 1, 75 to 125 m, had the highest 3-parameter index, 11.3% for fry, while the highest 6-parameter index for fry, 5.2%, was found in section 4 (Table 21). Habitat sections 1 and 4 had the highest quality of habitat indices, section 3 the lowest, and sections 2 and 5 intermediate values for both fry and juvenile-adults.

Section 4 had the highest biomass (g/m^2) of juvenile and adult cutthroat in 1977; however, it was the lowest in both fry and juvenile-adult densities and biomass in 1978 (Table 22). Total biomass in the 5 sections ranged from 1.003 to 1.970 g/m^2 in 1977 and 1.221 to 1.828 g/m^2 in 1978.

Average fry density in 1978 was negatively correlated with percent pool area (Table 23). Fry density was positively correlated with

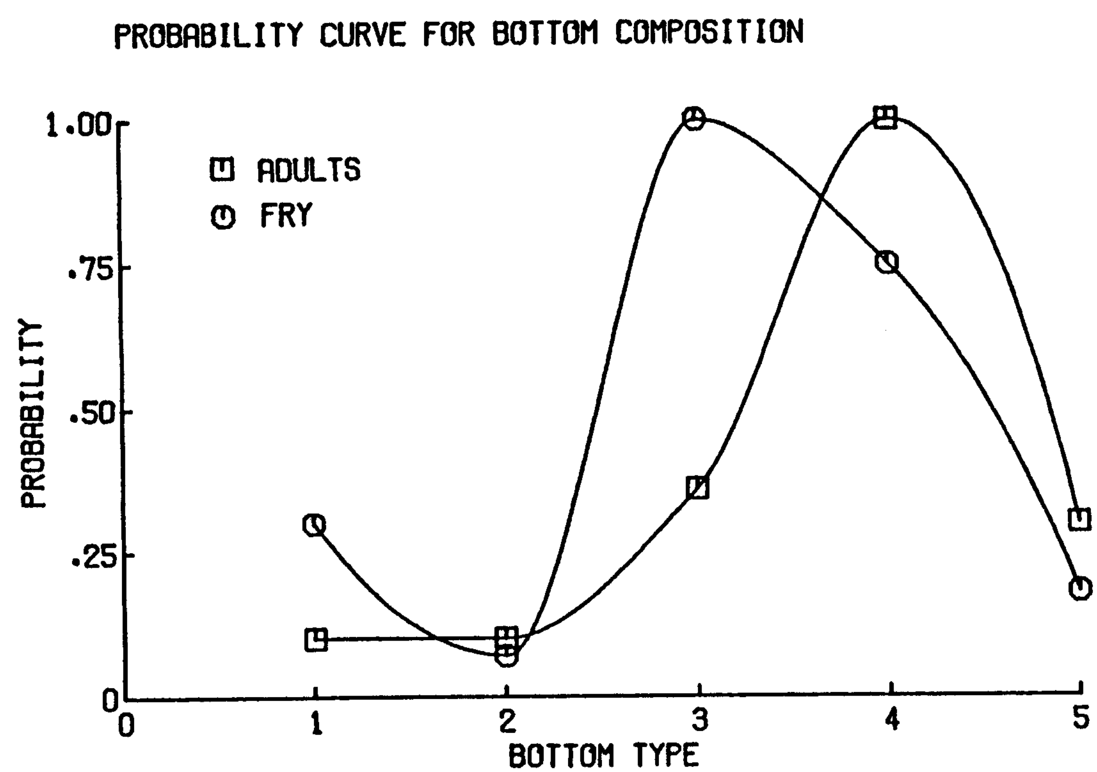


Fig. 21. Probability-of-use curves for bottom composition type by fry and juvenile-adult cutthroat trout during spring 1978 in Bear Creek.

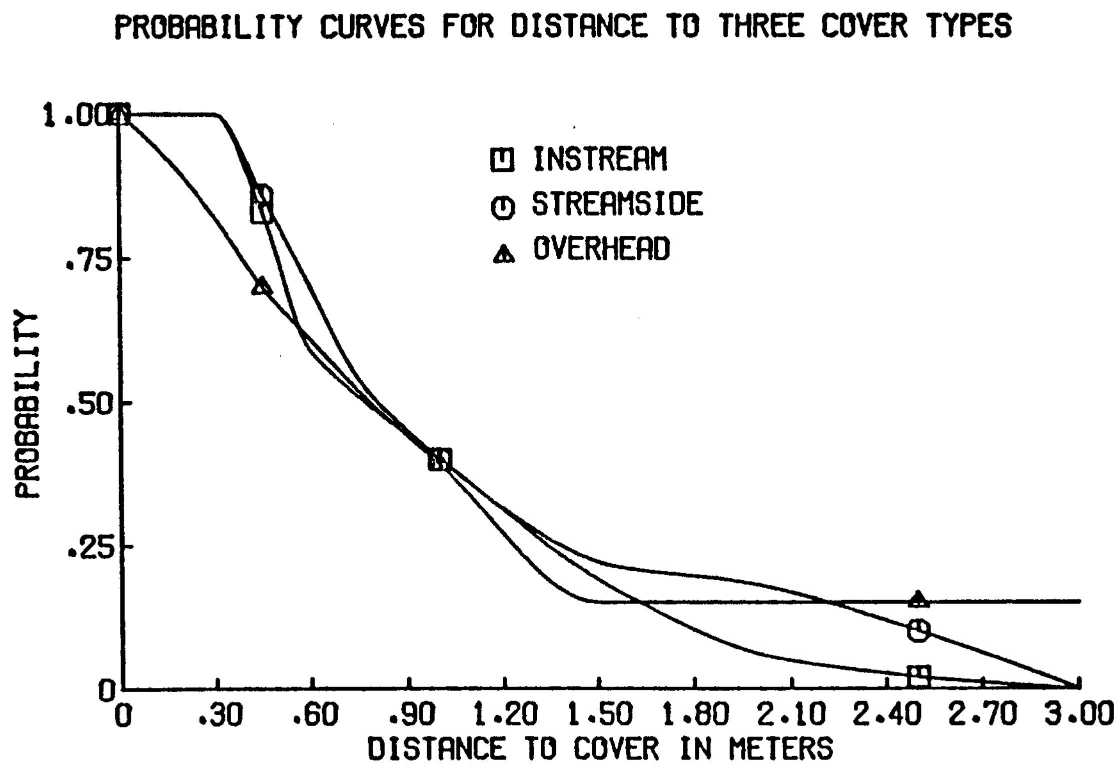


Fig. 22. Probability-of-use curves for distances to instream, streamside and overhead cover for cutthroat trout during spring 1978 in Bear Creek.

Table 21. Composite probability-of-use indexes based on three and six habitat parameters for fry and juvenile-adult cutthroat trout in five habitat study sections of Bear Creek during 1978.

Section	Spring wetted surface area	Fry		Adult-juvenile	
		Three parameter index (% of wetted area)	Six parameter index (% of wetted area)	Three parameter index (% of wetted area)	Five parameter index (% of wetted area)
1 75- 125 m	318 m^2	10.09 m^2 (3.2%)	2.16 m^2 (0.7%)	35.92 m^2 (11.3%)	10.98 m^2 (3.5%)
2 550- 600 m	244 m^2	4.84 m^2 (2.09%)	1.11 m^2 (0.5%)	23.78 m^2 (9.7%)	9.40 m^2 (3.9%)
3 900- 950 m	210 m^2	2.17 m^2 (1.0%)	0.38 m^2 (0.2%)	16.87 m^2 (8.0%)	4.01 m^2 (1.9%)
4 1000-1050 m	264 m^2	10.94 m^2 (4.19%)	3.24 m^2 (1.2%)	26.57 m^2 (10.1%)	13.81 m^2 (5.2%)
5 1125-1175 m	237 m^2	3.63 m^2 (1.5%)	0.57 m^2 (0.2%)	22.20 m^2 (9.4%)	5.75 m^2 (2.4%)

Table 22. Average cutthroat trout densities, mean weight and biomass observed in five habitat study sections in Bear Creek during 1977-78.

		Fry			Juveniles			Adult			Total		
Section	Year	No./m²	g/fish	g/m²	No./m²	g/fish	g/m²	No./m²	g/fish	g/m²	No./m²	g/fish	g/m²
1 75- 125 m	1977	.096	1.3	.116	.052	11.2	.587	.008	38.6	.300	.156	6.6	1.003
	1978	.118	2.6	.298	.083	8.7	.706	.027	28.7	.756	.228	7.8	1.759
2 550- 600 m	1977	.016	2.5	.027	.109	8.7	.952	.012	24.3	.298	.137	9.3	1.285
	1978	.195	2.7	.494	.059	11.2	.664	.025	27.3	.671	.279	6.9	1.828
3 900- 950 m	1977	.140	1.8	.110	.255	8.1	.881	.005	22.5	.107	.255	4.9	1.243
	1978	.159	2.3	.324	.076	9.4	.699	.014	27.1	.387	.250	6.4	1.410
4 1000-1050 m	1977	.098	1.7	.170	.081	10.1	.819	.017	57.7	.982	.197	10.0	1.970
	1978	.100	2.6	.243	.064	9.1	.578	.009	36.4	.389	.174	6.9	1.220
5 1125-1175	1977	—	—	—	—	—	NO SAMPLES TAKEN	—	—	—	—	—	—
	1978	.110	2.7	.285	.127	8.0	1.003	.019	22.9	.433	.255	6.8	1.721

Table 23. Correlation analysis of habitat parameters versus fry density, juvenile density and juvenile biomass measured in five habitat study sections of Bear Creek, 1978.

Habitat variable	Biological variable	r^2	Sig.
Percent pool area	Fry density	-.7660	.065
Percent area greater than 2m from instream cover	Fry density	.9630	.028
Percent area less than 6 cm/s average velocity	Juvenile density	.8723	.027
Percent area less than 6 cm/s average velocity	Juvenile biomass	.8415	.037

percent area 2 m or greater from instream cover objects. No significant correlations were found with other habitat variables or the 3 and 6-parameter weighted-usable-area indices. Average juvenile density and biomass had a significant positive correlation with percent slow flow area (Table 23).

Mean weight per individual adult cutthroat trout was positively correlated with both the 3 and 6-parameter weighted usable area indices (Table 24). The 6-parameter index had a closer correlation, r^2 of .9278, than the 3-parameter index, r^2 of .8604. Combined densities of juvenile and adult fish showed negative correlations with both weighted-usable-area indices (Table 24).

Changes in fry, juvenile, and adult densities in the five habitat sections were measured after a major storm, 4.5 m^3/sec, that occurred on September 9 and 10, 1978. Percent change in fry density was negatively correlated with the 3-parameter weighted useable area index but not significantly correlated with the 6-parameter index (Table 25). The higher the quality of habitat index, based on preferred depth, velocity, and instream cover values, the fewer fry displaced. Adding preferred values of bottom composition, streamside, and overhead cover did not strengthen the correlation. A positive correlation was found between percentage change in fry density and the percent riffle area. Significant negative correlations were found with percent run area, percent instream, and streamside cover and percent potential instream and streamside cover

Table 24. Correlation analysis of weight per adult cutthroat and densities of adult and juvenile cutthroat trout versus three and six parameter quality of habitat indexes measured in five habitat study sections of Bear Creek, 1978.

Habitat variable	Biological variable	r^2	Sig.
Three parameter index	grams/adult	.8604	.031
Six parameter index	grams/adult	.9278	.012
Three parameter index	adult and juvenile fish/m^2	-.8315	.040
Six parameter index	adult and juvenile fish/m^2	-.8676	.028

Table 25. Correlation analysis of habitat parameters and quality of habitat indexes versus relative changes in cutthroat trout fry after a storm in Bear Creek during August 1978.

Habitat variable	r^2	Sig.
Three parameter index	-.9849	.001
Six parameter index	-.5871	.149
Percent riffle area	.8549	.032
Percent pool area	-.7112	.089
Percent run area	-.8221	.044
Percent instream cover area	-.8157	.046
Percent potential instream cover area	-.8843	.035
Percent streamside cover area	-.8907	.021
Percent potential streamside cover area	-.8913	.021

available at higher flows. No decrease in adult or juvenile densities was observed after the September 1978 storm.

DISCUSSION

The cutthroat trout populations in Bear Creek were made up of resident and sea-run fish. Cutthroat trout of a much larger size than any captured during the study were observed in the study area in January of 1978. Three of these larger fish were associated with areas of recent spawning activity and were apparently mature sea-run fish. Two distinct periods of spawning activity were observed, January to the first of March and the middle of May. The redds observed in the first period were considerably larger than the one redd observed in May. No large sea-run cutthroat were captured in the April 1978 population sample, indicating that any sea-run fish had probably spawned in the earlier spawning period while the later period was due to resident fish spawning. Nine cutthroat trout were found to have spawning marks on their scales and no sea-run growth characteristics, indicating resident fish. The downstream waterfall may have been a block to sea-run cutthroat, as well as downstream resident spawning migrations into the study area during the drought of 1977. Population estimates and mean length and weight of the 0+ age group were lower in 1977 than in 1978, a normal water year. The increased number and size of fry in 1978 may have been due to sea-run cutthroat recruitment. Fry were first observed in mid-April in 1978 as compared with the end of May in 1977 and could have resulted from the earlier emergence of sea-run fry in 1978. Spring and early summer outmigration of age I+ and II+ cutthroat corresponded with other reported periods of sea-run cutthroat smolt outmigration

(Sumner 1962, Lavier 1963, Garrison 1978). Life history information for both sea-run and resident cutthroat was collected (Appendix E).

Life History of Cutthroat Trout

Upstream Migration

Upstream spawning migration by sea-run and resident cutthroat below the study area in Bear Creek was probably regulated by streamflow. A partial stream block caused by a waterfall and debris jam required high flows for fish passage. Similar dependence of other salmonids on streamflow for spawning migrations has been shown (Delesle and Eliason 1961, Hooper 1973). This block prevented upstream migration of coho salmon and steelhead trout. Sea-run cutthroat migrated into the study area in December and January. Similar run timing has been observed for sea-run cutthroat in Oregon (Sumner 1952), British Columbia (Anderson and Narver 1975) and other locations in Washington (Garrison 1978). Mature sea-run spawners averaged 300 to 400 mm fork length consistent with reports of Oregon spawners (Giger 1972).

Spawning

Sea-run cutthroat trout spawned in January, February, and March with peak spawning in February. Similar spawning periods were observed in Oregon (Cramer 1940) and on the Cowlitz River, Washington (Duff 1972). Sea-run cutthroat spawn in small tributary streams similar to Bear Creek (Cramer 1940, Duff 1972) choosing the tails of pools for most redd sites with depths of 5 to 10 cm. Hunter (1973) reports identical redd site descriptions for cutthroat in other Washington streams. Sea-run cutthroat kelts outmigrated before the end of April in 1978. Minter Creek, Washington (Johnston and Mercer 1976) and Oregon data (Giger 1972) show similar kelt outmigration timing.

Resident cutthroat trout spawned in April and May in 1978. Pool tailouts were utilized and resident redd size was 50% smaller than that observed for sea-run fish. Timing, location, and size of resident redds in Bear Creek compared closely with those reported for other Washington streams (Hunter 1973). Resident cutthroat trout in Bear Creek spawned at age 2+ at a mean length of 122 mm and age III+ at 144 mm. The difference in spawning times between sea-run and resident fish may maintain separate genetic stocks by reduced opportunity of interbreeding.

Incubation and Emergence

Emerging fry were first observed in Bear Creek at the end of April 1978, 14 weeks after the first cutthroat redd was observed. Mean time to emergence was 9 to 10 weeks, consistent with sea-run cutthroat reported in British Columbia (Scott and Crossman 1973). Peak emergence occurred in late May and early June as in other California, Oregon, and Washington areas (Dewitt 1954, Giger 1972). Newly emerged sea-run cutthroat trout were approximately 22 to 25 mm fork length.

Residence cutthroat trout emerged early in July 1978, 8 weeks after redd deposition. Early July emergence by resident cutthroat was found in other Washington streams (Lestelle 1978) and in Oregon (Aho 1976). Emergent resident cutthroat were similar in size to sea-run cutthroat.

The use of degree-day units to predict timing of emergence underestimated the time required for 5 redds, overestimated for 2 redds, and provided an accurate estimate for 3 redds. All estimates of range of emergence timing except one were within 12 days of the actual time of emergence. Calculating degree-day units may be useful in predicting timing of emergence accurate to within 2 weeks. The use of degree-day unit emergence predictions with emergence traps would allow better verification of this method.

Population Dynamics

Four age groups of cutthroat trout were identified in Bear Creek; 0, I, II, and III+. Numbers and density of age 0 cutthroat trout were dependent upon streamflow during spawning migration periods. Winter 1977 was a low-flow year and fry density in July was less than 1/3 that in 1978, a normal water year.

In 1978 number and density of age I+ cutthroat, 1977 year class, increased 100% between April and July. This increase was attributed to immigration of fish from overwintering areas downstream of the study area to the waterfall. This area contains many protected areas behind log jams and boulders. Young-of-the-year fry either moved or were displaced to these areas during the first fall storms in October and November 1977. They returned to the study area during April and May when flows decreased and water temperature increased. Lestelle (1978) found a similar increase in age I cutthroat between April and July in the west fork of a tributary to Stequaleho Creek. Migrations of cutthroat trout to over-wintering areas are known in Alaska (Armstrong 1971) and British Columbia (Andrusak and Northcote 1971). Densities of age 0 and I cutthroat in Bear Creek were lower than densities reported for other Pacific Northwest streams (Table 26). The low densities and numbers of cutthroat trout over 2 years old is consistent with other headwater streams (Aho 1976, Lestelle 1978). This may reflect the difficulty of aging older cutthroat through scale or length frequency analysis because of reduced growth or older resident fish may simply die or leave these areas at older ages and larger sizes. The use of headwater streams as spawning and nursery areas has been previously observed for salmonids (e.g., Burns 1971, Edie 1975). The large decrease in age II cutthroat density between April and July 1978 was due to outmigration as observed at the downstream trap. Most of these fish were probably sea-run cutthroat.

Biomass of age 0 fish in Bear Creek was higher than those reported for Mack Creek, Oregon (Aho 1976) and east fork Stequaleho Creek in Washington (Lestelle 1978), but less than that reported in Shawnigan Creek, British Columbia (Glova and Mason 1974) (Table 26). Mack and east fork Stequaleho Creeks are resident cutthroat trout streams with short growing seasons, July to August, while Shawnigan Creek contains only sea-run cutthroat and steelhead trout. The mixture of earlier emerging sea-run and resident cutthroat in Bear Creek may account for the intermediate relative biomass value.

Table 26. Comparisons of growth rates, biomass, density and yearly production of cutthroat trout in Bear Creek in 1978 with other streams in the Pacific Northwest.

Stream system	Interval July-April Growth rate		Interval Sept.-Oct. Biomass grams/m^2		Interval Sept.-Oct. Density fish/m^2		Yearly production grams/m^2	
	0 age	1+ age	0 age	All fish	0 age	All fish	0 age	All fish
Deer Cr., Oregon (Lowry 1966)				4.6		.12		4.0
Flynn Cr., Oregon (Lowry 1966)				4.8		.38		4.9
Needle Branch Cr., Oregon (Lowry 1966)				3.3		.39		3.5
East Fork Stequaleho, Washington (Lestelle 1978)			.17	1.96	.19	.39		
Mack Cr., Oregon (Aho 1976)	1.808	.500	.30	6.2	.22	.74	.39	2.6
"C" Trib., Vancouver (Glova and Mason 1974)				2.10				
Ritherdon Cr., Vancouver (Glova and Mason 1974)				1.94				
Shawnigan Cr., Vancouver (Glova and Mason 1974)			3.1	3.7				
Hidden Valley Cr., Vancouver (Glova and Mason 1974)				2.9		.50		
Hodges Cr., Vancouver (Glova and Mason 1974)				7.0		.44		
Bear Cr., Washington (1978)	2.420	.312	.55	2.18	.167	.273	.657	1.97

Cutthroat trout growth rates in Bear Creek were highest in the April to July period. Growth dropped off sharply in late August and September and no growth occurred over winter. Fish believed to be sea-run cutthroat obtained a larger length and weight during their first year than resident fish. This was probably due to the earlier emergence of sea-run cutthroat allowing a longer first summer growing season. Later-emerging resident cutthroat may have been out-competed for space and food by sea-run fry (Miller 1957), though no evidence existed in daily instantaneous growth rates.

Production per unit area for all ages of cutthroat in Bear Creek was lower than that reported in other Pacific Northwest streams (Table 26). Production of the 0+ age group in Bear Creek was twice that reported for Mack Creek (Aho 1976). Since production in the 0 age group is equal to or exceeds that reported for age 0 fish in other Pacific Northwest streams and total production is lower than most of these streams, reduced production in the I+ and older age fish must be the cause. Annual and daily instantaneous mortality rates for age I+ and II+ cutthroat trout were higher in Bear Creek than those reported in Oregon and Washington (Aho 1967, Lestelle 1978). The migration of sea-run cutthroat at age I+ and II+ may acount for this higher "mortality." Additionally resident cutthroat displaced downstream or migrating to overwintering areas may be lost by passing over the falls below the study area. Migrations of resident fish over blocks preventing return upstream movement has been reported (Northcote et al. 1970). These migrations, combined with slowed growth of remaining fish, reduce the overall yearly production in the study area.

Movement

Fry dispersed from the redd sites within 2 weeks after emergence mainly in a downstream direction. Approximately 20% of the total estimated fry population in 1977 passed downstream out of the study area. This passage of fry downstream was completed by June 30, prior to predicted resident cutthroat emergence in July. The downstream movement of these sea-run fry may be due to the larger number of fish emerging from sea-run redds compared with resident redds (Rounsefell 1957) causing competition for available space or due to displacement from higher flows during May and June than in July.

Movement within the study area during summer rearing was negligible. The movement of tagged fish was not correlated with increased or decreased growth. Mundie (1974) showed that residency rather than migration is more efficient energetically when food is not limiting. Lestelle (1978) found that resident cutthroat trout moved very little over the summer growing season. Mature, ripe tagged cutthroat moved more than nonripe cutthroat, probably to find suitable spawning areas and mates in May and June then returned to larger pools for the summer (LeBar 1971).

Sea-run cutthroat trout and possibly some resident cutthroat trout emigrated out of the study area on the decreasing flows of May and June freshets. Similar movements out of spring ponds have been shown for coho salmon smolts (Peterson 1980). Larger fish emigrated earlier than smaller fish as reported in 3 Oregon streams (Lowry 1965). Most emigrating cutthroat were age II and a similar size as those reported moving downstream from nursery streams in Oregon (Sumner 1962). Sumner proposed that these fish would spend one more year in the lower areas of the river prior to entering the sea. Sea-run outmigrants from Bear Creek may spend another year in the lower areas of Bear Creek or the main Bogachiel River prior to entering saltwater. Outmigrations of large age II fish prior to the June and July emergence of resident cutthroat fry may reduce predation effects, though the extent of cannibalism by cutthroat trout is unknown.

Habitat Utilization

The habitat model provided detailed descriptions of the quantity and distribution for ranges of values of 5 habitat parameters. SYMAP matrices will provide baseline descriptions for detailing physical habitat changes that may take place due to the proposed canopy removal. The five habitat study sections were selected to be very similar in habitat type in an attempt to isolate the effects of reduced shade cover on cutthroat trout. A wider range of habitat types would have been preferable for a general description of habitat utilization.

Probability-of-use curves based on observations of individual fish in Bear Creek were very similar within the range of values measured to those generated from data collected at many streams of different sizes (Bovee 1978). Adult fish were found in deeper pools and slower-velocity flows and fry in shallower, faster areas as found for other salmonids

(Wickham 1967, Everest 1969, Griffith 1972). The preferred velocities and depths of fry and adults found in Bear Creek were the same as those found for cutthroat trout in Idaho (Griffith 1972). Adult cutthroat were found over slightly larger sized substrate than fry, though no definite selection process was observed. Probabilities may be a function of the relative abundance of each substrate size as found by Wickham (1967). No differences between fry and adults were found in the distance of the position occupied from the three cover types; contrary to reports by Griffith (1972) and Everest (1969). However, cutthroat trout in Bear Creek were found closely associated with at least one of the cover types and were rarely round farther than 60 cm from some cover. Griffith (1972) determined a similar distance as the farthest distance from cover occupied by cutthroat. Cutthroat trout in Bear Creek were observed to seek out shade provided by any of the three cover types. Similar shade preferences have been observed for other species (Wickham 1967, Kraft 1968, Everest 1969, Bustard and Narver 1975).

Correlation analysis of habitat parameter values and the weighted-useable-area quality of habitat indices indicated that no single habitat parameter can explain biomass or density of cutthroat trout. Fry density in 1978 was negatively correlated with pool area, probably due to avoidance of larger yearling and older trout occupying the pools. The 3- and 6-parameter quality of habitat indices were not correlated with fry density or biomass during the summer months. Equal distribution of juvenile salmonids through areas with ranges of habitat quality has been suggested when food and cover were not limiting (Chapman 1966, Chapman and

Bjornn 1969, Burns 1971). The abundance of fry and the lack of correlation with specific habitat parameter values indicates that cutthroat fry can occupy a wide range of habitat types during the summer.

The low densities of adult cutthroat trout in the five study sections probably affected the correlation analyses with habitat parameters and quality of habitat indices. Mean weight per individual was significantly correlated with the quality of habitat indices. A better correlation was found with all six habitat parameters combined than with only depth, velocity, and instream cover. This indicates that larger trout seek to occupy the higher quality pools based on a combination of several habitat parameters. The size of fish has been related to pool quality (Griffith 1972) and optimum habitat (Everest 1969).

The percent decrease in fry density after a large storm in September 1978 was negatively correlated with the 3 parameter index of habitat quality but not the 6 parameter index. Favorably depth, velocity, and instream cover were apparently important in reducing fry displacement or migration due to high flows. Potential streamside and instream cover available to fry during high flows was important in reducing fry loss from the sections. Fry apparently utilized these areas; cover, pools, and decreased velocity, to maintain their positions. Fry were displaced from each habitat study section, indicating that protective habitat may be limited during high flows. Use of reduced velocity and cover objects has been found to be an important aspect of overwintering behavior for cutthroat (Bustard and Narver 1975) and steelhead trout (Everest 1969).

Overwintering habitat was likely the limiting factor of density of cutthroat trout in Bear Creek during 1977 and 1978. The return upstream of Age I cutthroat between April and July 1978 indicates that some fry were displaced downstream during fall and winter 1977-78, even though population numbers of age 0 fish were small. Overwintering habitat has been indicated as an important population regulator in other studies (Needham et al. 1945, Hartman 1965, Everest 1969). Fry densities and habitat characteristics in the five study sections were not measured after October 1978 so the permanence of the fry reduction and/or any habitat changes are unknown.

The results presented here suggest the difficulty of assessing the effects of canopy removal in Bear Creek. The varying numbers of sea-run spawners reaching the study section during the 2 years present the biggest problem in isolating canopy removal effects. The number of sea-run fry emerging affects not only population numbers and growth rates for young-of-the year fish during the first growing season but also outmigration movement the following year. If sea-run juvenile fish could be separated from resident fish by some physical characteristic the problem would be reduced; however, no practical way exists. The effects of canopy removal will have to be quite drastic to cause a detectable change in population levels or growth rates beyond those attributable to sea-run spawner variations which is independent of canopy removal. A concentration on changes in behavioral responses such as movement and habitat utilization seem more appropriate for Bear Creek.

CONCLUSIONS

1. Resident and sea-run cutthroat trout inhabited Bear Creek.

2. There were differences in timing of spawning of resident and sea-run cutthroat, possibly maintaining genetic isolation between the two population groups.

3. Life history characteristics of both sea-run and resident cutthroat in Bear Creek were similar to those reported for other Pacific Northwest streams.

4. Density, biomass, and production of cutthroat in Bear Creek were similar to values reported for cutthroat in Oregon, Washington, and British Columbia.

5. Cutthroat juveniles migrated or were displaced downstream to over-wintering areas by fall storms but returned to the study areas as age I fish between April and July.

6. Cutthroat trout moved very little within the study area during the summer months. However, ripe resident fish moved significantly more than unripe fish.

7. Sea-run juveniles, age I and II, migrated out of the study section in May and June on the decreasing flows of freshets.

8. Areas of value ranges of individual habitat parameter did not correlate significantly with density or biomass of cutthroat.

9. Quality-of-habitat indices among habitat sections were positively correlated with mean weight per adult cutthroat occupying those study sections.

10. Quality-of-habitat indices and relative areas of instream and streamside cover were negatively correlated with decreases in age 0 cutthroat densities after a major storm.

11. Natural variations in individual year classes in the study section were highly dependent upon fall and winter flows to allow passage of sea-run spawners over a downstream waterfall.

12. The effects of canopy removal on the density and growth of cutthroat trout in Bear Creek would have to be considerable to be separated from the effects caused by variable sea-run cutthroat recruitment.

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APPENDIX TABLES

Appendix Table 1. Date, length, weight and age at capture, calculated lengths at previous annuli and age and length at spawning for all spawning fish detected in scale analysis from Bear Creek cutthroat trout in 1978.

Date	Length	Weight	Age	Calculated length at annuli 1	2	3	4	Spawning Age	Spawning Length
4/04/73	230	119.50	4	75.6	112.3	140.3	168.4	3	142.5
	140	26.20	2+	77.7	112.3			2	127.4
7/14/78	214	100.80	4	73.4	114.4	140.3	172.7	3	142.5
8/02/78	154	33.14	3	82.0	114.4	146.8		3	148.9
10/07/78	183	60.54	3	73.4	118.7	146.8		2	120.9
11/11/78	163	42.20	3	73.4	116.6	140.3		3	142.5
	145	24.26	3	75.6	112.3	136.0		2	120.9
	198	79.82	4	71.2	112.3	138.2	166.2	2	144.6
	144	25.30	2	73.4	114.2			2	120.9
		Mean Length		75.0	114.2	141.2	169.1		
		Standard deviation		3.19	2.25	4.11	3.31		
				N = 9	N = 9	N = 7	N = 3		

Age	Year class	No. fish	% total	Mean length	S.D.
2	1976	5	55.6	122.5 mm	3.25
3	1975	4	44.4	144.2 mm	2.78

Appendix Table 2. Summary of statistics computed for observations on 47 tagged cutthroat trout in Bear Creek during 1977, 1978.

Statistic	Mean	Range
Length at initial capture	148.8 mm	122 to 206 mm
Weight at initial capture	33.3 g	16.2 to 83.9 g
Change in length from initial to final capture	4.3 mm	-7.0 to 14.0 mm
Change in weight from initial to final capture	2.9 g	-8.5 to 14.7 g
Days between initial and final capture	91 days	4 to 221 days
Daily instantaneous growth rate by length	.00029	-.0019 to .0016
Daily instantaneous growth rate by weight	.00099	-.0063 to .0066
Number of observations per fish	3.3	2 - 8

Appendix Table 3. Length-weight relationships for cutthroat trout by sample date and age group collected in the study area of Bear Creek, 1977-1978.

Sample date	Age group	Year class	No. fish	r^2	Constant x10-5	Slope
July 20, 1977	0+	1977	184	.5304	1.44	2.882
	I+	1976	318	.9100	1.17	2.967
	II+	1975	25	.6191	0.81	3.041
	III+>	1974+	15	.9831	0.45	3.149
	All fish		542	.9608	0.64	3.098
Sept. 7, 1977	0+	1977	177	.7478	5.05	2.613
	I+	1976	290	.8901	0.99	3.000
	II+	1975	25	.4741	0.38	3.192
	III+>	1974+	4	.9843	0.67	3.073
	All fish		506	.9753	1.47	2.914
	I	1977	107	.7317	0.85	3.040
	II	1976	102	.8600	0.58	3.113
	III>	1975+	25	.9171	1.90	2.884
	All fish		234	.9645	1.36	2.930
July 11, 1978	0+	1978	648	.8006	0.61	3.113
	I+	1977	303	.8395	1.22	2.940
	II+	1976	50	.7407	2.12	2.835
	III+>	1975+	28	.9668	1.03	2.987
	All fish		1029	.9635	0.96	2.997
Oct. 7, 1978	0+	1978	371	.8734	3.62	2.693
	I+	1977	233	.9611	0.92	3.000
	II+	1976	30	.7525	1.04	2.980
	III+>	1975+	23	.9674	0.17	3.340
	All fish		657	.9823	1.56	2.891

All sample dates combined

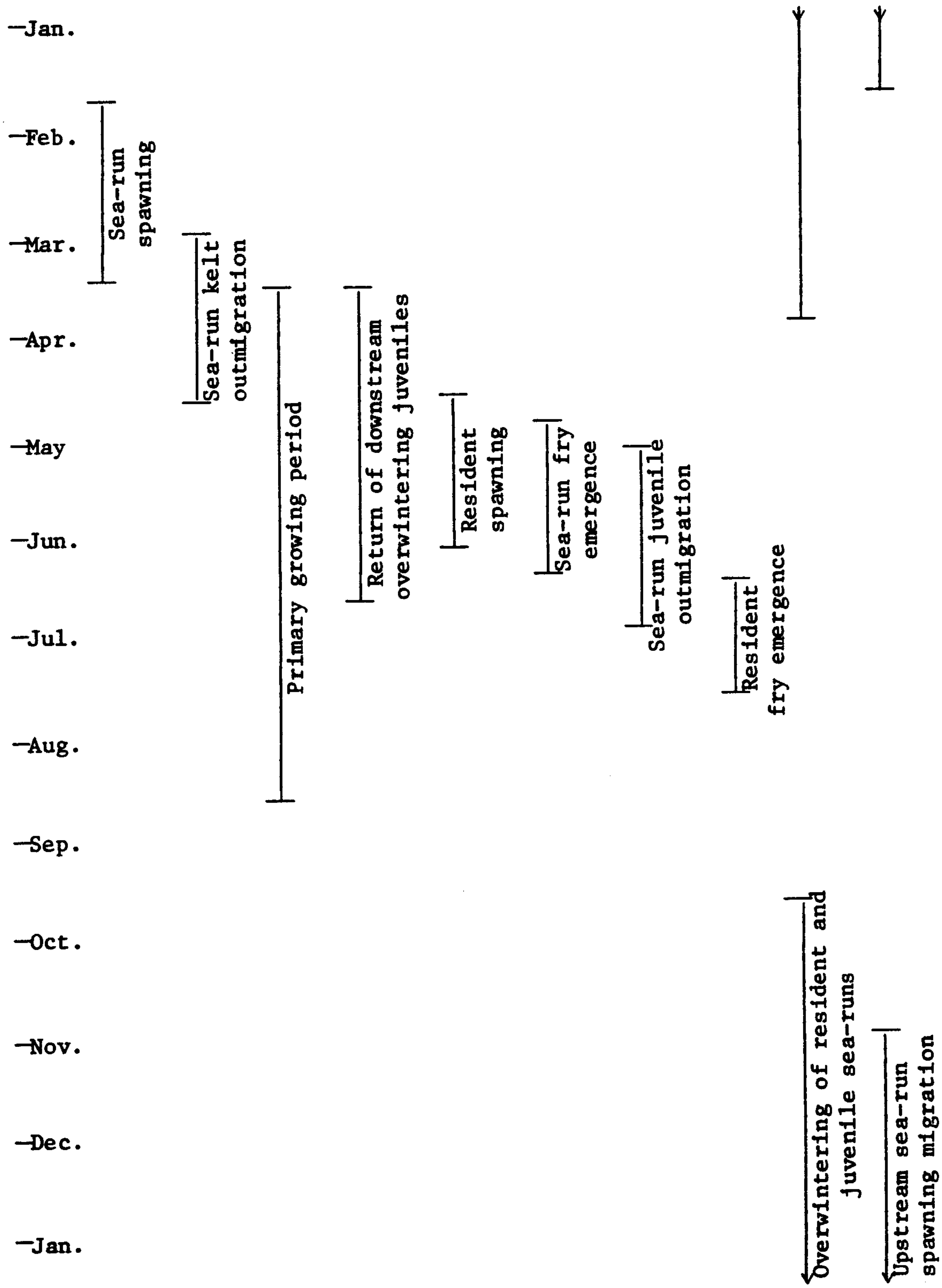
Weighted values

Age group	Constant x10-5	Slope
Age 0	2.06	2.820
Age I	1.03	3.004
Age II	0.87	3.022
Age III+>	0.63	3.089
All fish	1.14	2.966

Appendix Table 4. Cutthroat trout captured in a downstream trap at Bear Creek, Washington, from April 1, 1976 through July 30, 1978.

Date	Length	Weight	Probable age
April 28, 1978	131 mm	18.05 grams	2+
May 8, 1978	123 mm	16.69 grams	2
	141 mm	24.55 grams	3
June 15, 1978	128 mm	17.68 grams	2
	85 mm	6.05 grams	1
	102 mm	10.69 grams	1
	145 mm	29.10 grams	3
July 6, 1978	170 mm	51.62 grams	4
	151 mm	33.67 grams	3
	130 mm	20.10 grams	2
	95 mm	8.65 grams	1
	119 mm	16.52 grams	2
	104 mm	10.50 grams	1
	114 mm	12.97 grams	1

Age	No. fish	% of total	Mean length	Mean weight
1	5	35.7	100 mm	9.77 g
2	4	28.6	125 mm	17.75 g
3	4	28.6	142 mm	26.34 g
4	1	6.7	170 mm	51.62 g



Appendix Table 5. Life history characteristics of cutthroat trout in the Bear Creek study area 1977-1978.