A BIOLOGICAL AND PHYSICAL INVENTORY OF THE STREAMS WITHIN THE NEZ PERCE RESERVATION

Juvenile Steelhead Survey and Factors that Affect Abundance in Selected Streams in the Lower Clearwater River Basin, Idaho

Final Report
by

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EXECUTIVE SUMMARY

A biological and physical inventory of selected tributaries in the lower Clearwater River basin was conducted by the Nez Perce Tribe Department of Fisheries Management during 1983 and 1984. The purpose of the juvenile steelhead study was to collect information for the development of alternatives and recommendations for the enhancement of the anadromous fish resources in streams on the Nez Perce Reservation. Five streams within the Reservation were selected for study: Bedrock and Cottonwood Creeks were investigated over a two year period (1983-1984) and Rig Canyon, Jacks and Mission Creeks were studied for one year (1983). Biological information was collected and analyzed on the densitv, biomass, production and outmigration of juvenile summer steelhead trout. Physical habitat information was collected on available instream cover, stream discharge, stream velocity, water temperature, bottom substrate, embeddedness and stream width and depth.

The present report focuses on the relationships between physical stream habitat and juvenile steelhead trout abundance. It is one of several that address Nez Perce Reservation streams. Other reports that are available include Kucera et al. (1983), Fuller et al. (1984), Johnson (1985) and Fuller et al. (1986).

Physical Habitat Relationships to Juvenile Steelhead

Streams in the lower Clearwater River basin originate in the dry grassland environments of the camas prairie. Annual precipitation of 30-60 cm/yr falls more heavily during the winter and spring months of December through June. The majority of the watershed lies 280-1,850 m above sea level and loses its snowpack in spring runoff during March and April. Land use practices on the Nez Perce Reservation impact stream conditions and salmonid habitat. Streams originating in agricultural environments, on the camas prairie, are subject to high rates of soil erosion. Most streams flow through canvon areas where they are influenced by logging and grazing management practices. Lower stream reaches may be affected by roding and agricultural practices as well.

Stream flows in these lowlard valley streams are highy variable throughout the year. Annual flow varied from 376 fold in Cottonwood Creek up to 1,417 fold in Redrock Creek. Low summer stream flows ranged between .003 to .092 m^3/s. Peak spring runoff ranged as high as 7.52 m^3/s. Stream discharge was positively related (P(0.05) to yerling steelhead trout habitat and at summer base flows severely limited the available yearling habitat. Measured vearlinq habitat[1] onlv exceeded 10 percent of the total available summer stream area in one out of nine studv reaches. Generally, the available yearling steelhead cover was lacking under low flow conditions because-the maiority of habitat present (80-90s) was riffle habitat. Steelhead production was entirely eliminated in dewatered stretches of Rig Canyon Creek and Cottonwood Creek due to subsurface flows occurring during summer months.

High annual spring flows determine stream channel morphology and riparian zones. Peak spring runoff reduces channel stability by creating flood plains and braided streams and by preventing successful establishment of riparian vegetation. Stream channels may be completely altered from year to year within the scoured flood plain areas. Where broader flood plains exist, riparian vegetation which would help shade the stream and stabilize stream banks is absent. Where well-developed riparian vegetation and overhead canopy exist there is usually better channel stabilitv and stream shading, both of which improve the quality of juvenile steelhead trout habitat in lower Clearwater basin streams.

High rates of sedimentation and streambed loads are other consequences of spring runoff and poor land management practices. Sediment loads produced a cobble embeddednese ranging between 25.0 to 44.4 percent for the five studv streams. Mission Creek, which had the highest cobble embeddedness also had the lowest yearling steelhead densities observed during the study. Available spawning substrate ranged between 17.3 to 35.3 percent of the total stream area at the five study streams and did not appear to be a major limiting factor to steelhead spawning.

Juvenile Steelhead Relationships to Physical Habitat

Yearling rainbow-steelhead trout densitv and biomass varied considerably during the vear. Densities ranged from .02 to .66 fish/m^2 and biomass varied from .61 to 14.57 g/m^2 during the study period. Winter density and biomass of yearling steelhead, were low but more stable, ranging from .Q3 to .155 fish/m'- and .69 to 1.39 q/m" respectively.

[1]Two groups of fish were recognized in this report: yearlings (age I+ and older) and subyearlings (age O+). The yearling group was so defined because few ((10%) of the rainbow-steelhead trout in that group were age II+ fish. Measured yearling habitat included the following cover component-s: depth greater than 30 cm, undercut banks, surface trubulence, submerged rock and debris and overhanging vegetation.

Winter densities of yearling steelhead were very similar between years within each study area and suggested that a winter carrying capacity may be approached. Estimated yearling densities were greatest and fluctuated widely in pool areas. Densities ranged from .146 to 1.49 fish/m^2 and biomass varied from 2.17 to 30.50 g/m^2.

In contrast, subyearling densities varied as much as four-fold between years and depended, in part, upon the level of adult escapement. Subyearling steelhead density and biomass fluctuated from .21 to 2.34 fish/m^2 and .45 to 6.86 g/m^2 respectively. Densities of subyearling fish in November ranged from .21 to .61 fish/m^2 and biomass varied from .75 to 4.16 g/m^2 prior to the overwintering period.

Total juvenile steelhead production in Reservation streams varied-from low to middle ranges when compared to rainbow trout production in fluvial systems in the United States (Neves et al. 1985). Yearling steelhead production ranged from .04 to 2.03 g/m^2 in Reservation streams. Monthly production estimates were calculated from May to January for yearling fish. Therefore, some production from this cohort. was missed in the early spring and production was not presented as g/m^2/yr. Annual production for subyearling steelhead varied from 4.28 to 6.0 g/m^2/yr. Total steelhead production, yearling and subyearling combined, ranged from 1.84 to 6.78 g/m^2.

Fish densities were negatively correlated with both stream discharge and water velocity ($P<0.05$). Stream discharge, however, also influenced the amount of yearling habitat present throughout the year, as the two variables were positively (P(0.05) related. Thus, yearling steelhead dendity and yearling habitat were not signigicantly associated, and provided no predictive basis to estimate yearling densities. Other investigators (Burns 1971, Gordon and MacCrimmon 1982) have reported significant positive relationships between yearling and overyearling density and living space variables.

Yearling habitat comprised less thab 10 percent of the total stream area in the respective study areas. It was not significantly associated with yearling steelhead density or biomass in most cases. However, in some instances yearling density and measured yearling habitat were related during one of two years. This supports the contention that. population regulation can be a flexible process (McFadden 1969) and that factors which operate to regulate density may vary seasonally (Chapman 1966).

In general both monthly yearling and subyearling densities were positively associated ($P<0.05$) with monthly average water temperature in these lowland valley tributaries. Average water temperature, in some streams, approached 20 C (maximum-26 C) during the summer low flow period, with the lower-most stream reaches being warmest. These data did not indicate that water temperatures reduce the density or biomass of vearlinq or subyearling steelhead though it was above the optimum range of 12 to 18 C for rainbow trout (Raleigh et al. 1984). Fish growth and production is at or below a maintenance level for yearling fish durinq the summer period. However, subyearling fish continue to grow in length and weight throughout the summer and fall months.

Lack of consistent significant correlations between yearling habitat and yearling steelhead densities, between study areas in a stream and between vears, precluded the use of regression analysis to directly support that lack of habitat reduced densities. An intensive long term study would be required to more fully establish and model these relationships.

In summary, juvenile steelhead trout populations appeared to be limited by lack of yearling habitat (comprising stream depth of greater than 30 cm, undercut banks, surface turbulence, submerged rock and debris and overhanging vegetation), inadequate stream flow and by elevated stream temperatures. These conditions existed during the summer period in all study streams. Response of juvenile steelhead densities to winter habitat conditions were not evaluated during this study.

Habitat Restoration and Enhancement

Riparian revegetation is recommended to enhance the streams of the lower Clearwater River basin. Riparian revegetation would stabilize stream banks and the stream channel, reduce sediment input and in the long term mav increase stream flow. Well-developed riparian zones-would also provide shade and reduce high summer water temperatures.

The use of instream structures is recommended to provide more yearling habitat is selected stream reaches. The placement of instream structures such as boulders, root wads, woodv debris, check dams and rip rap could also be placed to help stabilize channels and trap sediment.

Flow augmentation is another method of enhancement to improve low summer stream flow conditions and dewatered sections of stream. Augmentation could be realized throuqh the enhancement of spring areas or construction of water storage reservoirs in the upper watershed. these measures, if feasible, would increase the amount of yearling habitat and decrease water temperatures during low flow periods.

An aggressive enhancement/restoration program of riparian revegetation, channel stabilization and instream structure placement would substantially increase steelhead sotl vield in these streams. The estimated improvement in steelhead smolt yield ranges between two to four fold if these enhancement measures were undertaken. Flow augmentation (of summer low flows), if determined to be feasible, could further improve instream cover and water temperatures and thus fish production.

Other Biological Considerations

The migratory movements and genetic character of juvenile summer steelhead trout were considered in the course of this study. Downstream outmigration was examined to determine the timing and relative magnitude of juvenile steelhead movement. Electrophoretic analysis was conducted to describe the genetic character of steelhead populations in Reservation streams and to compare these populations to other stocks in the upper Snake River drainage.

Juvenile rainbow-steelhead trout downstream outmigration was investigated during the two year study period. Seasonal movement of fish occurred during the fall and spring of both years, with limited downstream movement over the summer period. In 1983, a fall pulse in movement of subvearling rainbow-steelhead trout occurred after higher initial densities of age 0+ fish were present in the stream due to a larger adult escapement. When lower densities of subyearling fish were present in 1984, a smaller fall pulse in movement was observed. A strong pre-smolt[2] outmigration of the abundant 1983 year class occurred in the spring of 1984. In contrast, a limited number of pre-smolt fish were estimated to have moved past the trap site in the spring of 1985. This was not clearly understood. What contribution these pre-smolt fish make to the returning adult runs and whether they rear in mainstem river habitat or return to natal streams is unknown.

Steelhead smolt outmigration occurred from March to June. Smolts had the typical silvery appearance, elongated body and deciduous scales of steelhead trout smolts. An estimated 1,500 smolts outmigrated from the Cottonwood Creek system in the spring of 1984. However, onlv 255 steelhead smolts were estimated to have migrated in-1985. This was partially the result of stream conditions which reduced fyke netting efficiency, but was also believed to reflect a limited outmigrant movement in comparison to 1984. Cottonwood Creek smolts averaged 150 to 160 mm in total length, which was smaller than the mean length of wild steelhead smolts (181 mm) collected in the lower Clearwater River (Scully et al. 1984).

[2] Pre-smolt steelhead (age I+) averaged 88 mm in length, were generally less than 125 mm, still retained parr marks and did not have the deciduous scales of a steelhead trout smolt.

Electrophoretic analysis was conducted on fifteen steelhead populations from the Nez Perce Reservation and upper Snake River drainage. Five major groups were detected through pairwise comparisons and a cluster analysis of genetic similarity. Nez Perce Reservation populations broke out in two different groups. Fig Canyon Creek and Cottonwood Creek populations were not significantly different from each other. These populations belonged to a group of A-run populations which included Chesnimnus Creek (Grande Ronde River), Little Sheep Creek (Imnaha River) and Horse Creek, Sheep Creek, Bargamin Creek and the Secesh River (Salmon River). Johnson Creek was the only Salmon River tributary that was not included in this group. Two other Reservation populations, Bedrock Creek and Mission Creek, formed another group and were genetically indistinguishable. Bedrock Creek was the onlv steelhead population studied that was not siqnificantlv different from Dworshak Hatchery R-run steelhead. Two of the clusters consisted of only one population each: Dworshak Hatchery and Johnson Creek (South Fork Salmon River). The Middle Fork Clearwater River group contained three populations that were genetically similar. They were the Fish Creek (Lochsa River) Gedney Creek and Meadow Creek populations (Selway River).

In summary, the downstream outmigration of juvenile steelhead principally occurred during the spring and fall periods. Fall pulses in downstream movement were generally reflected in short term increases in yearling fish densities at lower stream sampling stations. Abundance of vearling steelhead in the spring of 1984 (May-June) actually increased as the smolt outmigration was completed. The redistribution of non-smolt age I+ fish into the sample station locations, apparently accounts for the increase.

Genetic stock assessment of four Reservation stream steelhead populations indicated that two of the streams may have been affected by Dworshak Hatcher-v steelhead. The remaining two populations were more similar to steelhead from the Grande Ronde, Imnaha and Salmon River systems. Comparison of the genetic stock information to other biological characteristics of the steelhead populations was beyond the scope of the present study.

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INTRODUCTION

The Nez Perce Tribe Fisheries Department and the Bonneville Power Administration (BPA) continued a contractual agreement in 1983 to conduct a biological and physical inventory of streams within the Nez Perce Reservation. This continuation allowed for a one year survey to document juvenile rainbow-steelhead trout (*Salmo gairdneri*) populations under varying habitat conditions and their outmigration patterns. The information was to be used to identify factors limiting production of juvenile steelhead and for future enhancement/restoration and management decisions on these lowland valley streams.

The one year juvenile steelhead survey was extended for an additional year in 1984. This second year of study allowed for examination of inter-year variation in population levels in relation to measured habitat variables and for a more in-depth study of two of the streams. Steelhead outmigrant trapping was extended through June of 1985 to follow the spring smolt outmigration.

Prior to the initiation of the BPA funded stream inventories, limited data was available on the extent of the anadromous fisheries resource in Reservation streams. The current report is but one of several that address Nez Perce Reservation streams. Other reports that are available include Kucera et al. (1983), Fuller et al. (1984) Johnson (1985) and Fuller et al. (1986). Maughan (1976) reported on the species composition of fishes in the Clearwater River and tributary streams. The presence or absence of adult steelhead has been documented, in some of these small streams, by area resource managers but the population levels in various habitats was unknown. Toward this end the study adds to the understanding of aspects of the juvenile ecology/early life history of steelhead in these small lowland valley streams.

The primary objective of the survey was to collect biological and hydrological information for the assessment of stream and habitat conditions to be utilized in the development of alternatives and recommendations for enhancement of the anadromous fish resource. This would be accomplished by determining juvenile steelhead population fluctuations under varying habitat conditions to more clearly delineate benefits associated with the various enhancement activities. Main areas of study which were undertaken to meet the study objective include:

1) Estimate monthly production, biomass and population density of juvenile steelhead in selected streams.
2) Measure instream habitat to correlate with juvenile steelhead population biomass and densities.
3) Monitor downstream outmigration and yield of juvenile steelhead from two study streams.

DESCRIPTION OF STUDY AREA

The Nez Perce Reservation, located in north central Idaho, is approximately 3,237 km in area, and includes a major portion of the lower Clearwater River drainage. Elevations in the lower basin range from 280 m to 1,844 m and include semi-arid canyons, agricultural prairie and coniferous forest habitats. Mean annual precipitation recorded at Lewiston, Idaho from 1973 to 1982, averaged 31.6 cm although more rainfall occurs at higher elevations. Maximum air temperatures during the summer low flow period range from 37.7 C at lower elevations to about 26.6 C in the forested habitats.

The five study streams, Bedrock, Big Canyon, Cottonwood, Jacks and Mission Creeks, are lowland valley streams which drain agricultural lands and discharge into the Clearwater River (Figure 1) Bedrock Creek is approximately 14.5 km in length and flows in a southeasterly direction to its confluence with the Clearwater River at river kilometer (rkm) 32.2. The study areas on Bedrock Creek in 1983 and 1984 were located at stream kilometer (skm) 5.2 for the upper and 0.8 for the lower and an additional station in 1984 was at skm 2.4. The pool station at the upper study area was located above the sample stations with the pool station at the lower study area being located between the sample stations. A fish weir which sampled all downstream migrants was located at skm 0.6. Big Canyon Creek is 48 km in length and flows in a northerly direction before discharging into the Clearwater River at rkm 42.5. The upper study area was located in a relatively inaccessible canyon (skm 13.6) that had little riparian vegetation and the lower study area was in a U-shaped canyon (skm 7.4), again with sparse riparian vegetation. Big Canyon Creek was sampled during 1983. Cottonwood Creek flows for 25.6 km, the lower 9.6 km having perennial flow, and discharges into the Clearwater River at rkm 21.1. The upper study area was located at skm 8.8 in a broadened valley of dense, riparian vegetation and was situated about 1 km below where subsurface water flow re-entered the stream channel, which kept water temperatures cooler than the lower study area. Riparian development was sparse to moderate at the lower study area, with a higher woody canopy, and was situated at skm 6.7. The Cottonwood Creek fish trap was positioned at skm 4.4. Cottonwood Creek was sampled in 1983 and 1984. Jacks Creek is about 12.9 km in length and courses in a northerly direction through a canyon area, has well developed riparian vegetation, and discharges into the Clearwater River at rkm 36.2. Only one study station, the upper study area, was sampled in 1983 and it was situated at skm 7.7. Mission Creek, a tributary to Lapwai Creek, flows for 34.3 km and discharges into Lapwai Creek (skm 15) and Lapwai Creek flows into the Clearwater River at rkm 10.2. The upper Mission Creek study area was located in a canyon area with sparse riparian vegetation. The upper study area (skm 12.9) was sampled during 1983 only.

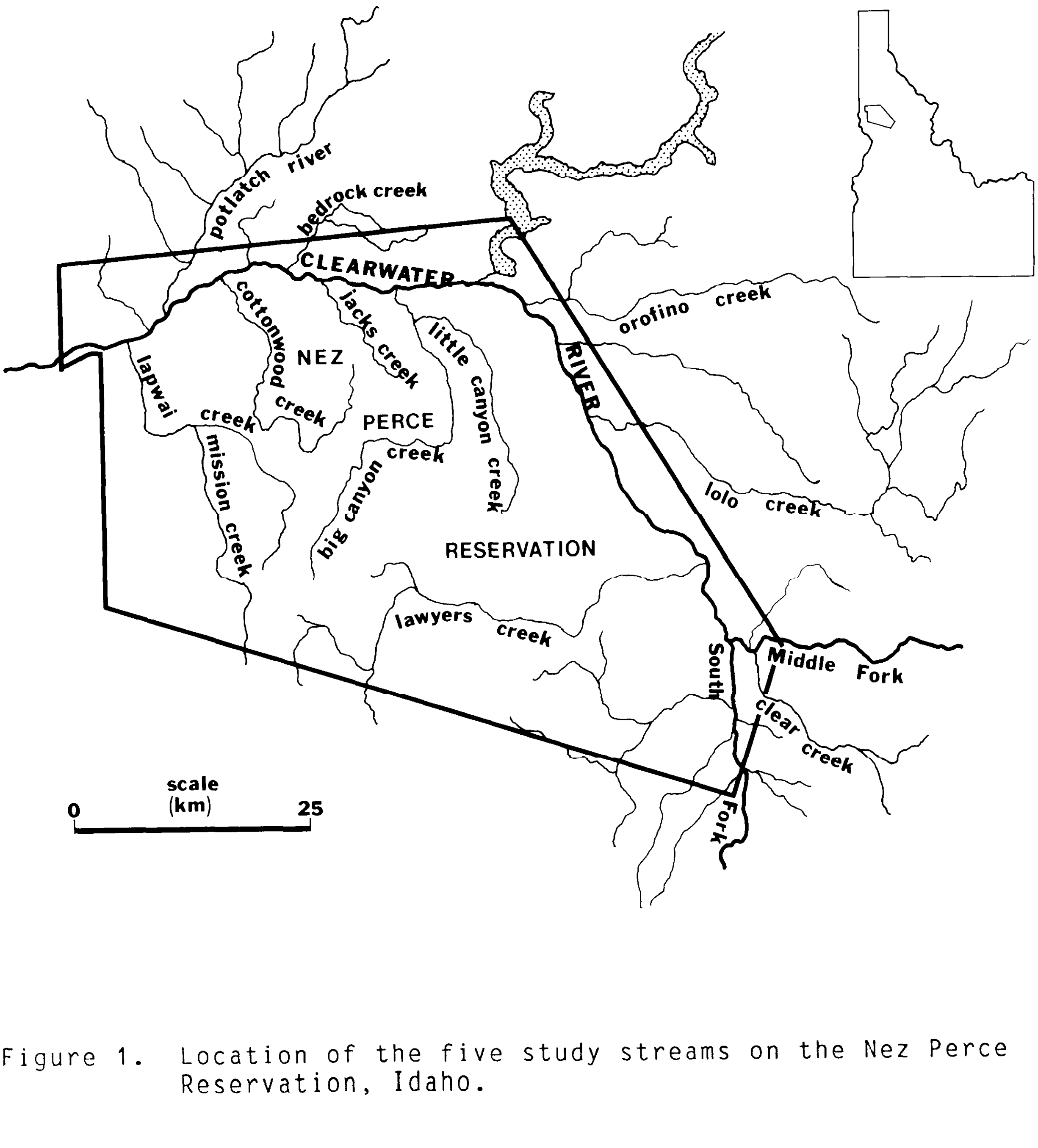


Figure 1. Location of the five study streams on the Nez Perce Reservation, Idaho.

METHODS

Selection of stream study areas was made after walking each target stream and identifying the accessible representative habitat types. Study areas were then designated within these habitat types and 50 meter sampling stations set up. Study areas were stratified by habitat type but were not selected randomly as stream habitat was not homogeneous. Sampling stations were then established within the study areas. Once designated, the same 50 meter stations were randomly selected and sampled monthly to provide point estimates of fish biomass (standing crops) and densities and physical habitat variables.

In 1983 five study streams were selected to survey juvenile rainbow-steelhead trout populations and associated habitat conditions. The term rainbow-steelhead trout is utilized in this report because we could not differentiate between resident fish and anadromous steelhead under field conditions. The five study streams included Bedrock Creek, Big Canyon Creek, Cottonwood Creek, Jacks Creek and Mission Creek (Figure 1). Two study areas were established on Bedrock, Big Canyon and Cottonwood Creek with two 50 meter sample stations assigned per study area. Jacks Creek and Mission Creek had one study area established per stream with two 50 meter sample stations per area. Stream sampling was conducted monthly from May thru either December or January; except the upper Big Canyon study area which became inaccessible from November on.

After the project was extended for a second year, the 1984 sampling design was changed to examine Bedrock Creek and Cottonwood. Three study areas were set up on Bedrock Creek (the two 1983 study areas plus one additional area) and the same two study areas on Cottonwood Creek. However, three 50 meter sampling stations were established per study area with the exact same 50 meter stations sampled in 1983 being repeated in 1984. The only exception was at the lower study area on Cottonwood Creek where a county roads department project channelized a portion of the stream, removing one of the 50 meter stations, which then was not repeated in 1984. Two pool stations were established on Bedrock Creek and were sampled monthly from August to December in 1983 and from May to November in 1984. One pool site was located at the upper study area and the other pool site was at the lower study area.

Fish Sampling

Once a study area was established, 50 meter sampling stations were selected to collect monthly fish population information. Electrofishing methods were used exclusively during the study with a Georator portable generator (model 31-002) with a single positive electrode and a negative wire screen placed in the stream. Fish population data was collected at each station using removal methods (Zippin 1958; Seber and LeCren 1967). If a 70 percent reduction in numbers of salmonids was not attained between shocking passes an additional pass was made. The specific computer program used (Platts et al. 1983) for fish population estimates utilized a maximum likelihood model. The model uses a successive depletion in catch size to estimate the population size by determining the likelihood of possible population sizes that are greater than or equal to the total catch. Then the population size with the highest likelihood is considered the best estimate. Boundaries of each 50 meter station were permanently marked, for ready location, and blocked with 6.35 mm (l/4 inch) bar mesh minnow seines prior to electrofishing. During the removal procedure fish were shocked, while the crew moved upstream, with 230 volts direct current. Fish collected during a pass were placed in large plastic garbage cans, immediately weighed and measured after the pass and placed in a live net in a pool area away from the station, prior to the next shocking run. After completion of electrofishing all fish were placed back into the sampled area. Through observation and discussion with other fisheries scientists (David Bennett-personel communication), it was believed that yearling fish were effectively sampled through December with reduced efficiency in January. Some difficulty was experienced in efficiently collecting subyearling fish when they started to enter substrate chambers from November on.

Monthly fish production was calculated by the instantaneous growth method (Ricker 1975; Chapman 1967) where production (P) equals the instantaneous growth (G) times the mean biomass (B). Production estimates were calculated for subyearling and yearling fish, separately, from May to December or January. Some of the production of these cohorts was missed during the early spring. Annual production for age 0+ steelhead production was obtained in 1983 when estimates were made from November 1983 to May 1984. Age I+ fish population estimates and biomass were utilized in May to estimate age 0+ production between the November to May interval.

Subsamples of the monthly fish catch were used to obtain length and weight data. Juvenile steelhead were anesthetized with tricaine methanesulfonate (MS-222) measured to the nearest mm in total lenth and weighed. Weights for yearling fish (aqe I+, and II+) were obtained from a Hanson model' 1.440 dietetic spring scale (+l g) in 1983 and from Pesola hanging scales (+0.5 g) in 1984. Subyearling fish (age 0+) were weighed in lots of 5 on the dietetic spring scale in 1983 and individually from hanging scales (+0.2 g) in 1984 Additional subyearling rainbow-steelhead trout were weithed on hanging scales in 1983 to gather and ividual weights for use in length-weight relationships. Juvenile rainbow-steelhead were aged by the scale method (Hile 1941; Van Oosten 1.929) and compared with length frequency histograms for age group designation. Scales were removed from below the anterior portion of the dorsal fin above the lateral line and placed in a scale envelope which contained the fishes total length, weight, date sampled and location. In the laboratory, scales were cleansed in water, then dried, mounted between slides and aged using a Bioscope model 500 microprojector and recorded on data forms. Fish condition factors were calculated according to the formula: $K=W\times10^5/TL^3$, where W = weight in grams and TL = total length in millimeters (Carlander 1969). The terms subyearling, young-of-the-year (YOY) and age 0+ rainbow-steelhead are equivalent in this report. The term yearling fish includes both age I+ and II+ individuals. So few (<10%) age II+ fish were sampled that no population estimate could be generated for them as a separate group.

Juvenile rainbow-steelhead density (fish/m^2 and fish/m^3 was derived by dividing the fish population estimate by the stream area or volume sampled (see habitat measurements). Biomass (grams/m^2 and grams/m^3) information was calculated by multiplying the fish population estimate times the average weight of a fish (per age group) and then dividing by the sampled stream area or volume. When the number of fish collected was less than 20 individuals, the average total length was calculated from the sample and the weight computed from the log length - log weight regression equation. This weight value was then input to obtain biomass estimates. Fish density and biomass was calculated separately for subyearling (age 0+) and yearling (age I+ and II+) fish.

Habitat Measurements

Physical habitat variables were measured at the 50 meter sampling stations to provide monthly point estimates of the available habitat. Measurements were usually taken the same day or within a one day period of the biological sampling. The physical variables measured were water temperature, stream velocity, stream discharge, stream width, stream depth, stream area, stream volume, and five components of instream cover; depth greater than 30 cm, undercut banks, overhanging vegetation, surface turbulence and submerged rock and debris. Bottom substrate was measured, ocularly during low flow periods, along 10 transects per station using a 50 cm^2 frame and estimating particle sizes within the frame using a modified Wentworth scale (Table 1). Spawning substrate was calculated by adding one-half of the small cobble value with the very coarse gravel and coarse gravel categories. Onlv one-half of the small cobble area was used in calculating the total percent spawning gravel as the upper size range (130 mm) is too large for optimum spawning substrate. Water quality samples were collected from each stream in one quart plastic containers, labeled, placed on ice in coolers and immediately transported to the Analytical Services Laboratory at the University of Idaho. Variables measured, methodology and detection limits are presented in Table 2.

Water temperatures were monitored through use of Ryan model J-90 thermographs placed in each stream. Strip charts were replaced every 90 days throughout the study period. The monthly maximum and average stream temperatures were used as point estimates in relation to juvenile rainbow-steelhead density and biomass information.

Table 1. Classification of stream substrate materials based on a modified Wentworth scale.

Substrate Class	Size Range (mm)
Boulder (B)	>250
Large Cobble (LC)	130 - 250
Small Cobble (SC)	64 - 130
Very Coarse Gravel (VCG)	32 - 64
Coarse Gravel (CG)	16 - 32
Medium Gravel (MG)	8 - 16
Fine Gravel (FG)	4 - 8
Pea Gravel (PG)	2 - 4
Very Coarse Sand (VCS)	1 - 2
Sand (S)	.062 - 1
Silt - Clay (SLT-C)	<.062

Table 2. Water sample analysis outlining constituents measured, methods of detection and detection limits for samples taken from the streams on the Lower Clearwater River Basin, Idaho.

Constituent	Detection Method	Detection Limit
pH	Colorimetric	0.10 unit
Calcium, Ca	Inductively Coupled Plasma-Atomic Emission Spectrometer	0.15 mg/l
Magnesium, Mg	Inductively Coupled Plasma-Atomic Emission Spectrometer	0.25 mg/l
Sodium, Na	Inductively Coupled Plasma-Atomic Emission Spectrometer	0.10 mg/l
Potassium, K	Inductively Coupled Plasma-Atomic Emission Spectrometer	0.50 mg/l
Chloride, Cl	Titrimetric-Silver nitrate and potassium chromate	0.01 mg/l
Carbonate, CO3	Titrimetric-H2SO4 and phenolphthalein	0.22 mg/l
Bicarbonate, HCO3	Titrimetric-H2SO4 and methyl orange	0.09 mg/l
Sulfate, SO4	Turbidimetric	1.0 mg/l
Nitrate, NO3	Colorimetric, automated cadmium reduction	0.01 mg/l
Orthophosphate, PO4	Colorimetric, automated ascorbic acid	0.01 mg/l

Stream velocity was recorded monthly at a permanent flow station location at each 50 meter station. Velocity was measured at a depth of 0.6 from the surface using a Marsh McBirney model 201-M direct readout water current meter (±0.5 cm/s) attached to a top-setting rod. Stream discharge was calculated by multiplying the average depth and velocity times the stream width at the flow station to achieve a discharge in m^3/s.

Stream widths and depths were measured monthly along 10 equally spaced transects within each 50 meter sampling station. Along each width (transect), ten depth readings were recorded (±1 cm), and averages calculated to provide a monthly point estimate. Stream area was derived by multiplying average stream width by the station length (50 m), and stream volume was calculated by multiplying the above two factors by average stream depth.

Five components of instream cover were measured monthly at each station to evaluate their importance as vearling rainbow-steelhead habitat. The five components included: depth greater than 30 cm, undercut banks, surface turbulence, submerged rock and debris, and overhanging vegetation. Each component was measured to the nearest centimeter while walking upstream through the sampling station. Two of the variables, depth greater than 30 cm and undercut banks are rather self explanatory and will not be defined further. Surface turbulence was measured and recorded as yearling habitat if it had some appreciable depth associated with it (15 cm). This particular component was somewhat subjective but supplied an important source of cover in the smaller streams. Submerged rock and debris was represented by aquatic vegetation, sunken logs and large rock and boulders with interstices and crevices. Only interstices and crevices aroung the logs and boulders were measured. Overhanging vegetation refers to trees, grasses and other vegetation on the stream bank that physically hang over the water surface. A summation of the five measured habitat components was used as the total yearling steelhead habitat available.

Downstream Migrant Trapping

Juvenile rainbow-steelhead outmigrants were trapped on two of the study streams, Cottonwood Creek and Bedrock Creek. The Cottonwood Creek trap was fished continuously from June 27, 1983, to June 27, 1985, and the Bedrock Creek trap from June 27 through December 28, 1983, and May 10, 1984, to January 11, 1985. A fish weir (Figure 2) was located at stream Kilometer (skm 4.4) and monitored on Cottonwood Creek from June 27, 1983, to February 14, 1984, from May 8, 1984, to February 13, 1985, and from April 17, to June 27, 1985. High spring runoff necessitated the use of a fyke net (Figure 3) from February 15 to May 7, 1984, and February 14 to April 17, 1985. The fish weir was used exclusively to trap downstream migrants in Bedrock Creek, weir location at skm 0.6, and was fished during the period that fish population estimates were made.

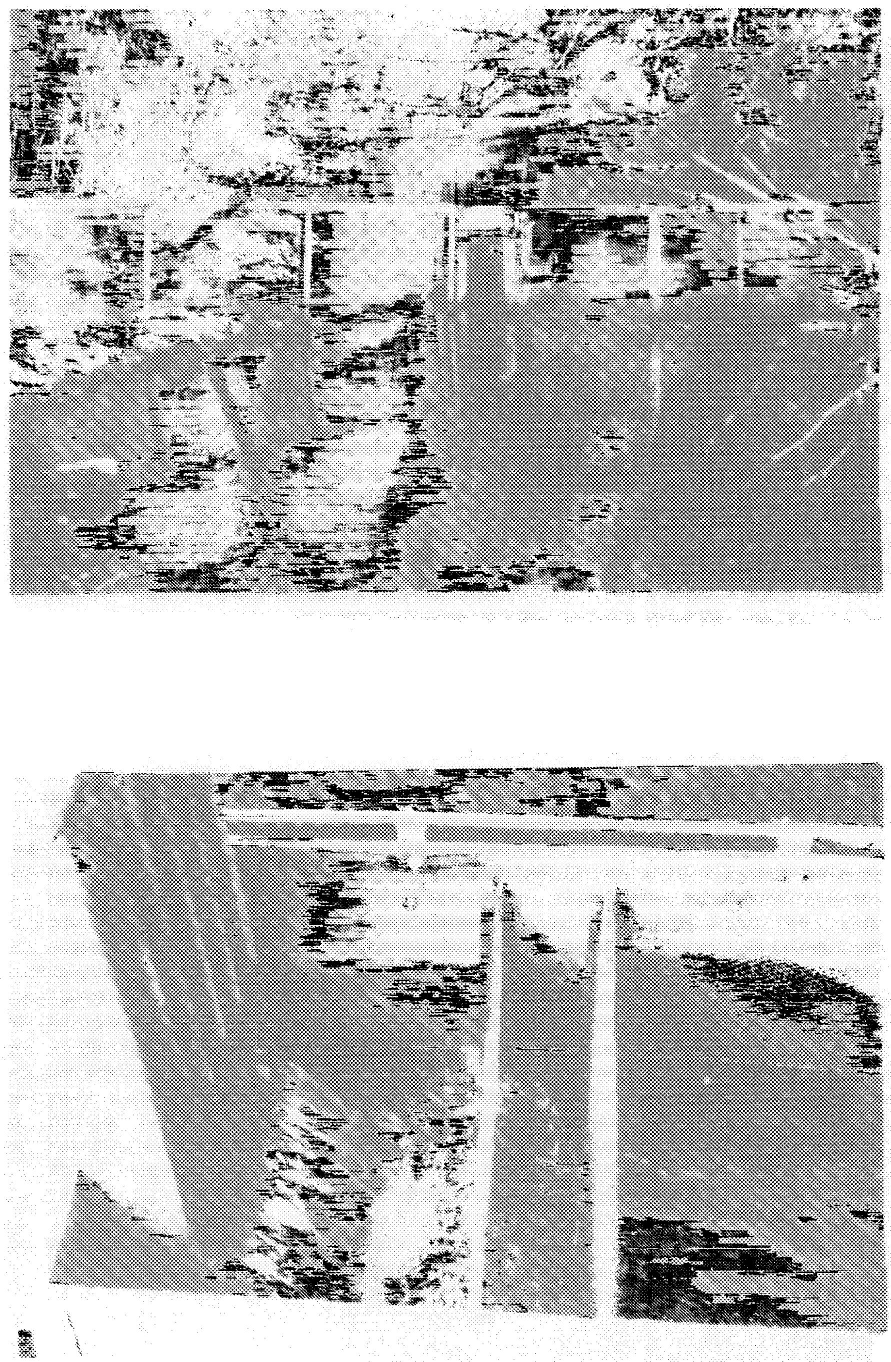


Figure 2 Cottonwood Creek fish weir (upper photo) and the interior of the live box trap (lower photo)

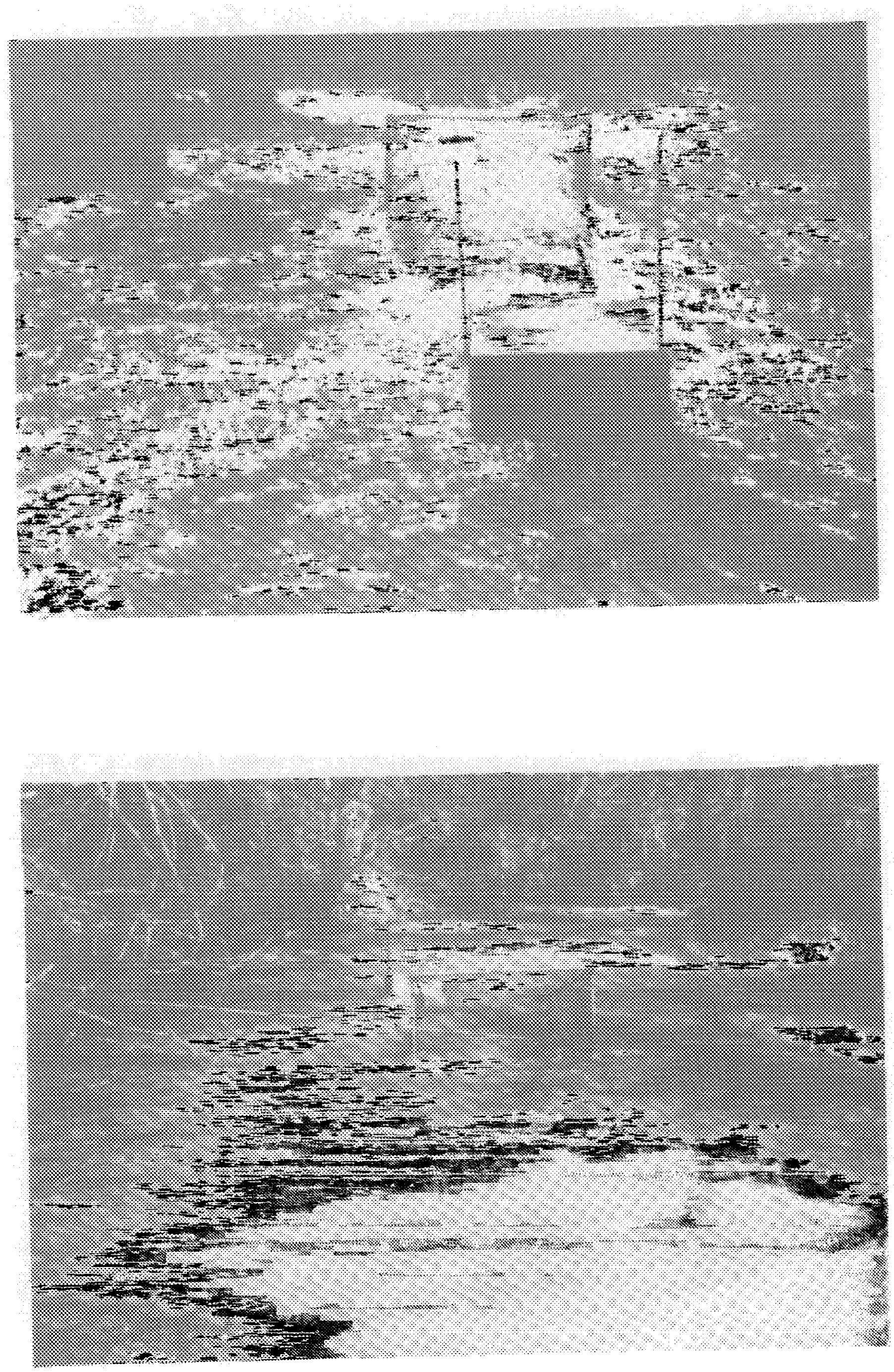


Figure 3. Cottonwood Creek fyke net.

The fish weir followed the design of Conlin and Tutty (1979) and consisted of attached wings of 6.35 mm hardware cloth on each side which directed fish into a sluice and the live box. A 15 cm vertical water drop (Figure 2) from sluice to the live box created a turbulent front half and a calmer back half where fish tended to congregate. The live box was usually checked daily and rainbow-steelhead trout were measured, weighed, recorded and released below the fish weir.

The fyke net (1.07 m high and 1.52 m wide frame) was 5.18 m in length with graduated mesh sizes (mouth to cod end) of 1.9, 1.3 and 0.6 cm bar measure, which attached to a live box. The net was centered in the stream where the greatest volume of flow could be fished. Despite placement of a trash rack upstream of the fyke net the throat inside the net clogged with leafy debris and limbs from the deciduous bottomland within half an hour. This precluded fishing the net with a functional throat section, which prevented fish from escaping back out of the net. The trapping mechanism therefore was a velocity barrier created by the decreasing size and mesh size of the net, which reduced trapping efficiency on the more mobile yearling and overyearling fish. During the spring of 1984 a definite channel existed which allowed us to fish a greater volume of water with the fyke net. In the spring of 1985 no definite channel area was present and the fyke net fished a lesser volume of water. We believe that this may have been one factor which led to the low trapping efficiency and estimates of yearling and overyearling outmigrants in 1985. The live box was monitored daily and captured rainbow-steelhead were fin clipped and released approximately 100 m upstream of the fyke net. Marked fish recaptured by the following day were utilized in generating a trap efficiency, for age 0+ and age I+ and II+ fish separately, which in turn was used in estimating the total number of outmigrants. The fyke net was not fished during the following times due to extreme flows or net repair: January 25 to February 6, 1984; March 14, 22nd to 25th, 1984; March 18, 19, 1985; and April 5th to 9th, 1985.

Trap efficiencies for the fyke net were calculated by dividing the number of fish recaptured by the number of fish marked per day. An estimate of downstream migrants was then made by dividing the number of fish sampled per day by the trap efficiency. These efficiencies were used because the regression between stream discharge and trap efficiency was not significant due to extremely variable trap efficiencies. Therefore, discharge could not be used to adequately estimate trap efficiency. Weekly trap efficiencies were used to estimate the number of subyearling (age 0+) and small yearling (age I+) size fish. The small yearling (SM YR) category designates the smaller pre-smolt steelhead after annulus formation (March 1). The terms young-of-the-year (YOY) and yearling (YR) were used prior to annulus formation and small yearling (SM YR) and large yearling (LG YR) to differentiate the pre-smolt and smolt steelhead after annulus formation. A seasonal trap efficiency was used to estimate the number of YR (age I+) and LG YR (age II+) size fish that moved past the trap site. Smolts are fish that will migrate to the ocean and have the typical silvery appearance, elongated body and deciduous scales of a steelhead smolt. Pre-smolts are smaller fish, generally less than 125 mm, that have none of the above characteristics.

The estimates (fyke net) of the YOY/SM YR outmigrants are probably more accurate than those of the YR/LG YR migrants. Weekly trap efficiencies reflected short term variation in movement which may not be evident when using a seasonal trap efficiency. Due to sampling problems, not enough YR/LG YR fish were recaptured to calculate weekly trap efficiencies. The seasonal efficiency provided the next best estimate of downstream movement.

During the fall, winter and spring of 1983-84, fish > 120 mm were considered to be YR/LG YR rainbow-steelhead. In the fall, winter and spring of 1984-85, fish > 100 mm were considered to be YR/LG YR fish. The discrepancy in the lower limit of the yearling size classification, reflected differences in fish growth over the two year sample period.

Precipitation data from 1983 and 1984 was averaged from the Winchester and Craigmont U.S. Geological Survey gage stations which are located approximately nine miles south-southeast from Cottonwood Creek. It was assumed that an average depth of the daily precipitation of these gage stations would reflect the contribution of local precipitation on the daily stream discharge especially during the summer and fall period. The relationship between stream discharge and precipitation and number of outmigrants and precipitation were examined to indicate which may affect downstream migration.

Statistical Analysis

The sampling design to gather fish density, biomass, production and outmigration information was a mensurative survey. The survey information is presented with biological inferences between fish population data and habitat variables between study areas being the main focus. Correlation matrices were calculated for juvenile steelhead densitv and biomass and all physical habitat variables measured at each stream study area. Significant correlation is presented to describe the strength of the association betewwn two varables (Ott 1984), but not to infer cause-effect phenomena (Sokal. and Rohlf 1969). Where other investigations in the literature report similar results, it would tend to support a cause-effect relationship. Regression analysis between vearling steelhead and instream cover is not presented as the relationships were not consistent and usually not significant at the different study areas within a stream.

Where sufficient evidence, biological and statistical, is apparent from the current survey data and other literature it may lend some direction in the design of a manipulative experiment. Statistical comparisons between study areas and between streams are not presented as confusion between treatment effect and a position or location effect may result (Hurlbert 1984), and because of small sample sizes. This results because the data does not meet the strict assumptions of independence and randomness that the statistical tests require. Unless otherwise specified all tests are performed at the .05 level of significance.

Length-weight relationships were calculated by use of a non-linear least squares regression. The length-weight relationship was expressed by the formula $W = aL^b$; where W = weight in grams, L = total length in mm, and a and b are constants. The log length-log weight relationship was expressed by the formula log W = a + b (log L); where W = weight in grams, L = total length in millimeters and a and b are constants.

BEDROCK CREEK

This system is comprised of two small drainages which converge to form Bedrock Creek (Figure 4). Louse Creek is about: 8.4 km long, provides the majority of flow during the summer months (Fuller et al. 1984), and joins with the mainstem of Bedrock Creek 4.8 km above the mouth. Roth creeks eminate in agricultural environments and flow through steep canyons to their confluence. Being located in a steep canyon, Louse Creek is relatively inaccessible, provides limited grazing, and has a well developed riparian zone. About 2.4 km above the confluence with Louse Creek the upper Bedrock Creek canvon widens and supports cattle grazing. Approximately 0.9 km below the confluence the canyon narrows, has limited access, and the stream has a dense riparian zone. The lower 2.4 km of stream is somewhat braided, has been heavily grazed and has sparse riparian habitat. Past flooding in this lower section indicates that the stream channel does not adequately contain high runoff. Logging has occurred in the past, throughout the drainage and many old logging roads remain.

During the two year study period stream discharge ranged from 0.003 to over 4.25 m^3/s; a 1,417 fold difference. Such severe stream flow variability has created wider flood plains in places and reduced channel stability. Stream channels mav be altered from year to year, in these flood plain areas, and peak spring runoff inhibits riparian vegetation which helps shade the stream and stabilize stream banks. Conversely, stream channels were more stable in areas of good riparian vegetation and overhead canopy. Discharge during the fish population sampling period ranged from 0.003 to 0.37 m^3/s (Figure 5). Monthly average water temperatures (Figure 5) ranged from 1.5 to 19.5 C, with summer maximum temperatures up to 25.1 degrees Centigrade. Stream gradient averaged 2.5 percent (range: 1.5 to 5.5). Water qualityu analysis (Table 3) indicate that, with a pH of 8 and a total dissolved solids level of 113, Bedrock Creek is moderately productive and not limiting to fish production. Fish species inhabiting Bedrock Creek include rainbow-steelhead trout, chinook salmon (Oncorhynchus tshawytscha), cutthroat trout, (Salmo clarki), speckled dace (Rhinichthys osculus), chiselmouth (Acrocheilus alutaceus), northern squawfish (Ptvchocheilus oreaonensis), redside shiner (Richardsonius balteatus), bridgelip sucker (Catostomus columbianus) and Paiute sculpin (Cottus beldinqi). Adult steelhead have been collected in Bedrock Creek during the study period. Because of the collection of adult steelhead and the low number ((10%) of age II+ and older rainbow-steelhead it is believed that the fish were steelhead and not a resident population of rainbow trout. based on electrophoretic analvsis the bedrock Creek population was not significantly different from Dworshak Hatchery steelhead (Appendix A). No known

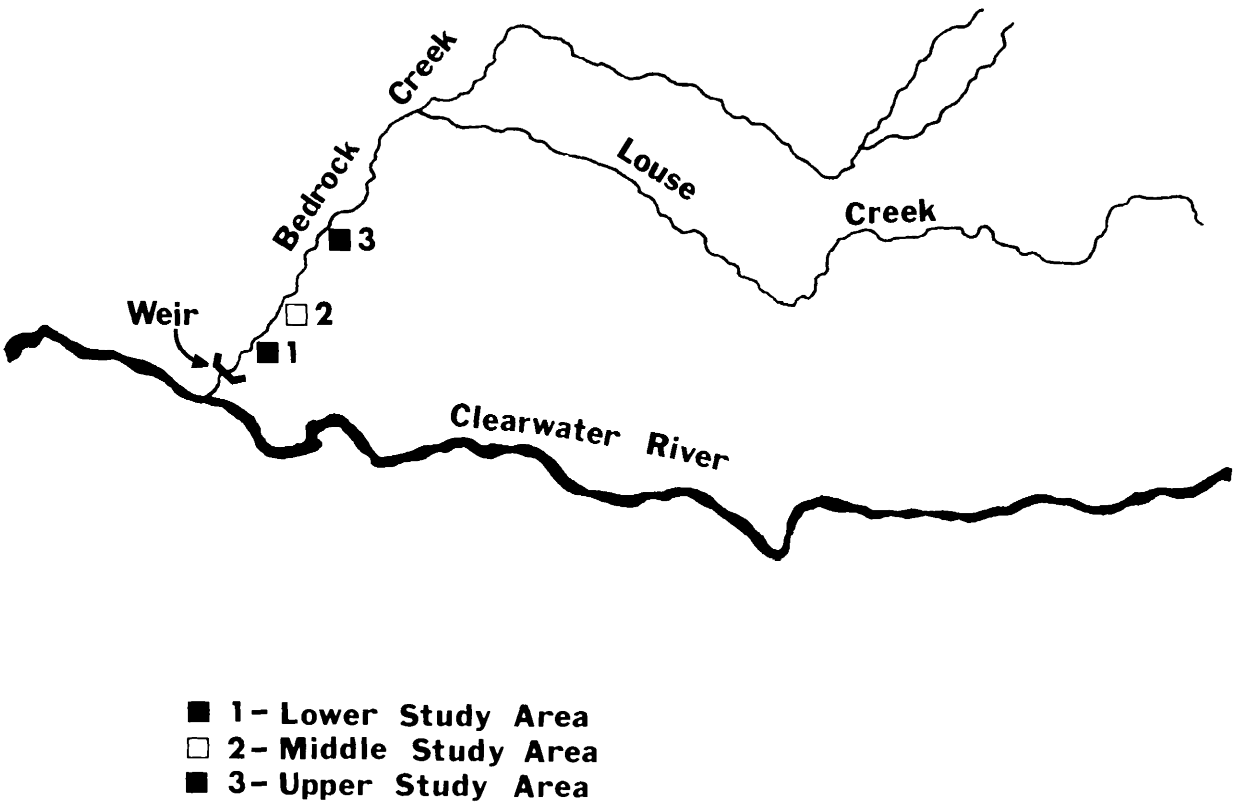


Figure 4. Map of Bedrock Creek indicating the two study areas sampled in 1983 (dark squares), the middle study area added in 1984 (open square) and the fish weir location.

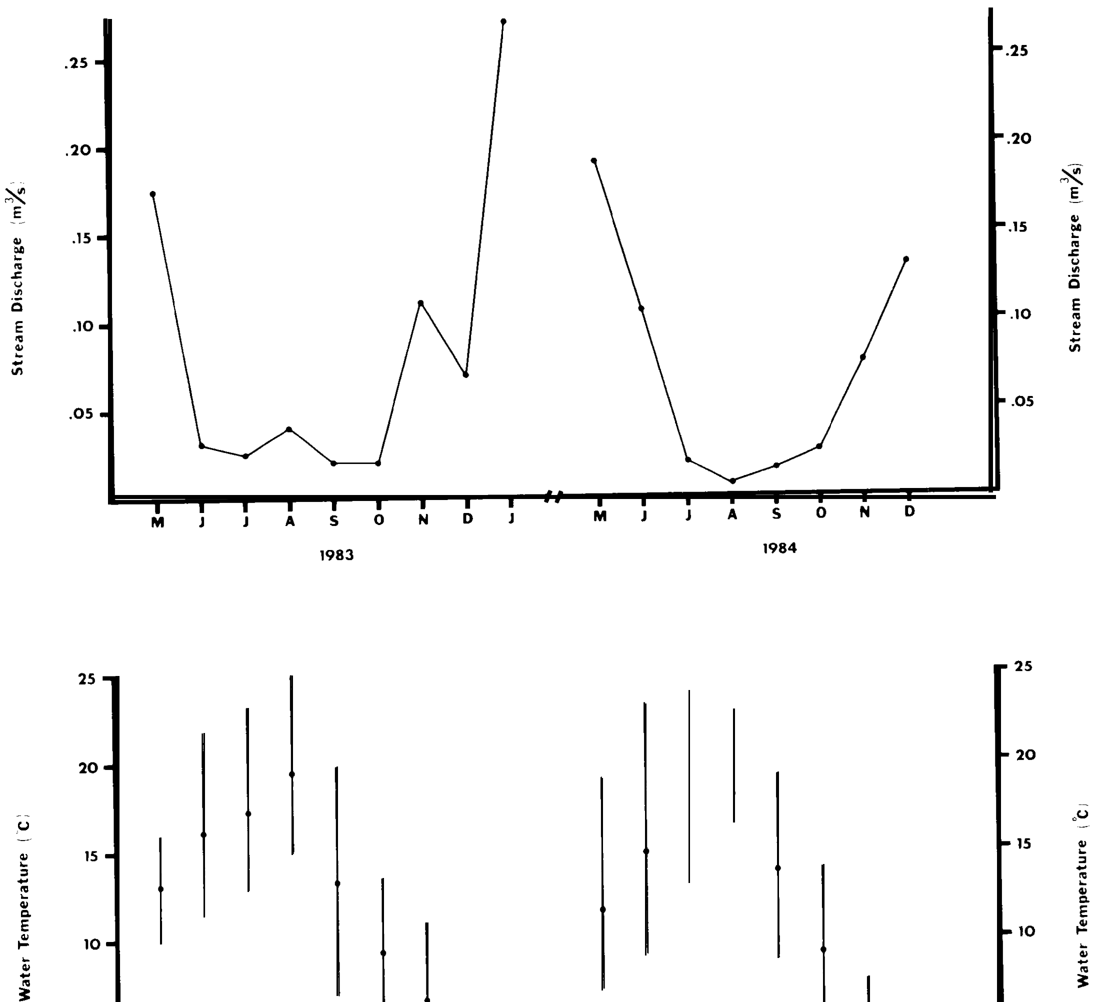


Figure 5 Monthly average and range in water temperature (lower graph) and average stream discharge (upper graph) for Bedrock Creek in 1983 and 1984.

Table 3. Chemical analysis of water collected from Bedrock Creek on August 4, 1983 and September 14, 1984.

Constituent	Year 1983	1984
pH	8.33	8.07
Calcium, Ca, mg/l	14.78	18.29
Magnesium, Mg, mg/l	5.05	7.21
Sodium, Na, mg/l	5.04	7.15
Potassium, K, mg/l	2.16	2.61
Chloride, Cl, mg/l	0.35	2.84
Carbonate, CO3, mg/l	Nil	Nil
Bicarbonate, HCO3, mg/l	81.71	104.27
Sulfate, SO4, mg/l	1.0	2.0
Nitrate, NO3, mg/l	0.20	0.37
Orthophosphate, PO4, mg/l	0.08	0.17
Total Residue, mg/l	118.0	119.0
Non-Filtered Residue, mg/l	5.0	3.5
Total Dissolved Solids, TDS	113.0	115.5

stocking of Dworshak fish into Bedrock Creek has ever been recorded. Adult bridgelip suckers from the Clearwater River ascend the Creek each spring to spawn. Fishing mortality was not quantified but fishing pressure was belived to be light to moderate.

Upper Study Area

Rainbow-steelhead trout was the only anadromous salmonid sampled, in this study area, during the two year study period. Yearling densities during 1983 (Figure 6) fluctuated from .21 fish/m^2 in May, to a high of .29 fish in June and decreased to .03 fish/m^2 in January of 1984 (Table 4) It was believed that yearling fish were effectively sampled through December with some inefficiency in January. Densities in 1984 were generally similar to the 1983 data, ranging from .25 fish/m^2 in May, to a higher level of .66 fish in July, and decreasing to .l0 fish/m^2 in December 1984 (Figure 7). Densities of fish in December of both years were exactly the same, .l0 fish/m^2, suggesting that the carrying capacity in winter may be .l0 fish/m or lower. The June, 1983, density of .29 fish/m^2 occurred when stream discharge dropped from .2082 m^3/s in May to .0382 m^3/s in June (Table 5) thus constricting available instream habitat. Similarly, the July 1984 high density of .66 fish/m^2 occurred when a dramatic reduction in instream flow from .1221 m^3/s in June to . 0229 in July constricted the aquatic habitat. After a low flow of .0096 m^3/s was reached in August (1984), densities declined to .41 fish/m^2 and then to .215 fish/m^2 in September where the decline from then on was more constant. Yearling density comprised 29 to 35.7 percent of the total salmonid density in 1983 and accounted for 24.3 to 40.7 percent of the total in 1984. Subyearling rainbow-steelhead trout density made up the remaining percentages.

Fish population estimates in 1983 were similar from September to December and in 1.984 populations were essentially the same from September to November. These more stable steelhead numbers occur after a decrease takes place (Appendix-Table 13.2.) during the summer period. This suggests a period of population regulation during the summer low flow period. One specific factor that regulated yearling numbers could not be identified but, rather, the time of population decline was. Densities (number per unit area), as opposed to populations (numbers only), generally decline in the late fall and winter as stream discharge increases thus increasing the total available area for a similar number of fish. Since yearling numbers do not increase in response to higher flows and increased habitat, this supports the idea that population requlation has already transpired through mortality and/or emigration. No major downstream movement of yearling steelhead was noted at the fish weir during the summer period. Fish population numbers also dropped in January, 1984, partly due to

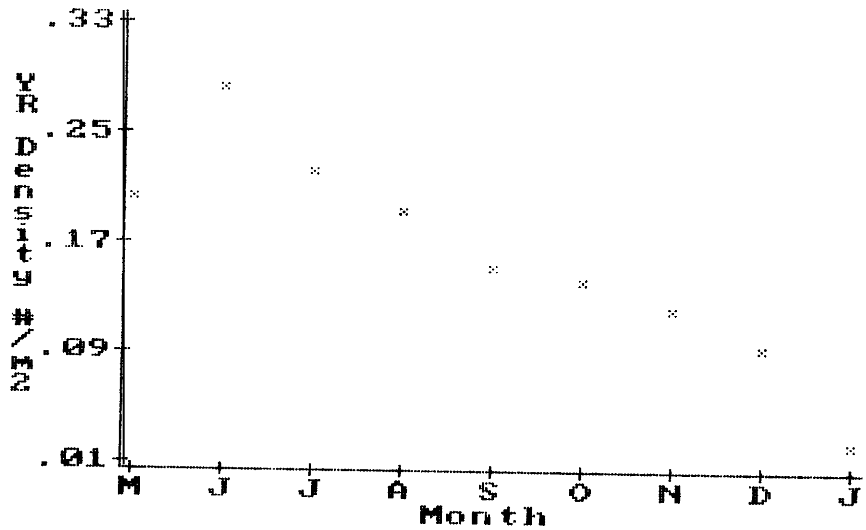


Figure 6. Yearling rainbow-steelhead trout density at the upper study area on Bedrock Creek from May, 1983 to January, 1984.

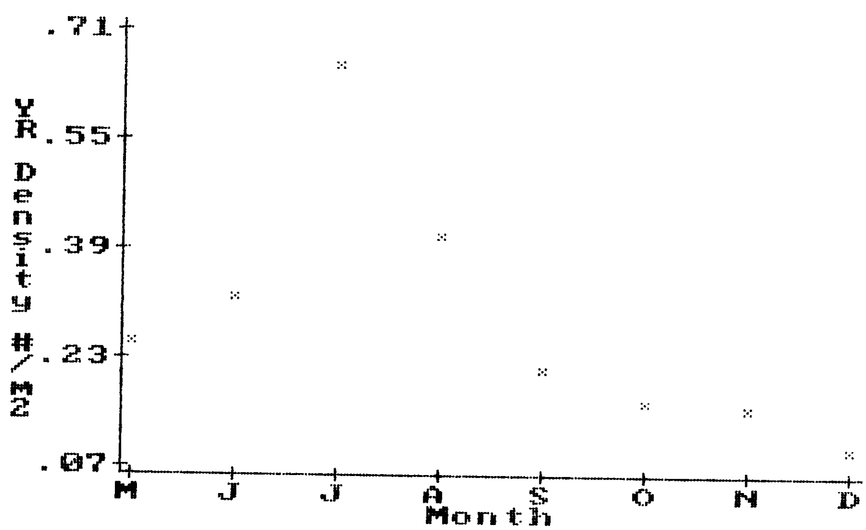


Figure 7. Yearling rainbow-steelhead trout density at the upper study area on Bedrock Creek from May to December, 1984.

Table 4. Monthly values of stream area and stream volume sampled and average density and biomass (standard deviation in parenthesis) of yearling rainbow-steelhead trout measured in the upper study area on Bedrock Creek in 1983 and 1984.

Month	Stream Area Sampled (m2)	Stream Volume Sampled (m3)	Density Number/m2	Density Number/m3	Biomass Grams/m2	Biomass Grams/m3
1984 a						
May	884.4	133.2	0.255	1.69	2.98	19.66
			(.04)	(.13)	(.0)	(2.66)
June	791.1	98.8	0.320	2.60	6.16	50.02
			(.04)	(.58)	(.52)	(7.88)
July	555.9	47.5	0.660	7.77	14.57	169.61
			(.06)	(1.03)	(3.46)	(23.13)
August	466.2	35.8	0.410	5.31	8.33	106.92
			(.07)	(.54)	(3.28)	(34.95)
September	513.3	40.5	0.215	2.80	4.19	54.27
			(.09)	(1.32)	(1.54)	(22.48)
October	584.4	62.5	0.170	1.62	4.19	39.55
			(.07)	(.78)	(1.58)	(17.23)
November	672.0	85.5	0.160	1.25	3.71	29.11
			(.03)	(.30)	(.94)	(7.34)
December	633.9	121.8	0.100	0.53	2.75	13.87
			(.05)	(.22)	(1.63)	(6.85)
1983 b						
May	596.4	81.0	0.210	1.57	3.92	29.31
			(.01)	(.22)	(.46)	(6.19)
June	448.0	36.7	0.290	3.48	5.41	67.15
			(.06)	(.05)	(.28)	(14.46)
July	398.2	31.2	0.230	3.01	4.53	58.06
			(.007)	(.29)	(.29)	(8.90)
August	399.2	37.8	0.200	2.08	3.27	34.46
			(.04)	(.49)	(1.47)	(15.50)
September	373.6	27.1	0.160	2.17	2.63	35.70
			(.04)	(.38)	(1.19)	(13.19)
October	400.4	35.7	0.150	1.77	3.36	37.49
			(.007)	(.28)	(.50)	(.95)
November	484.4	66.0	0.130	0.99	2.83	21.17
			(.01)	(.20)	(.39)	(5.15)
December	453.8	49.6	0.100	0.97	2.30	21.12
			(.007)	(.09)	(.39)	(3.81)
January	554.0	101.8	0.030	0.18	0.67	3.70
			(.02)	(.10)	(.20)	(1.31)

a Average of three 50 meter sample stations.
b Average of two 50 meter sample stations.

Table 5. Average monthly physical characteristics, standard deviation in parenthesis, of the upper study area on Bedrock Creek sampled in 1983 and 1984.

Month	Stream Disch. (m3/s)	Stream Veloc. (cm/s)	Stream Width (cm)	Stream Depth (cm)	Average Water Temp. (C)	Depth >30cm (m2)	Undercut Bank (m2)	Overhang. Vegetatn. (m2)	Surface Turb. (m2)	Subm. Rock (m2)	Total Habitat (m2)
1984 a											
May	0.1824	19.95	589.7	15.1	11.6	10.25	1.51	2.36	5.33	0	19.45
	(.030)	(4.61)	(22.5)	(1.2)		(1.58)	(1.45)	(3.22)	(2.05)		(2.11)
June	0.1221	15.20	527.1	12.4	14.8	8.96	1.28	1.93	5.04	0	17.21
	(.030)	(5.97)	(45.2)	(1.3)		(4.06)	(1.33)	(2.63)	(1.30)		(5.05)
July	0.0229	5.30	370.6	8.5	18.0	2.26	1.07	2.29	1.80	0	7.43
	(.003)	(1.46)	(43.4)	(.5)		(1.97)	(1.22)	(3.06)	(.43)		(1.12)
August	0.0096	2.77	310.6	7.7	18.1	1.67	0.82	1.88	0.88	0	5.25
	(.004)	(.51)	(21.9)	(.6)		(1.23)	(1.46)	(2.59)	(.55)		(.83)
September	0.0141	3.56	342.3	7.8	13.9	2.02	0.77	2.10	0.94	0	5.85
	(.002)	(.34)	(23.2)	(.9)		(1.79)	(1.34)	(2.83)	(.12)		(1.14)
October	0.0206	4.36	389.8	10.7	9.2	3.11	0.92	2.08	1.18	0	7.30
	(.002)	(1.12)	(49.8)	(1.0)		(2.55)	(1.16)	(3.03)	(.46)		(.78)
November	0.0504	7.91	447.9	12.8	4.9	3.75	1.03	2.01	1.11	0	7.91
	(.020)	(4.71)	(44.0)	(.4)		(2.24)	(1.20)	(3.11)	(.47)		(.93)
December	0.1381	15.90	422.7	19.4	1.5	8.12	0.89	1.74	1.83	0	12.60
	(.030)	(5.71)	(58.4)	(2.3)		(3.29)	(1.22)	(2.63)	.61)		(2.11)
1983 b											
May	0.2082	32.07	596.5	13.5	13.1	-	-			-	
	(.001)	(3.43)	(13.4)	(1.3)							
June	0.0382	12.32	448.0	8.2	16.1	5.05	1.55	4.50	2.1	1.3	14.56
	(.003)	(2.36)	(34.6)	(1.6)		(2.5)	(2.2)	(5.0)	(1.4)	(1)	(4.9)
July	0.0277	7.66	398.2	7.9	17.3	4.89	1.28	3.40	0.5	0	10.06
	(.002)	(2.5)	(33.2)	(.7)		(.54)	(1.82)	(3.8)	(.1)		(2.48)
August	0.0553	11.74	399.3	9.5	19.5	4.19	1.25	5.67	0.3	0	11.40
	(.003)	(1.47)	(0)	(0)		(.88)	(1.77)	(2.56)	(.2)		(1.48)
September	0.0228	5.60	373.5	7.3	13.3	3.21	1.95	3.44	0.4	0	8.28
	(.006)	(2.97)	(17.2)	(.6)		(1.47)	(1.69)	(4.87)	(.01)		(1.7)
October	0.0220	4.38	400.4	8.9	9.3	3.03	1.28	2.47	0.3	0	7.07
	(.006)	(1.80)	(29.1)	(1.1)		(2.15)	(1.82)	(3.15)	(.07)		(.74)
November	0.1116	14.82	484.5	13.5	6.6	6.77	1.03	3.46	1.0	0	12.30
	(.03)	(7.46)	(47.2)	(1.5)		(.87)	(1.46)	(4.89)	(1.3)		(2.96)
December	0.0680	10.86	453.9	10.9	2.5	7.98	1.31	3.41	2.0	0	14.72
	(.004)	(2.24)	(42.1)	(1.2)		(3.07)	(1.85)	(4.83)	(1.13)		(4.92)
January	0.3448	32.55	554.0	18.4	1.5	-		-			
	(.04)	(3.6)	(15.7)	(1.0)							

a Average of three 50 meter sample stations.

b Average of two 50 meter sample stations.

decreased sampling efficiency and numbers declined during the winter (December) of 1984. The data is less precise than the summer reduction, but there, potentially, may be another period of population regulation during the winter period.

Yearling biomass was highly correlated ($P<0.05$) with density for both years of study. Biomass ranged from 3.92 g/m^2 in May 1983, to a high of 5.41 in June, and then gradually decreased to .67 g/m^2 in January, 1984 (Table 4). Estimates of yearling biomass in 1984 fluctuated from 2.98 g/m^2 in May to a high of 14.57 in July, decreasing to a low of 2.75 g/m^2 in December of 1984. While yearling densities, at the most were 40.7 percent of the total salmonid density present, yearling biomass made up 62.3 to 86.4 percent of the total salmonid biomass in 1983 and 59.8 to 85.3 percent in 1984.

Yearling steelhead production at the upper study area (Table 6) was 2.4 g/m^2 in 1984 and .12 g/m^2 during 1983. Since production was measured from May to December or January, some production from this cohort was missed in the early spring. Monthly production estimates followed a pattern with positive production occuring in May and June and maintenance or declining values during the summer period when higher water temperatures and low stream flows occur. Production was positive during September (Table 6) with a period of weight loss for yearling fish during the winter. Accumulation of yearling fish flesh was highest at the upper study area and lowest at the lower study area. Fish emigration is a factor that can affect production estimates and marked yearling steelhead moved out of the sampling stations and into the pool site during summer months. However, the estimates are considered the production, or accumulation of fish flesh per unit of time, that occured within the sampling stations. The total juvenile steelhead production for Bedrock Creek, averaged over the study areas, was 3.67 g/m^2 in 1984 and 4.32 g/m^2 in 1983. The 1983 data reflect subyearling production estimates from November (1983) to May (1984) which the 1984 estimates lack. These estimated production values fall into a middle range of rainbow trout production reported for fluvial systems within the United States (Neves et al. 1985). Neves reported production values ranging from 2.4 to 13.2 g/m^2. Goodnight and Bjornn (1971) reported that steelhead production for two Idaho streams ranged from 2.4 g/m^2 for the Lemhi River up to 10.4 g/m^2 for Big Springs Creek.

Survival estimates for yearling steelhead were calculated during the sampling period (May-December) in 1983 and 1984. Since yearling steelhead could and did emigrate out of the sampling stations the estimates are considered rough approximations. Estimated survival in 1984 ranged from 9 to 29.3 percent at the middle and upper study areas respectively. The lower study area survival was 24.3 percent. Yearling

Table 6. Production estimates of yearling and subyearling rainbow-steelhead trout from three study areas on Bedrock Creek in 1983 and 1984.

Month	Upper Study Area Production (g/m2)		Middle Study Area Production (g/m2)		Lower Study Area Production (g/m2)	
	Yearling	Subyearling	Yearling	Subyearling	Yearling	Subyearling
1984						
May	2.15		2.23	--	1.70	--
June	140	--	.63	.69	.29	.93
July	- .77	.36	- .90	.26	- .58	.15
August	- .47	.65	.42	.08	.06	.20
September	1+01	.63	.05	.10	.14	.32
October	- .10	- .21	.06	.08	- .12	0
November	- .42	.10	- .27	.11	- .02	- .03
December						
					-em--	
TOTALS	2.4	1.53	2.21	1.82	1+47	1.57
1983						
May	.01				.50	--
June	.20	.47			- .07	1.12
July	- .61	- .05			- .20	- .09
August	.03	.61			.20	.99
September	.70	.27			.08	.40
October	- .15	.24			.03	.87
November	- .01	.09			- .10	.04
December	- .05				.02	
January						
Nov-May [a]		1.60				2.0
					e--S-	
TOT&S	.12	3.23			- .04	5.33

a - Age 0+ steelhead only+

survival in 1983 varied from 36.1 (lower area) to 38.1 percent (upper area) from May to December. Higher densities of fish were present in 1984, compared to 1983 density information, and estimated survival was lower. Survival from age I+ to smolt outmigrant (age II+) could not be estimated due to spring pre-smolt outmigration of the age I+ fish. Also, survival estimation was not the main focus of the present study. Bjornn (1978) reported the survival of yearlinq steelhead migrants, from stocked trout fry, ranged from .4 to 1.2 percent over a 12 year period in Big Sprinqs Creek, Idaho.

As fish densities decreased over the summer period most yearling fish were found congregated in pool areas within the respective 50 m stations. Total measured yearling habitat, never exceeded 10 percent of the total available stream area during any month and appeared limiting in the study area. Average stream depths during the summer were less than 12 cm and water velocities were less than 15 cm/s. These depths and velocities are at a minimum level in terms of probability-of-use data for juvenile steelhead reported by Bovee (1978). Yearling fish density from one pool sampled in the upper study area in 1983 (Figure 8 and Table 7) was .88 fish/m^2 in August and declined to .335 fish/m^2 in December. Pool densities in 1984 (Figure 9) fluctuated from .13 fish/m^2 in June to a maximum of 1.49 in Auqust and then reduced to .495 fish/m^2 in November. The August 1984 maximum density was over 1.5 times higher than the August 1983 maximum, but the November 1984 density (.495 fish/m^2) was very comparable to the 1983 level (.52 fish/m^2) prior to the overwintering period. Yearlinq steelhead densities at the pool site were up to five times the sampling station densities (Figures 10 and 11). The more pronounced 1984 density decreases, at the sample stations from July to August, occurs while the density of fish in the pool increases (Figure 11) to the maximum level observed during the study period. Reduction in yearling densities at the sample stations cannot be equated to natural mortality as fish can emigrate, but not out of the stream system during the summer because of subsurface flows at the stream mouth. As previously discussed, when the 1984 summer low flow is attained (Table 8) in August (.0096 m^3/s) densities decrease pointedly from Auqust to September at both the station and pool area. Densities from this pool area (Figure 11) were up to four times greater than that observed during any month at the representative sample stations. the representative sample stations. Pool areas provide crucial summer and winter habitat as indicated by the much hiqher fish densities at the pool site compared to the sample station densities (Figures 10 and 11). The pool area contained a root wad as an undercut bank, was shaded and had water depth greater than 35 cm, compared to depths of less than 19.4 cm at the sample stations. Everest and Chapman (1972) reported a higher density of age I+ steelhead, in Crooked Fork Creek, generally in depths greater

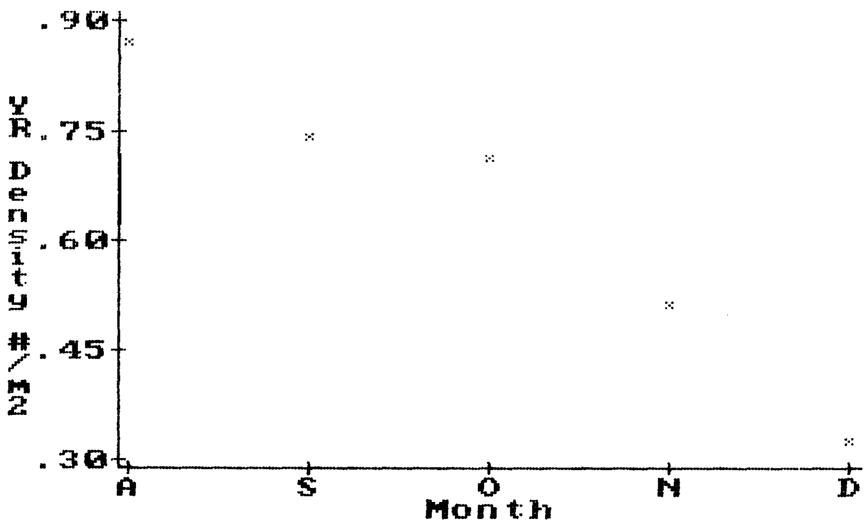


Figure 8. Yearling rainbow-steelhead trout density at the pool site at the upper study area on Bedrock Creek from August to December, 1983.

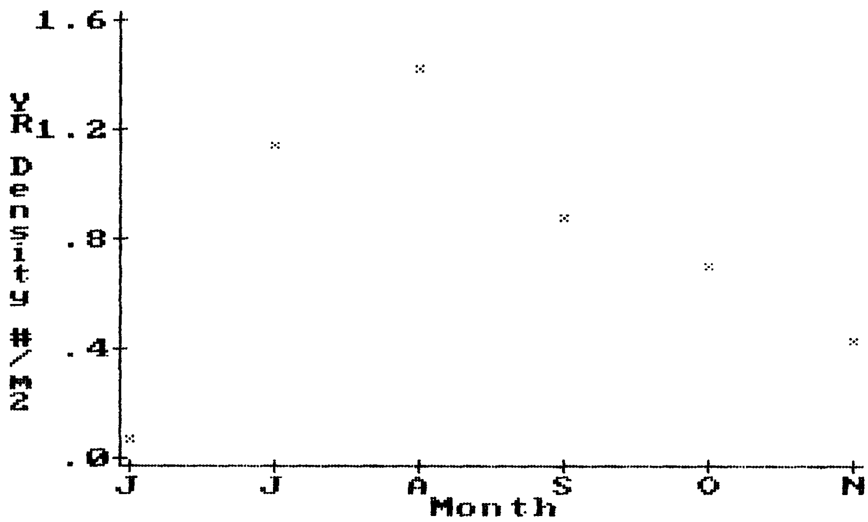


Figure 9. Yearling rainbow-steelhead trout density at the pool site at the upper study area on Bedrock Creek from June to November, 1984.

Table 7. Monthly values of strea, area sampled, stream volume sampled, density and biomass of yearling fall nbow-steelhead trout at the pool site of the upper study area on Bedrock Creek sampled in 1983 and 1974.

Month	Stream Area Sampled (m2)	Stream Volume Sampled (m3)	Density		Biomass	
			Number/m2	Number/m3	Grams/m2	Grams/m3
1984						
May				–	–	–
June	80.3	32.48	0.135	0.34	2.17	5.37
July	67.7	28.69	1.210	2.86	24.28	57.30
AUqUSt	68.4	24.57	1.490	4.15	30.03	83.65
September	65.5	21.68	0.950	2.86	18.82	56.91
October	77.0	33.04	0.770	1.78	19.77	46.07
November	78.9	29.67	0.495	1.31	10.09	26.81
December	–		–			
1983						
May	–	–	–	–	–	–
June	–	–	–	–	–	–
July	–			–		
August	64.3	25.03	0.880	2.28	19.31	49.64
September	60.3	23.70	0,750	1.90	14.34	36.45
October	55.4	20.26	0,720	1.97	16.40	44.82
November	65.8	27.29	0.520	1.24	15.38	37.06
December	71.3	27.88	0,335	0.86	7.15	18.29
January		–				

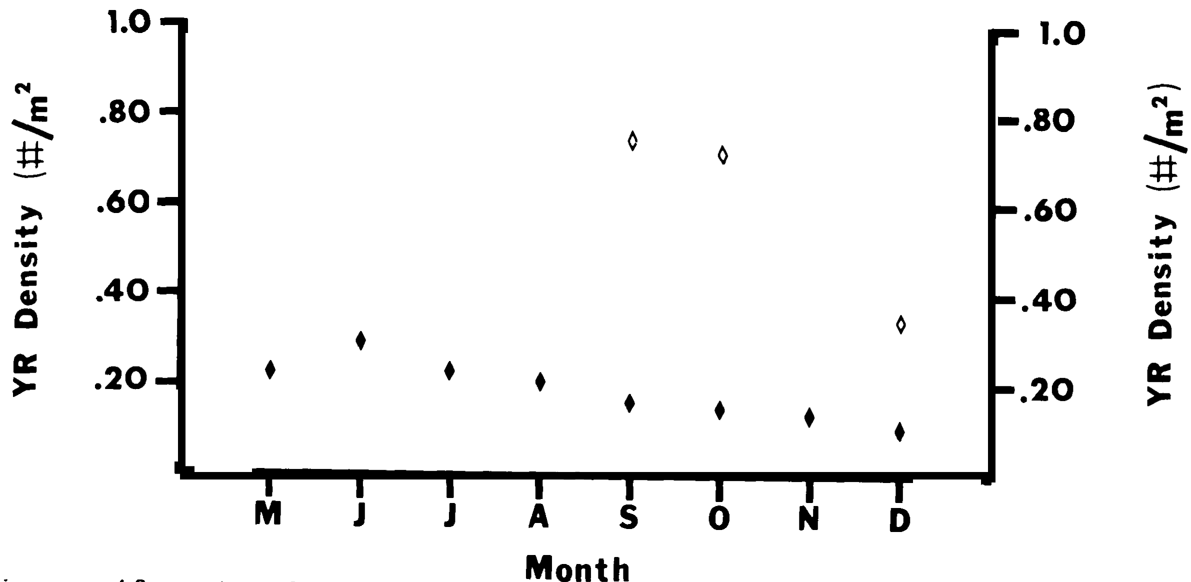


Figure 10 Yearling rainbow-steelhead trout density at the sampling stations (solid diamond) versus the pool site (open diamond) at the upper study area on Bedrock Creek in 1983.

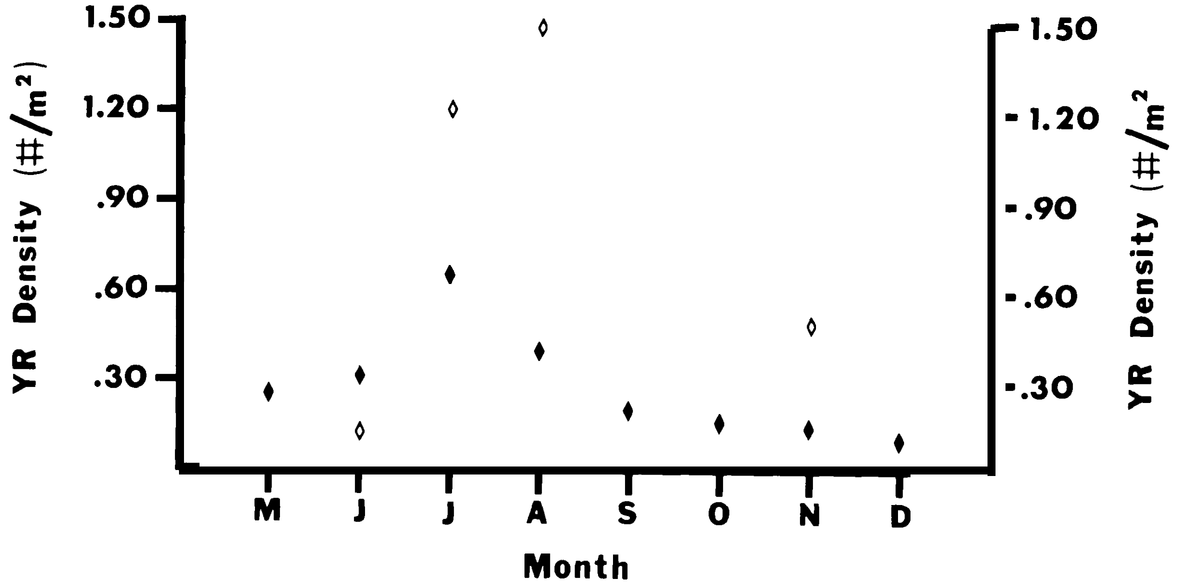


Figure 11. Yearling rainbow-steelhead trout density at the sampling stations (solid diamond) versus the pool site (open diamond) at the upper study area on Bedrock Creek in 1984.

8 out

Table 8. Monthly physical characteristics, standard deviation in parenthesis, at the pool site of the upper study area on Bedrock Creek sampled in 1983 and 1984.

Month	Stream Discharge (m3/s)	Stream Velocity (cm/s)	Stream Width (cm)	Stream Depth (cm)	Average Water Temp. (C)
1984					
May	-	-	-	-	
June	0.0929	11.05	554.4	40.4	14.8
		(9.72)	(162.8)	(35.3)	
July	0.0193	4.15	466.6	42.4	18.0
		(3.04)	(58.4)	(37.7)	
August	0.0139	3.28	472.0	35.9	18.1
		(2.34)	(96.8)	(31.7)	
September	0.0126	3.30	451.8	33.1	13.9
		(2.44)	(79.7)	(28.1)	
October	0.0208	3.83	531.2	42.9	9.2
		(2.66)	(64.6)	(35.2)	
November	0.0360	5.45	544.2	37.6	4.9
		(4.84)	(147.3)	(31.1)	
December					-
1983					
May					
June					
July			-		
August	0.0578	12.78	459.6	40.5	19.5
		(4.85)	(87.9)	(30.6)	
September	0.0271	7.70	430.4	39.3	13.3
		(6.10)	(97.5)	(29.3)	
October	0.0263	5.65	395.4	41.1	9.3
		(3.62)	(133.4)	(28.5)	
November	0.1320	20.10	469.8	41.5	6.6
		(7.75)	(97.0)	(32.8)	
December	0.0715	12.45	509.6	39.1	2.5
		(9.30)	(80.3)	(30.2)	
January			-	-	

than 15 centimeters. Rainbow trout density has been reported to be significantly related to current velocity in pool environments where rainbow and brown trout (Salmo trutta) occured in sympatry (Lewis 1969). No significant relations were noted between yearling density and velocity or instream cover, at the pool site, during this studv. Comparatively higher densities at this pool area occur as yearling rainbow-steelhead trout apparently seek pool habitat when cover is extremely limited and water temperature elevated during low flow conditions.

Yearling biomass in the pool during 1983 was 19.31 g/m^2 in August with a sharp drop from 15.38 in November to 7.15 g/m^2 in December. The 1984 pool biomass fluctuation, from 2.17 g/m^2 in June to 24.28 in July, occured during a sharp drop in stream discharge from .0929 m^3/s in June to .0193 m^3/s in July (Table 7). This substantial increase in biomass resulted from fish movement into the pool area during these low flows. Biomass increased to a high of 30.03 g/m^2 in August and decreased to 10.09 g/m^2 by November.

Correlation matrices between yearling rainbow-steelhead density and biomass and habitat variables were calculated for the upper study area. Few significant correlations existed, that provided a biological basis to relate yearling density or biomass information to habitat data. Regression analysis, therefore, was not a useful tool in delineating factors that limit steelhead densities and the discussion is supported by the literature when possible. Average water temperature and yearling density (Figures 12 and 13) were significantly associated during both years of study. The average water temperature of 19.5 C in 1983 was higher than the 18.1 C average temperature reached in 1984 despite the fact that summer low flow conditions in 1984 (.009 m^3/s) were less than one-half of that in 1983 (.022 m^3/s). The figures indicate that yearling density increases with increasing water temperature, which would occur only to a point where lethal temperatures were approached at which point the curve would truncate downward. There is also some interaction between yearling density and reduced discharge which tends to concentrate fish as water temperature is increasing. Fish density and temperature then decrease in the fall and winter as stream discharge increases. The data did not indicate that increased water temperatures reduced yearling densities. Raleigh et al. (1984) state that the optimum range in water temperature for rainbow trout is 12 to 18 C. Average water temperature was up to 19.5 C during 1983 and fish survived an 11 day period in early August when water temperature varied between 17 C and 25.1 degrees Centigrade. A similar 10 day period occured in late July and early August in 1984 when water temperatures ranged between 18 and 23.9 degrees Centigrade. However, as stated previously, populations decrease during the

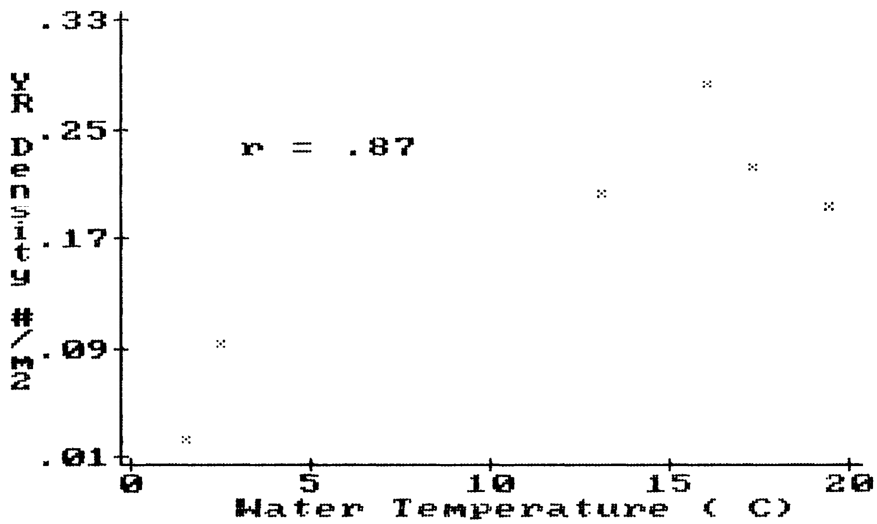


Figure 12. Relation between yearling rainbow-steelhead trout density and average water temperature at the upper study area on Bedrock Creek from May, 1983 to January, 1984.

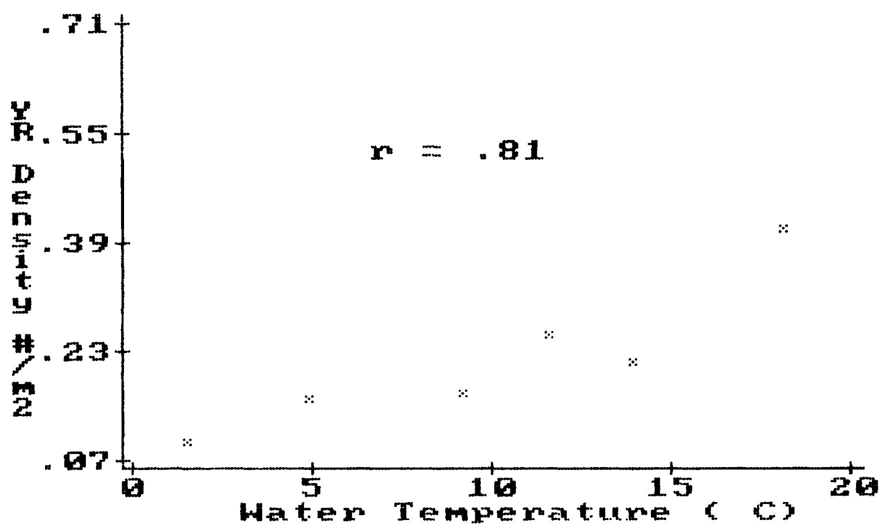


Figure 13. Relation between yearling rainbow-steelhead trout density and average water temperature at the upper study area on Bedrock Creek from May to December, 1984.

summer period but the decrease can not be attributed specifically to elevated water temperatures or low stream flows alone. A significant relationship between water temperature and density also existed at the pool station in 1983 but not in 1984. Yearling densities and instream cover were not significantly associated at the pool site. Stream discharge and density was negatively correlated at the sampling stations, indicating that as flow was reduced juvenile steelhead were concentrated in remaining habitat. Rut higher flows do not reduce yearling fish densities. The highest correlation observed between components of instream cover and yearling density was with overhanging vegetation in 1983 (r=.47) and in 1984 (r=.43) despite the lack of measured habitat present ((10%). Depth greater than 30 cm and overhanging vegetation made up the majority of yearling habitat present. Riffle areas comprised the remaining 90 percent of the total stream area. Lack of a significant positive relationship between density and instream cover suggests that the variables examined, sample size or time frame was inadequate or some other mechanism(s), other than space, operate to regulate density (Chapman 1966). Other researchers (Burns 1971; Gordon and MacCrimmon 1982) have reported significant correlations between steelhead and rainbow trout density and living space variables. McFadden (1969) described population regulation as a highly flexible process, not dependent on any single environmental factor, and the primary density regulator may even change seasonally (Chapman 1966). Food supply was not examined during this study.

Subyearling rainbow-Steelhead trout densities in 1983 decreased from .63 fish/m^2, when fish first recruited to the gear in June at a total length of 50 mm, to an estimated .12 fish/m^2 in January 1984 (Figure 14 and Table 9). Some difficulty was experienced in efficiently sampling subyearling fish when they started to enter substrate chambers from late November on. Densities in 1984 (Figure 15 and Table 93 were initially higher than in 1983, ranging from .96 fish/m in July, to a sharp decrease from .86 fish in August to .62 fish/m^2 in September, and decreasing to .34 fish/m^2 in December. A similar pointed decrease in yearling density occurred in 1984 at the pool site and sample stations when the lowest summer flow in August was .0096 m^3/s; and flow remained low in September (.0141 m^3/s). The higher initial densities in 1984 were related to a larger adult escapement into the stream as reflected by adult catch rates of 3 fish/man day in 1984 versus 1 fish/man day in 1983. Subyearling levels o$ abundance in December of each year were the same at .24 fish/m". Obviously, higher initial densities may be beneficial to fully seed other habitats, but similar overwintering abundances mav indicate that the carrying capacity is being approached. Subyearling fish accounted for 69 to 80 percent of the total. Salmonid density in 1983 and 59.3 to 75.7 percent in 1984.

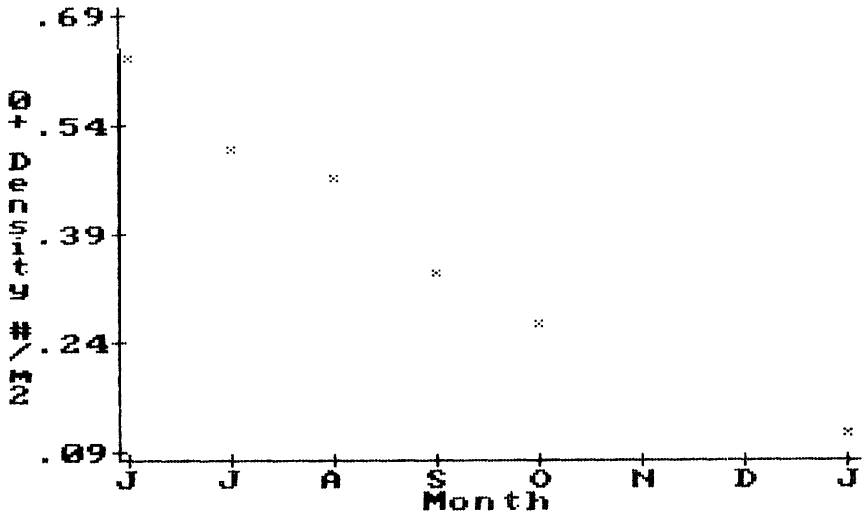


Figure 14. Subyearling rainbow-steelhead trout density at the upper study area on Bedrock Creek from June, 1983 to January, 1984.

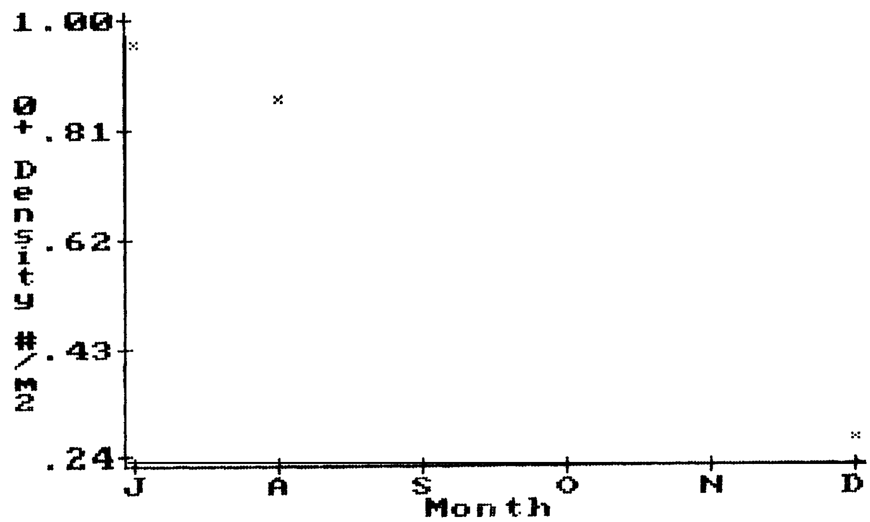


Figure 15. Subyearling rainbow-steelhead trout density at the upper study area on Bedrock Creek from July to December, 1984.

Table 9. Monthly values of stream area and stream volume sampled and average density and biomass (standard deviation in parenthesis) of subyearling rainbow-steelhead trout measured in the upper study area on Bedrock Creek in 1983 and 1984.

Month	Stream Area Sampled (m2)	Stream Volume Sampled (m3)	Density		Biomass	
			Number/m2	Number/m3	Grams/m2	Grams/m3
1984 a						
May	884.4	133.2	-			
June	791.1	98.8	-			
July	555.9	47.5	0.960	10.95	2.50	28.85
			(.52)	(4.68)	(1.0)	(8.30)
August	466.2	35.8	0.865	11.23	2.72	35.56
			(.09)	(1.43)	(.16)	(3.11)
September	513.3	40.5	0.620	7.96	2.52	32.63
			(.04)	(1.36)	(.35)	(.65)
October	584.4	62.5	0.530	4.94	2.71	25.29
			(.03)	(.61)	(.32)	(3.99)
November	672.0	85.5	0.410	3.21	1.89	14.94
			(.10)	(.88)	(.32)	(2.88)
December	633.9	121.8	0,275	1.43	1.36	7.16
			(.07)	(.50)	(.30)	(2.37)
1983 b						
May	596.4	81.0	-			
June	448.0	36.7	0,635	7.72	0.85	10.22
			(.10)	(.17)	(.21)	(.58)
July	398.2	31.2	0.510	6.43	1.08	13.77
			(.11)	(.82)	(.16)	(1.85)
August	399.2	37.8	0.470	5.01	1.00	10.54
			(.01)	(.15)	(.10)	(1.02)
September	373.6	27.1	0,340	4.70	1.12	15.39
			(.12)	(1.26)	(.27)	(2.38)
October	400.4	35.7	0.270	2.95	1.21	13.34
			(.09)	(.72)	(.38)	(2.66)
November	484.4	66.0	0.300	2.33	1.67	12.69
			(.12)	(1.16)	(.64)	(6.11)
December	453.8	49.6	0.240	2.23	1.39	12.81
			(.11)	(1.09)	(.78)	(7.36)
January	554.0	101.8	0,120	0.68	0.70	3.91
			(.06)	(.39)	(.30)	(1.87)

a Averaqe of three 50 meter sample stat ions+
b Average of two 50 meter sample stations,

Biomass estimates of subyearling fish in 1983 (Table 9) varied from .85 g/m^2 in June to a maximum of 1.67 in November and down to .70 g/m^2 in January, 1984. Fish biomass in 1984 was higher than in 1983, ranging from 2.50 g/m^2 in July to a high of 2.72 in August and decreasing to 1.36 g/m^2 in December. Cordon and MacCrimmon (1982) reported ranges in salmonid biomass of from .5 to 48.7 g/m^2 in European and North American streams. Although subyearlings comprised the majority in terms of numbers of total salmonids present they made up only 13.6 to 37.7 percent of the total salmonid biomass in 1983 and 14.7 to 33.1 percent of the total in 1984.

Subyearling steelhead production (Table 6) at the upper study area was 1.53 g/m^2 in 1984 and 3.23 g/m^2 during 1983. In 1983, production of age 0+ fish was estimated from November of 1983 to May of 1984 and provided the best estimate of annual production. Calculations in 1984 lacked this estimate. Monthly production values indicated that subyearling fish accumulated biomass durinq most months except for October (1983) and July in 1984. Production estimates between study areas (Table 6) were very similar in 1984 ranging between 1.53 to 1.82 g/m^2. The estimated accumulation of subvearling biomass in 1983 was more variable, ranging from 3.23 to 5.33 g/m^2. Age 0+ steelhead production continued to be positive except as stated above, even during low summer flow conditions and average water temperatures that approached 19.5 C; with maximum water temperatures up to 25.1 degrees Centigrade.

Survival estimates for subyearling steelhead were calculated from June to December (1983-84). Fish movement precluded estimating survival from December to the following May (1984). Estimates are considered to be too high as survival was computed from when the first population estimate could be made. Initial numbers of age 0+ fish were unknown. Subyearling fish could also emigrate from the sampling stations, thus making the estimates rough approximations only. Estimated survival in 1984 varied from 33 to 34.8 percent at the middle and lower study areas respectively. The upper study area survival was 33 percent. Age 0+ survival in 1983 ranged from 17.4 percent (lower area) to 38.3 percent (upper area). higher subyearling numbers were present at the lower study area in 1983, compared to other study areas, and the projected survival was much lower (17.4%). Wentworth and LaBar (1984) estimated that the over-winter survival of steelhead averaged 16 percent (ranqe 13-44%). They further report an averaqe survival of four percent from stockinq of fry to age I.

Subyearlinq steelhead density and biomass and habitat variables were examined via correlation matrices. Average water temperature and subyearling density had the only significant positive association observed (Figures 16 and 17).

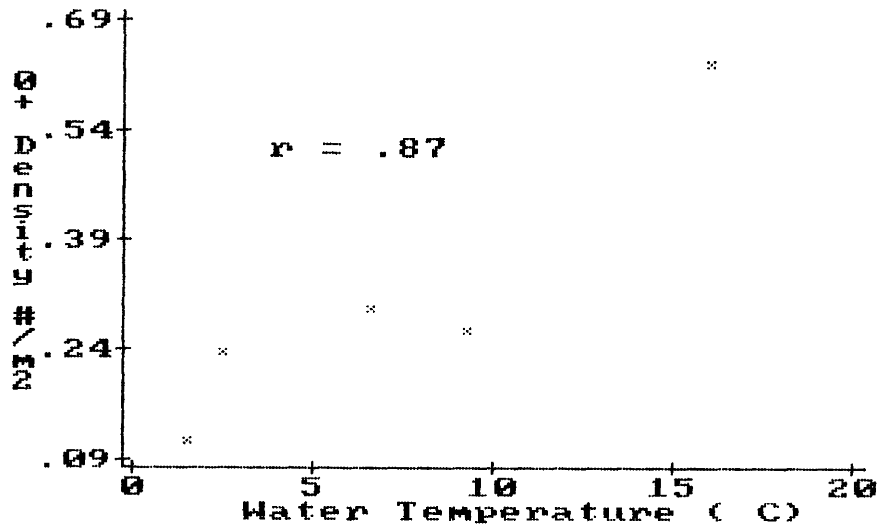


Figure 16. Relation between subyearling rainbow-steelhead trout density and average water temperature at the upper study area on Bedrock Creek from June, 1983 to January 1984.

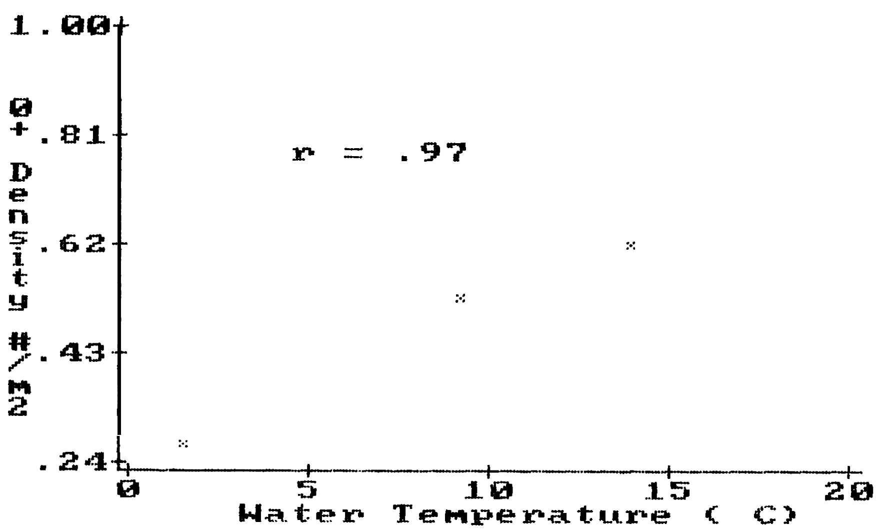


Figure 17. Relation between subyearling rainbow-steelhead trout density and average water temperature at the upper study area on Bedrock Creek from July to December, 1984.

Densities could only increase along with water temperature until lethal temperatures were approached, at which point the graph would truncate downward. Average stream temperatures reached 19.5 C in Auqust of 1983 and 18.1 C in July of 1984. Subyearling densities did not decrease in response to the elevated water temperatures. Fish density and stream discharge were negatively correlated, with the only significant association occurring in 1984 between biomass and discharge (r=-.94). This showed that reduced stream flow concentrates fish into smaller and smaller available area, but higher flows do not cause lower densities. Densities remained low as flow increased in the fall and winter. Durinq 1983 and 1984 a significant relationship existed between subyearling density and yearling density in numbers/m^2 and numbers/m^3. Subyearlinq-yearling density (No. fish/m^2) in 1983 was hiqhly correlated (r=.98) as was density expressed in number of fish per cubic meter (r=.98). Similar results in 1984 indicated that subyearling density and yearlinq density (No. fish/m^2) was again siqnificantly associated (r= 93) as was the respective densitv expressed in number of fish per cubic meter (r=.91). If intraspecific predation of the larger yearling fish on subyearlings was occurring, it is unclear from these data due to concurrent reduction in discharge and habitat. Abundance of both groups declined over time during the study period. The summer-autumn habitat utilization of subyearling steelhead in lower Clearwater River tributaries has been described by Johnson and Kucera (1985). To what degree subyearling habitat utilization overlaps with the yearling fish (if any), and the food habits of the yearling steelhead, is unknown.

Substrate samplinq during the study period indicated that there was sufficient spawning gravel present for adults. Estimated available spawning substrate in 1983 was 26.8 percent of the total stream bottom area, and in 1984 was 27.1 percent. The percent of each substrate classification present is given below with the 1983 data presented first and 1984 values in parenthesis: boulder 18.8 (29); larg cobble 37 (22); small cobble 30 (33.3); very coarse gravel 11.1 (8.4); coarse gravel 7 (2.1); medium gravel 2.5 (2.4); fine gravel 0 (.4); pea gravel 0 (.3); sand .3 (.02) and silt .5 (.3) percent. Cobble embeddedness was estimated to be 26.7 percent in 1983 and 30.5 percent in 1984.

Middle Study Area

This study area was added to gain additional information on the Bedrock Creek system and was sampled only in 1984. Rainbow-steelhead trout was the only anadromous salmonid sampled and yearling densities (Figure 18 and Table 10) ranged from .35 fish/m in May to a high of .425 fish/m^2 in July.

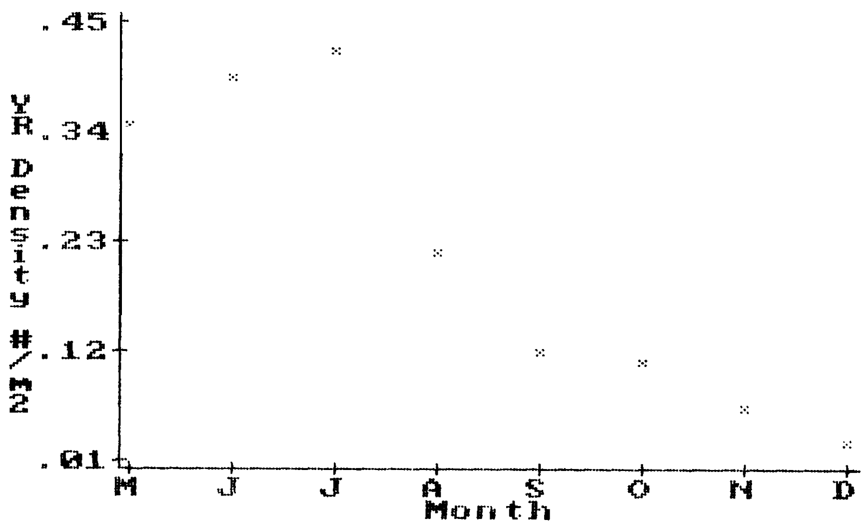


Figure 18. Yearling rainbow-steelhead trout density at the middle study area on Bedrock Creek from May to December, 1984.

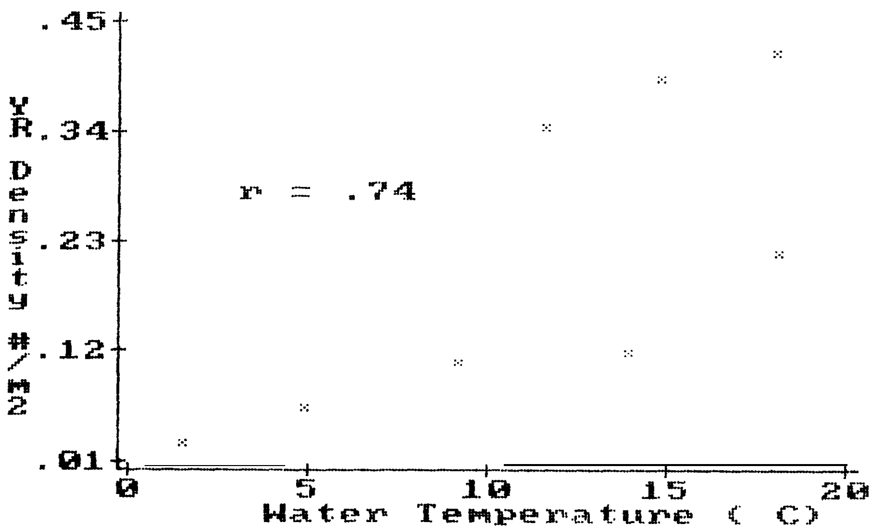


Figure 19. Relation between yearling rainbow-steelhead trout density and average water temperature at the middle study area on Bedrock Creek from May to December, 1984.

Table 10, Honthly values of stream area and stream volume sampled and average density and biomass (standard deviation in parenthesis) of yearling rainbow-steelhead trout collected in the middle study area on Bedrock Creek in 1984.

Month	Stream Area Sampled (m2)	Stream Volume Sampled (m3)	Density Number/m2	Density Number/m3	Biomass Grams/'m2	Biomass Grams/m3
1984 a						
May	665.7	97.1	0.350 (.03)	2.38 (.30)	5.06 (.88)	34.14 (4.43)
June b	336.4	28.4	0,400 (.13)	4.45 (.30)	7.70 (3.01)	85.42 (11.52)
July	398.7	30.4	0.425 (.21)	5.40 (1.83)	9.03 (6.14)	111.74 (54.90)
August	372.0	19.9	0.225 (.13)	4.15 (2.34)	4.12 (3.08)	73.39 (47.46)
September-	501.3	47.0	0.125 (.03)	1.32 (.24)	2.41 (.60)	25.54 (2.46)
October	498.9	62.0	0,115 (.01)	0.97 (.17)	2.45 (.64)	19.98 (3.48)
November	564.3	88.8	0.070 (.02)	0.44 (.18)	1.55 (.76)	9.97 (5.31)
December	580.5	105.5	0.035 (.02)	0.19 (.11)	0.69 (.43)	3.80 (2.39)

a Average of three 50 meter sample stations+
b Average of two 50 meter sample stations+

Densities dropped to .225 fish/m^2 in August and declined to .035 fish/m^2 in December, 1984. The drop in fish density from July to August occurred as stream discharge dropped from .0141 m^3/s to a summer low of .0055 m^3/s in August (Table 11). Average yearling abundance in December was .035 fish/m^2 compared to a density of .10 fish/m^2 at the upper study area in 1984. The upper study area contained several pools with undercut banks while this study area had more run/glide habitat. This may indicate that the pools provide better overwintering habitat than the run/glide habitat. Average stream depth in this section never exceeded 18.2 cm and was less than 10 cm during the summer period. Stream velocity was highest in May (24 cm/s) but was less than 12 cm/s during the low flow period. In terms of probability-of-use data presented for juvenile steelhead (Bovee 1978) these stream depths and velocities are at minimum levels. Instream cover was less than about six percent of the available stream area. Depth greater than 30 cm, overhanging vegetation and surface turbulence formed the majority of the total measured yearling habitat present. Yearling rainbow-steelhead trout comprised 13.7 to 31.2 percent of the total salmonid density present at this study area in 1984.

Yearling density and biomass was highly correlated (5=.97; p<(0.05) in this study area. Biomass varied from 5.06 g/m^2 in May peaked in July at 9.03, and decreased to .69 g/m^2 in December. A pointed decrease from 9.03 g/m^2 in July to 4312 g/m^2 in August occurred as discharge dropped from .0141 m^3/s to the summer low flow of .0055 m^3/s (Table 11). Whereas, yearling densitite made up only 13.7 to 31.2 percent of the total yearling biomass encompassed 39 to 81.4 percent of the total salmonid biomass present.

Estimated yearling steelhead production at the middle study area in 1984 was 2.21 g/m^2 (Table 6). Some production of this cohort was missed during the early spring because no sampling was conducted. Monthly production values showed that most of the accumulation of yearling fish flesh took place in May and June with negative production occurring in July. Little increase in production occurred during the fall with a decrease in fish weight, and thus production, taking place in November. The estimated production in the middle study area (2.21 g/m^2) was more similar to the upper study area value (2.4 g/m^2) than the lower study area estimate of 1.47 g/m^2.

Correlation matrices were calculated between yearling rainbow-steelhead density and biomass and all habitat variables measured. The highest correlation observed was between water temperature and yearling density (Figure 19). As discussed previously, density could only increase until the lethal maximum temperature was approached and then the relationship would truncate. Reduced stream discharge appears to affect

Table 11. Average monthly physical characteristics, standard deviation in parenthesis, of the middle study area on Bedrock Creek sampled in 1984.

Month	Stream Disch. (m3/s)	Stream Veloc. (cm/s)	Stream Width (cm)	Stream Depth (cm)	Aver. Water Temp. (C)	Depth >30cm (m2)	Undercut Bank (m2)	Overhang Vegetatn. (m2)	Surface Turb. (m2)	Subm. Rock (m2)	Total Habitat (m2)
1984 [a]											
May	0.1937	24.43	444.1	14.9	11.6	4.37	0.06	0.56	9.81	0	14.01
	(.05)	(5.43)	(116.5)	(2.0)		(3.76)	(.11)	(.81)	(6.97)		(3.45)
June	0.0422	12.0	336.5	8.5	14.8	1.08	0.16	1.22	4.88	0.23	7.58
	(.006)	(4.48)	(51.6)	(1.8)		(1.25)	(.28)	(.43)	(1.08)	(.23)	(1.85)
July	0.0141	5.70	265.7	7.5	18.0	0.26	0.13	0.60	1.43	0.12	2.56
	(.001)	(1.90)	(28.0)	(1.8)		(.46)	(.22)	(.69)	(.66)	(.15)	(.80)
August	0.0055	2.45	247.8	5.3	18.1	0.55	0.20	0.78	0.40	0	1.94
	(.0007)	(.65)	(20.8)	(1.0)		(.96)	(.34)	(.60)	(.18)		(1.50)
September	0.0315	8.10	334.2	9.4	13.9	0.54	0.13	1.08	1.34	0.04	3.15
	(.01)	(1.93)	(47.2)	(1.4)		(.79)	(.23)	(.87)	(.49)	(.07)	(2.12)
October	0.0251	6.98	332.8	12.2	9.2	0.69	0.22	0.97	1.46	0	3.35
	(.006)	(2.75)	(49.6)	(2.2)		(1.15)	(.38)	(.93)	(.70)		(2.12)
November	0.1114	16.80	376.2	15.8	4.9	1.27	0.35	1.40	1.84	0	4.87
	(.02)	(1.74)	(46.2)	(1.5)		(1.31)	(.62)	(1.39)	(.38)		(2.89)
December	0.1214	17.73	387.1	18.2	1.5	3.63	0.23	1.95	2.69	0	8.51
	(.003)	(.38)	(84.8)	(.8)		(2.77)	(.40)	(1.81)	(.68)		(3.46)

a Average of three 50 meter sample stations.

density from July to the summer low flow in August, as yearling steelhead density declined from .425 fish/m^2 to .225 fish/m^2. However, overall; fish density and stream discharge was negatively correlated (r=-.11) and not significant. The highest correlation attained between yearling density and instream habitat components was with surface turbulence (r=.44). Total yearling habitat and yearling density was not significantly correlated (r=.19) during 1984.

Density of subyearling steelhead (Figure 20 and Table 12) ranged from initial values of .88 fish/m^2 in June to 1.195 fish/m^2 in July. Densities decreased markedly in August and September and to a low of .22 fish/m^2 in December. The increase from June to July apparently was due to protracted spawning of adults and recruitment of young fish to the sampling gear. A marked decrease in density was noted from 1.195 fish/m^2 in July to .89 in August to .57 fish/m^2 in September. This corresponds with a reduction in stream discharge to a low of .0055 m^3/s in August as average water temperature reached its highest level of 18 C (maximum of 23.9 C). Subyearling density in December (.22 fish/m^2) was very comparable to the upper study area value of .24 fish/m^2 during both years of study. As expected, subyearling rainbow-steelhead comprised the majority (69-86%) of the total salmonid density present.

Subyearling biomass varied from 1.76 g/m^2 in June to a high of 3.61 in July and gradually declined to a value of 1.08 g/m^2 in December of 1984. Ranges in biomass estimates were generally similar to those observed in 1984 at the upper study area. Density and biomass was closely associated (r=.87; P<0.05) during study period. As two variables were highly correlated their individual relationships to physical habitat variables were similar. Age 0+ fish accounted for 18.6 to 61 percent of the total salmonid biomass present, with yearling fish making up the remainder.

Production of age 0+ steelhead in 1984 (Table 6) was 1.82 g/m^2. Estimated production was calculated from June to November, thus some of the cohort production was missed. Monthly production estimates indicated that subyearling fish accumulated weight during all months in the middle study area. Smaller increases in production occurred during the fall and early winter months. Production estimates of subyearling steelhead between study areas were very similiar in 1984, ranging from 1.53 to 1.82 g/m^2.

Analysis of age 0+ fish density with habitat variables again showed that density and water temperature had the highest correlation (Figure 21). Density increased as average water temperature increased up to 18.1 C in July and August, maximum daily water temperature approached 23.9 C, and then both

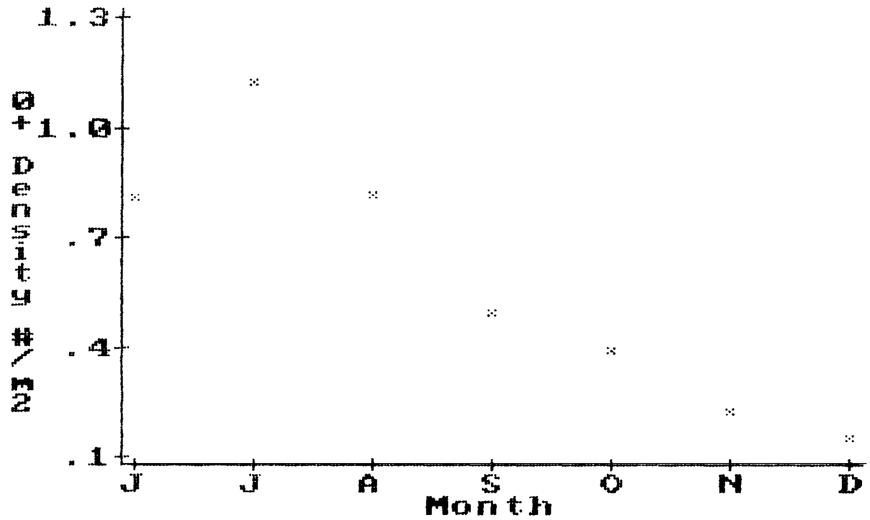


Figure 20. Subyearling rainbow-steelhead trout density at the middle study area on Bedrock Creek from June to December, 1984.

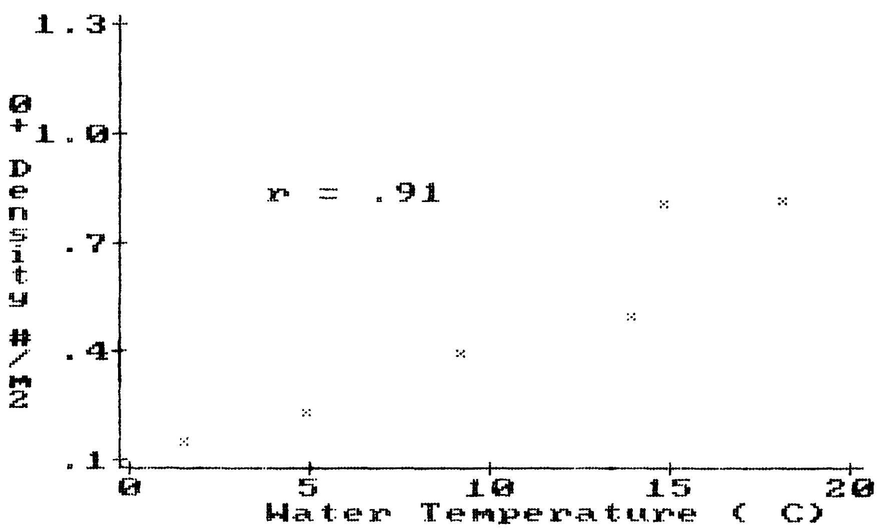


Figure 21. Relation between subyearling rainbow-steelhead trout density and average water temperature at the middle study area on Bedrock Creek from June to December, 1984.

Table 12. Monthly values of stream area and stream volume sampled and average density and biomass (standard deviation in parenthesis) of subyearling rainbow-steelhead trout collected in the middle study area on Bedrock Creek in 1984,

Month	Stream Area SampLed (m2)	Stream Vo lume Sampled (m3)	Density		Biomass	
			Number/m2	Number/m3	Grams/m2	Grams/m3
1984 a						
May	665.7	97.1	-	-	-	-
June b	336.4	28.4	0.880 (.14)	10.47 (4.35)	1.76 (.07)	20.68 (6.21)
July	398.7	30.4	1.195 (.08)	16.71 (4.85)	3.61 (.54)	50.92 (16.90)
August	372.0	19.9	0.890 (.15)	17.50 (5.51)	2.93 (.75)	57.96 (22.40)
September	501.3	47.0	0.570 (.17)	6.20 (2.05)	2.37 (.80)	25.46 (7.93)
October	498.9	62.0	0.465 (.10)	3.93 (1.23)	2.02 (.56)	17.00 (5.85)
November	564.3	88.8	0.295 (.06)	1.88 (.49)	1.33 (.24)	8.53 (2.06)
December	580.5	105.5	0.220 (.04)	1.19 (.24)	1.08 (.21)	5.91 (1.05)

a Average of three 50 meter sample stat ions*
b Average of two 50 meter sample stat ions+

variables decreased through the fall and winter months. The data did not indicate that elevated water temperatures caused a reduction in fish density, even though it exceeded the optimum range of 12 to 18 C for rainbow trout (Raleigh et al. 1984). As noted for both yearling and subyearling fish, from this study area, there is a reduction in density from July to September as stream discharge declines. Overall, there is a significant negative correlation (r=-.78) between density and stream discharge, indicating an inverse relationship. Density of subyearling and yearling fish (No. fish/m^2) was highly correlated (r=.93), as was this relationship at the upper study area. It is not clear from the data if intraspecific predation is occurring or whether abundances are decreasing over time in response to reduced habitat or some other effect. Food habit analysis would need to be examined on the yearling fish as other forage is present with abundant speckled dace, Paiute sculpin and crayfish as well as aquatic and terrestrial insects.

Substrate sampling in the middle study area indicated that spawning substrate was not limiting to steelhead production. Approximately 25.3 percent of the substrate within the sampling stations was estimated to be spawning sized material (25-76 mm)l The percent of each bottom substrate classification present in 1984 was: boulder 20; large cobble 28.4; small cobble 32.7; very coarse gravel 5.5; coarse gravel 3.5; medium gravel 5.4; fine gravel 2.1; pea gravel .6; sand 1.3 and silt 1 percent. Cobble embeddedness averaged about 27 percent in this study area.

Lower Studv Area

Rainbow-steelhead trout was the main anadromous salmonid in lower Bedrock Creek with chinook salmon being sampled occasionally during 1984. The chinook are believed to have moved into the stream from a planting of 260,000 Leavenworth fish in the North Fork Clearwater River, by Dworshak Hatchery, in March and April 1984. Kooskia Hatchery also released 170,000 chinook in March into Clear Creek. Densities of yearling steelhead in 1983 (Figure 22 and Table 13) varied from .11 fish/m^2 in May to a peak in June (.18) and declined to .02 fish/m^2 in January of 1984 (the lowest density observed on Bedrock Creek). Yearling densities in 1984 were higher from May to July ranging from .24 fish/m^2 to .17 fish/m^2. Densities declined to .05 fish/m^2 in August and leveled off to .065 fish/m^2 in December (Figure 23 and Table 13). Estimated population numbers and densities in the sample area were fairly stable from September to December (1984) after the main decrease in numbers occurred in July and August (Appendix-Table 73.2.). Population numbers were more variable in the fall of 1983 as a small increase in density from October to November appeared to be due to fish downstream emigration

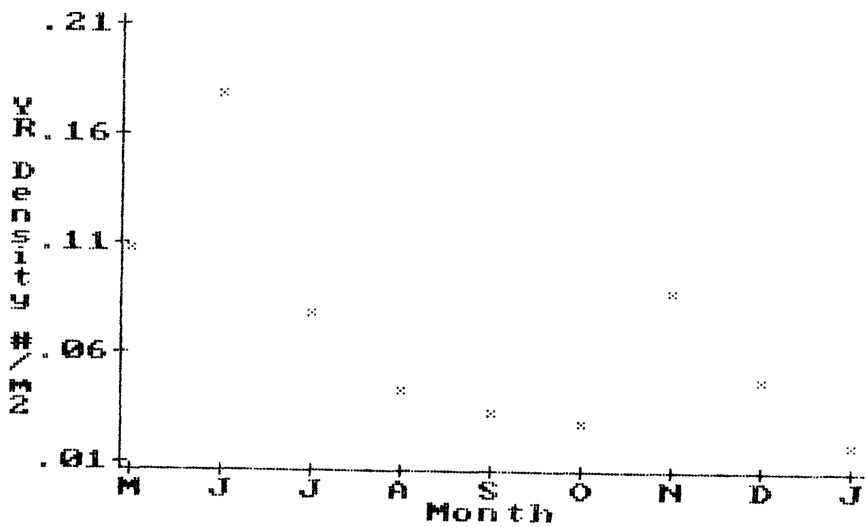


Figure 22 Yearling rainbow-steelhead trout density at the lower study area on Bedrock Creek from May, 1983 to January, 1984.

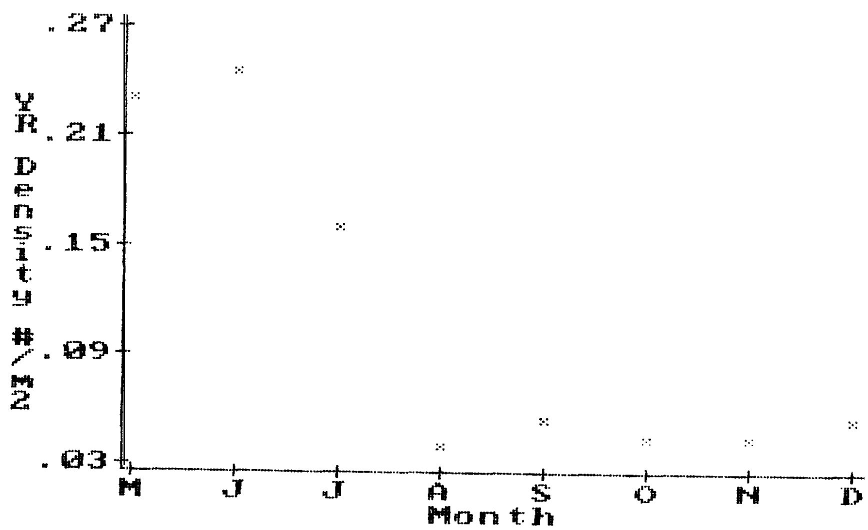


Figure 23 Yearling rainbow-steelhead trout density at the lower study area on Bedrock Creek from May to December, 1984.

Table 13. Monthly values of stream area and stream volume sampled and averaqe density and biomass (standard deviation in parenthesis! of yearling rainbow-steelhead trout measured in the lower study area on Bedrock Creek in 1983 and 1984,

Month	Stream Area Sampled (m2)	Stream Volume Sampled (m3)	Density Number/m2	Density Number/m3	Biomass Grams/m2	Biomass Grams/m3
1984 a						
May	911.4	129.8	0,240	1.71	3.78	26.77
			(.03)	(.35)	(.55)	(6.36)
June	789.3	80.8	0.255	2.53	5.94	58.28
			(.08)	(.90)	(2.50)	(26.75)
July	583.8	33.1	0.170	3.12	4.26	76.35
			(.09)	(1.82)	(1.87)	(39.66)
August	485.4	21.9	0.050	1.12	0.96	21.62
			(.05)	(1.30)	(1.05)	(25.48)
September	603.3	44.3	0.065	0.85	1.18	16.08
			(.04)	(.45)	(.59)	(8.35)
October	705.0	75.7	0.055	0.53	1.17	11.12
			(.02)	(.29)	(.56)	(6.07)
November	765.0	105.6	0,055	0.38	1.11	8.11
			(.03)	(.24)	(.68)	(5.56)
December	799.5	125.1	0.065	0.42	1.24	8.13
			(.03)	(.21)	(.75)	(5.34)
1983 b						
May	643.0	68.7	0,110	1.05	1.90	17.82
			(.01)	(.10)	(.02)	(.15)
June	552.8	31.4	0,180	3.26	3.70	66.25
			(.15)	(2.75)	(.30)	(55.57)
July	492.0	22.7	0.080	1.85	1.47	32.01
			(.007)	(.03)	(.14)	(.75)
August	456.4	22.5	0.045	0.98	0.74	15.24
			(.007)	(.25)	(.09)	(2.97)
September	434.0	21.0	0.035	0.71	0.71	14.56
			(.007)	(.09)	(.29)	(5.03)
October	474.4	26.3	0.030	0.49	0.65	11.39
			(.01)	(.08)	(.34)	(4.13)
November	598.8	58.2	0.090	0.94	2.0	20.82
			(.03)	(.36)	(1.24)	(13.39)
December	558.6	42.9	0.050	0.62	0.99	13.27
			(.01)	(.25)	(.44)	(7.01)
January	603.6	89.5	0.020	0.18	0.57	3.84
			(.007)	(0)	(.15)	(.32)

a Averaqe of three SO meter sample stat ions,
b Average of two 50 meter sample stat ions.

(Figure 24). Densities in December of both years were almost identical at .05 fish/m^2 in 1983 and .065 fish/m^2 in 1984. In 1983, the most pronounced decrease in density occurred between June (.18 fish/m^2) and July (.08 fish/m^2). The sharpest decline in density observed in 1984 was from July (.17 fish/m^2) to August (.05 fish/m^2) when the stream discharge dropped from .0161 m^3/s to the summer low flow of .0048 m^3/s (Table 14). This decline in abundance followed a pattern similar to that of the middle study area. Yearling fish comprised 6 to 20.7 percent of the total salmonid density present in 1983 and 11 to 36.4 percent of the total in 1984. Subyearling rainbow-steelhead trout made up the remaining percentage.

Biomass ranged from 1.90 g/m^2 in May of 1983 to a high of 3.7 in June and declined to .57 g/m^2 in January of 1984 (Table 13). Yearling biomass estimates from 1984 were initially higher at 3.78 g/m^2 in May and increased to 5.94 g/m^2 in June. A sharp decrease occurred from 4.26 to .96 g/m^2 from July to August, and biomass averaged 1.24 g/m^2 in December. Biomass and density of yearling steelhead was highly correlated during both years ($P<0.05$) and followed similar patterns over time. In 1983 yearling biomass accounted for 25 to 64.4 percent of the total salmonid biomass and in 1984 comprised from 40 to 91 percent of the total salmonid standing crop.

Production of yearling steelhead varied from -.04 g/m^2 (1983) to 1.47 g/m^2 in 1984 (Table 6). Some production of this cohort was missed as sampling was not conducted in the early spring. Monthly production estimates followed a pattern of initial accumulation of fish flesh in May and smaller production values during the fall. Maintenance or negative production occurred over the summer and winter months during both years. Fish emigration is a factor that can affect estimates of production. Marked yearling steelhead moved out of the sample stations and into the pool site during low flow periods. The estimate of production, however, was that which occurred within the representative sample stations. The total juvenile steelhead production for Bedrock Creek, averaged over the study areas, ranged from 3.67 g/m^2 in 1984 to 4.32 g/m^2 in 1983. The 1983 information includes subyearling production from November, 1983 to May, 1984 which the 1984 estimates lack. Both years lack estimates of yearling production from January to May so the annual production of juvenile steelhead is probably higher than the reported values. Bedrock Creek production estimates fall within a middle range of rainbow trout production, of 2.4 to 13.2 g/m^2, reported for streams within the United States (Neves et al. 1985).

As fish densities decreased over the summer period there was little instream cover available at the lower study area. Total measured yearling instream habitat never exceeded four

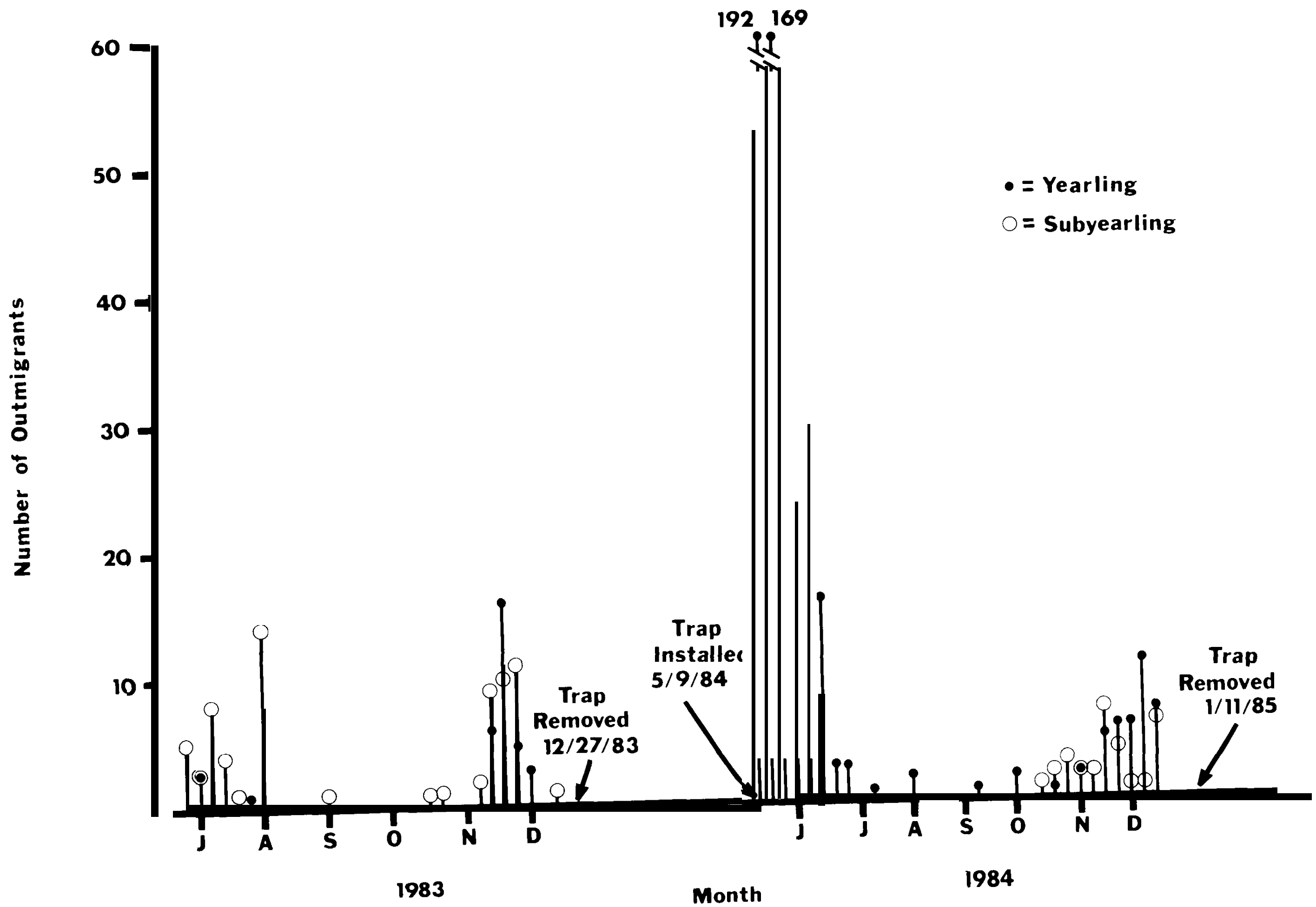


Figure 24. Number of rainbow-steelhead trout that moved past the Bedrock Creek trap site during 1983 and 1984.

Table 14, Average monthly physical characteristics, standard deviation in parenthesis, of the lower study area on Bedrock Creek sampled in 1983 and 1984,

Month	Stream Disch+ (m3/s)	Stream Veloc (cm/s)	Stream Width (cm)	Stream Depth (cm)	Aver+ Water Temo (C)	Depth >30cm (m2)	Undercut Bank (m2)	Overhang, Vegetation (m2)	Surface Turb+ (m2)	Subm Rock (m2)	Total Habitat (m2)
1984 a											
May	0.2000	21.43	607.6	14.4	11.6	2.90	0.25	2.32	7.11	0	12.59
	(.004)	(2.48)	(84.1)	(1.7)		(2.99)	(.44)	(3.20)	(1.64)		(1.75)
June	0.0905	13.16	527.4	10.3	14.8	0.78	0.49	2.60	6.72	0	10.60
	(.010)	(1.72)	(54.8)	(2.2)		(1.11)	(.57)	(4.51)	(.87)		(3.84)
July	010161	4.85	389.3	5.7	18.0	1.02	0.17	0.79	1.84	0	3.82
	(.004)	(.18)	(77.9)	(.6)		(1.76)	(.29)	(.69)	(.59)		(.89)
August	0.0048	2.62	323.8	4.6	18.1	0.44	0.11	1.08	0.25	0	1.88
	(.001)	(1.62)	(39.8)	(.6)		(.76)	(.19)	(1.22)	(.19)		(.71)
September	0.0182	5.0	402.1	7.4	13.9	0.80	0.03	0.85	1.21	0	2.90
	(.01)	(2.17)	(35.4)	(.8)		(1.39)	(.05)	(.98)	(.96)		(.01)
October	0.0343	7.30	470.2	10.7	9.2	1.05	0.14	1.33	1.58	0	4.11
	(.005)	(.49)	(49.9)	(.7)		(1.82)	(.24)	(1.88)	(.66)		(1.69)
November	0.1027	15.36	510.2	14.1	4.9	2.0	0.14	1.59	1.98	0	5.73
	(.03)	(5.22)	(117.5)	(2.2)		(3.36)	(.25)	(2.36)	(.96)		(2.17)
December	0.1251	15.40	533.1	15.7	1.5	2.95	0.13	2.59	3.16	0	8.84
	(.03)	(2.69)	(53.3)	(.9)		(3.55)	(.22)	(3.21)	(1.23)		(1.05)
b											
May	011557	21.20	643.3	10.7	13.1						
	(.020)	(7.85)	(66.6)	(.05)							
June	0.0349	9.40	557.7	5.7	16.1	1.24	0.41	7.38	0.85	0	9.89
	(.004)	(1.70)	(14.5)	(.2)		(1.75)	(.58)	(4.92)	(.19)		(2.39)
July	0.0239	6.25	491.9	4.6	17.3	1.07	0.04	4.44	0.11	0	5.67
	(.003)	(0)	(7.2)	(.3)		(1.52)	(.05)	(4.22)	(.007)		(2.65)
August	0.0281	8.07	456.6	4.9	19.5	0.68	0.40	4.67	0	0	5.75
	(.002)	(1.31)	(34.1)	(.4)		(.96)	(.57)	(4.51)			(2.97)
September	0.0190	4.76	434.0	4.8	13.3	0.81	0.18	3.96	0.08	0	5.03
	(.003)	(.71)	(43.7)	(3.3)		(1.14)	(.25)	(3.76)	(.03)		(2.33)
October	0.0234	5.19	474.6	(1.15	9.3	0.87	0.27	3.31	0.21	0	4.67
	(.004)	(.27)	(18.7)			(1.24)	(.38)	(2.92)	(.05)		(1.36)
November	0.1131	15.97	598.8	9.7	6.6	2.11	0.39	4.76	0.42	0	7.63
	(.004)	(.39)	(20.1)	(.3)		(2.98)	(.55)	(5.05)	(.35)		(1.79)
December	0.0707	11.77	558.7	7.7	2.5	1.14	0.28	3.72	0.40	0	5.54
	(.0002)	(.17)	(4.9)	(.8)		(1.62)	(.39)	(3.84)	(.08)		(1.91)
January	0.1991	22.30	603.5	14.8	1.5					0	
	(.020)	(.99)	(.07)	(2.7)							

a Average of three 50 meter sample stations+
b Average of two 50 meter sample stations,

percent of the total available stream area. Instream habitat averaged about two percent of the total available habitat during summer months. Stream depth averaged less than 10 cm from June to October (Table 14) and was usually less than 15 cm during the other months. Stream velocity averaged less than 13 cm/s during the same period. The stream depths and velocities in lower Bedrock Creek are at the minimum level in terms of probability-of-use for juvenile steelhead (Bovee 1978). Everest and Chapman (1972) also found a higher density of age I+ steelhead, in Crooked Fork Creek, Idaho, in depths greater than 15 cm. Yearling densities from one pool/run area sampled in 1983 (Figure 25) ranged from .58 fish/m^2 in August declining to .25 in September and down to .16 fish/m^2 in December (Table 15). Abundance of fish in the pool/run area was three to ten times the density observed at the sampling stations. Density in 1984, in the pool/run, was .21 fish/m^2 in June increasing to .91 fish/m^2 in July. A major drop occurred from .79 fish/m^2 in August to .24 fish/m^2 in September, leveling off at .25 fish/m^2 in November (Figure 26 and Table 15). The sharp decrease in yearling density from August to September occurs during both years as water temperature concurrently drops 4-5 degrees Centigrade. Fish, during this time, apparently redistribute to other habitats or undergo mortality. No pulse in downstream movement was noted at the fish weir during this time (Figure 24). Since pool habitat is scarce in this stream section, the redistribution of relatively few fish would not appreciably increase yearling density at the sample stations and is not reflected in increased densities. Yearling steelhead densities at the pool/run site were five times the densities at the sampling stations during the summer months (Figures 27 and 28). This points out the critical late summer habitat that pools or runs provide in the lower stream section. Winter densities at the pool site are three to four times that of the sampling stations which also indicates they provide important winter habitat. Stream depth in the pool/run averaged approximately 20 cm during summer low flow (Table 16) compared to depths of about 5 cm at the sample stations (Table 14). Yearling rainbow trout (Wesche 1980) and steelhead trout (Everest and Chapman 1972) are reported to utilize depths more often as depth exceeds 15 centimeters. Depths greater than 15 cm are more available at the pool site than at the sampling stations. Winter density of fish at the pool/run site was very comparable between years at .23 fish/m^2 in November, 1983 and .25 fish/m^2 in November of 1984. Yearling density at the pool site in the upper study area, in November was twice the estimated yearling density at the pool/run site in the lower study area during both years (Tables 7 and 15). The upper pool site- apparently provided better overwintering habitat. The pool at the upper study area, beside having an undercut bank, contained water depth greater than 35 cm and was shaded. The pool/run (lower study area) lacked an undercut bank, had a stream depth of about 20 centimeters and was not shaded.

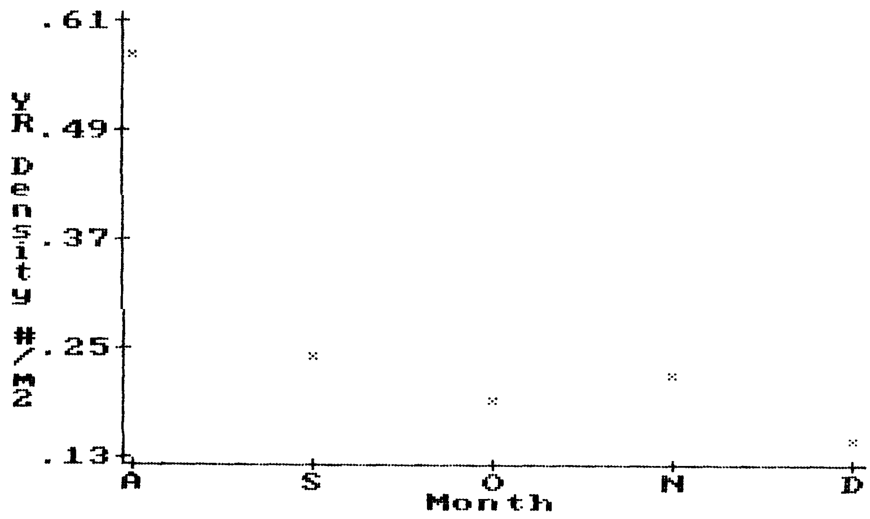


Figure 25. Yearling rainbow-steelhead trout density at the pool/run site at the lower study area on Bedrock Creek from August to December, 1983.

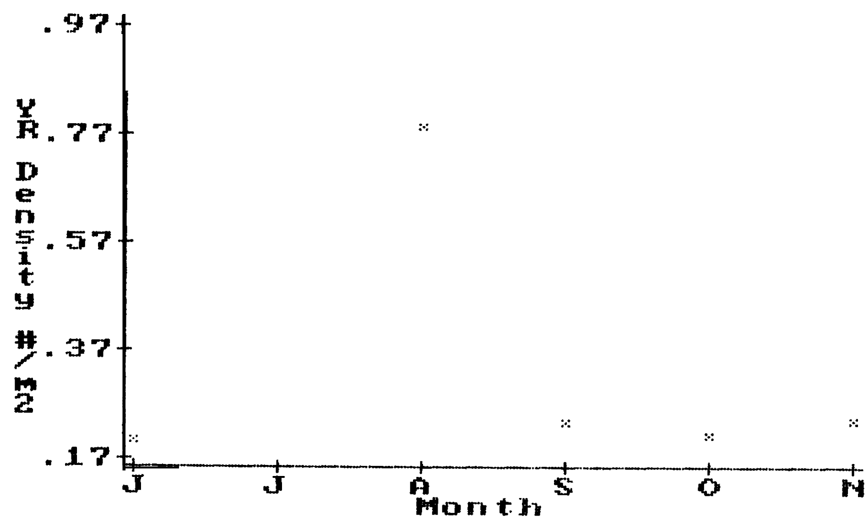


Figure 26. Yearling rainbow-steelhead trout density at the pool/run site at the lower study area on Bedrock Creek from June to November, 1984.

Table 15. Monthly values of stream area sampled, stream volume sampled, density and biomass of yearling rainbow-steelhead trout collected at the pool/run site in the lower study area on Bedrock Creek in 1983 and 1984.

Month	Stream Area Sampled (m2)	Stream Volume Sampled (m3)	Density Number/m2	Density Number/m3	Biomass Grams/m2	Biomass Grams/m3
1984						
May	-	-	-	-	-	-
June	80.6	18.86	0.210	0.90	4.07	17.40
July	65.8	12.04	0.910	4.98	30.50	166.69
August	62.1	13.53	0.790	3.62	21.50	98.69
September	65.7	14.32	0.245	1.12	5.71	26.20
October	67.6	15.34	0.220	0.98	5.37	23.66
November	72.2	16.69	0.250	1.08	5.41	23.40
December	-	-	-	-	-	-
1983						
May	-	-	-	-	-	-
June	-	-	-	-	-	-
July	-	-	-	-	-	-
August	51.9	10.85	0.580	2.76	13.55	64.84
September	60.9	11.69	0.250	1.28	5.25	27.33
October	64.8	13.74	0.200	0.95	3.89	18.35
November	77.0	19.02	0.230	0.95	4.80	19.45
December	86.8	22.75	0.160	0.61	4.03	15.38
January	-	-	-	-	-	-

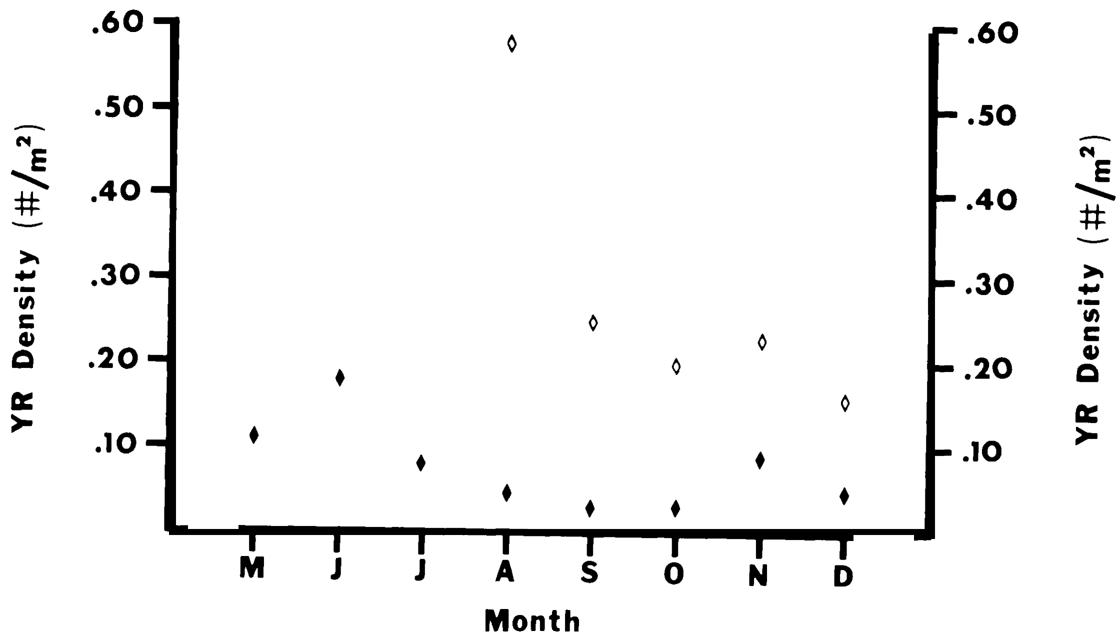


Figure 27. Yearling rainbow-steelhead trout density at the sampling stations (solid diamond) versus the pool/run site (open diamond) at the lower study area on Bedrock Creek in 1983.

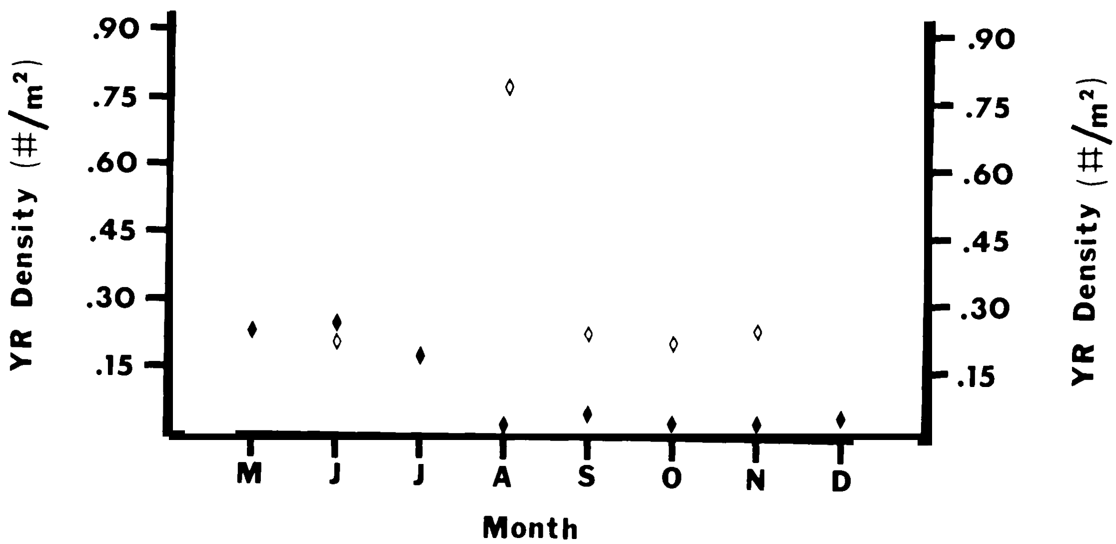


Figure 28. Yearling rainbow-steelhead trout density at the sampling stations (solid diamond) versus the pool/run site (open diamond) at the lower study area on Bedrock Creek in 1984.

Table 16. Monthly physical characteristics, standard deviation in parenthesis, at the pool/run site of the lower study area on Bedrock Creek sampled in 1983 and 1984,

Month	Stream Discharge (m3/s)	Stream Velocity (cm/s)	Stream Width <cm)	Stream Depth (cm)	Aver Water Temp. (C)
1984					
May	-	-	-	-	
June	0.0989	13.65 (10.08)	403.0 (67.9)	23.4 (17.1)	14.8
July	0.0167	5.0 (5.28)	329.0 (41.9)	18.3 (16.0)	18.0
August	0.0031	0.78 (1.0)	310.4 (37.3)	21.8 (17.2)	18.1
September	0.0113	3.60 (3.20)	328.4 (42.8)	21.8 (16.6)	13.9
October	0.0398	7.10 (5.35)	338.0 (39.2)	22.7 (16.4)	9.2
November	0.0772	11.70 (9.84)	361.2 (35.7)	23.1 (16.3)	4.9
December		-			-
1983					
May	-	-	--	-	-
June	-	-	-		-
July			-	-	-
August	0.0267	7.15 (5.45)	331.0 (76.0)	20.9 (16.1)	19.5
September	0.0211	5.26 (4.18)	348.0 (31.2)	19.2 (16.3)	13.3
October	0.0262	5.38 (3.27)	370.4 (40.9)	21.2 (18.8)	9.3
November	0.1163	16.25 (8.76)	440.0 (102.2)	24.7 (21.1)	6.6
December	0.0705	11.90 (6.30)	496.2 (111.1)	26.2 (20.5)	2.5
January					-

Estimated yearling biomass in the pool/run in 1983 was 13.55 g/m² in August dropping to 5.25 in September and 4.03 g/m² in December (Table 15). Biomass values in 1984 ranged from 4.07 g/m² in June to 30.5 g/m² in July. A marked decrease occurred from 21.5 g/m² in August to 5.71 g/m" in September, decreasing to 5.41 g/m² in November. Sharp decreases in biomass from August to September during both years paralleled the decrease in fish densitv, as water temperature dropped 4-5 C, and fish either redistributed to other habitat or underwent mortality.

Correlation matrices between yearling steelhead density and habitat variables indicated that significant relationships existed between density and instream cover. Yearling steelhead density and surface turbulence had a significant relationship during both years of study (Figures 29 and 30). During 1983, when two 50 m stations were sampled, fish density and surface turbulence had a correlation of .85 even though the range within each variable was limited. In 1984, three sample stations were studied and the correlation remained about the same (r=.87). However, in 1984 measurement of surface turbulence was emphasized in areas where instream cover was limited. In the lower study area there were few pools, runs or undercut banks providing yearling fish habitat. Overhanging vegetation and fish density had a significant correlation in 1983 (r=.95; P<0.05) but did not in 1984 (r=.47). In 1983 only one of the two sample stations contained much overhanging vegetation, and most of the yearling fish were collected under the vegetation. Total habitat, a summation of the instream cover variables, was significantly associated (r=.96) with yearling density in 1983 (Figure 31) and in 1984 (r=.72) (Figure 32). This study area was the only one on Bedrock Creek where a significant (P<0.05) relationship between yearling steelhead density and instream cover was demonstrated. Lack of consistent relationships between yearling density and instream cover (total habitat) for the other study areas suggests that other factor(s) other than space alone operate to control fish density in the Bedrock Creek system.

Densities of subyearling steelhead in 1983 decreased from a high of 1.32 fish/m² in June down to .73 fish m/² (August) and to .105 fish/m² in January of 1984 (Figure 33 and Table 17). Subyearling abundances (Table 17) decreased more sharply from high initial values in June to October. Age 0+ density declined less sharply from October to January. Densities in 1984 varied from .445 fish/m² in June to .625 fish in Julv and then to .15 fish/m² in December (Figure 34 and Table 17). Marked decreases in age 0+ abundance occurred from July to September, when stream discharge was at its lowest, and then decreased slowly into the winter period. Density of subyearling fish supported in this lower study area in December of 1983 (.225 fish/m²) was similar to December,

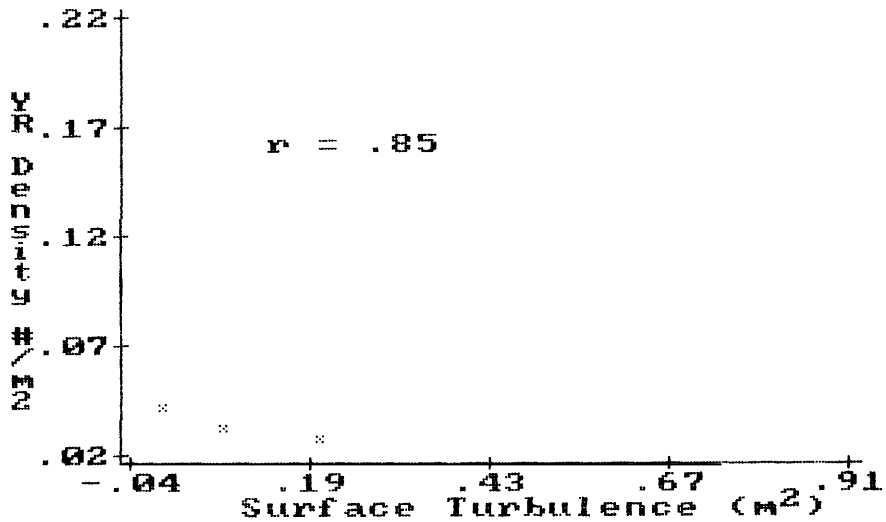


Figure 29. Relation between yearling rainbow-steelhead trout density and surface turbulence at the lower study area on Bedrock Creek from May, 1983 to January, 1984.

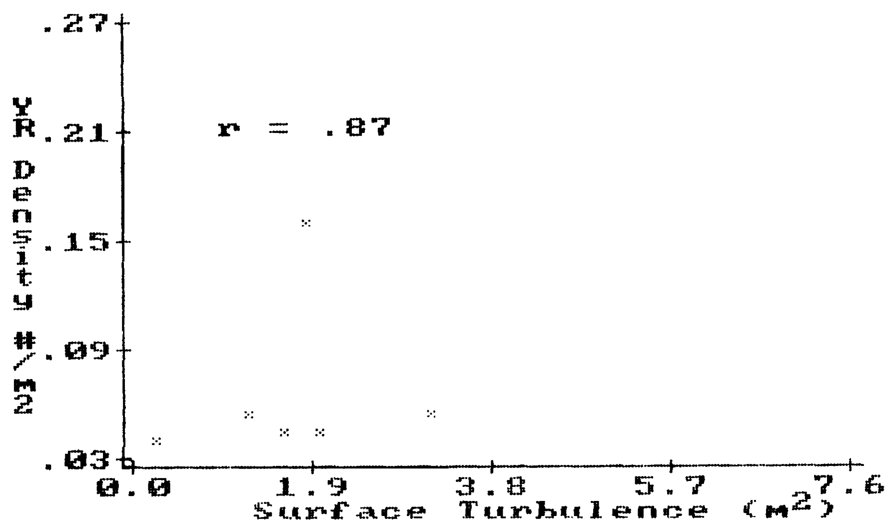


Figure 30. Relation between yearling rainbow-steelhead trout density and surface turbulence at the lower study area on Bedrock Creek from May to December, 1984.

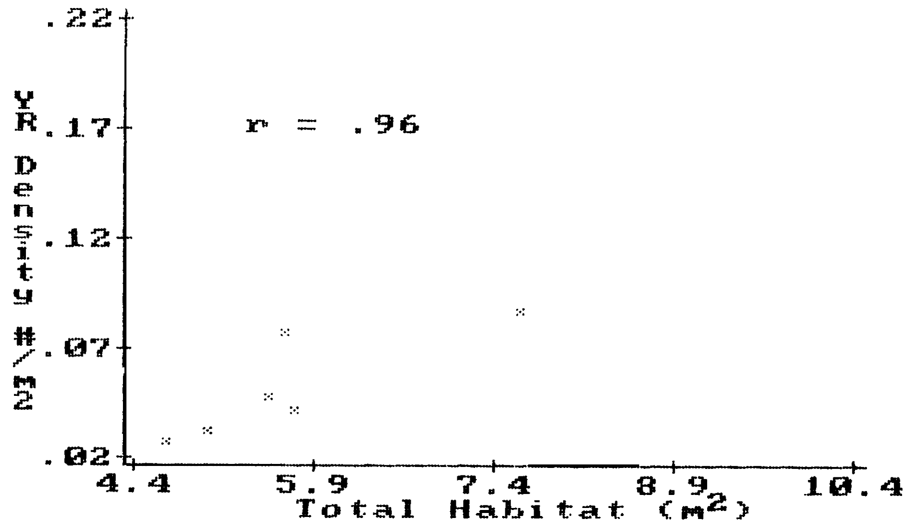


Figure 31. Relation between yearling rainbow-steelhead trout density and total habitat at the lower study area on Bedrock Creek from May, 1983 to January, 1984.

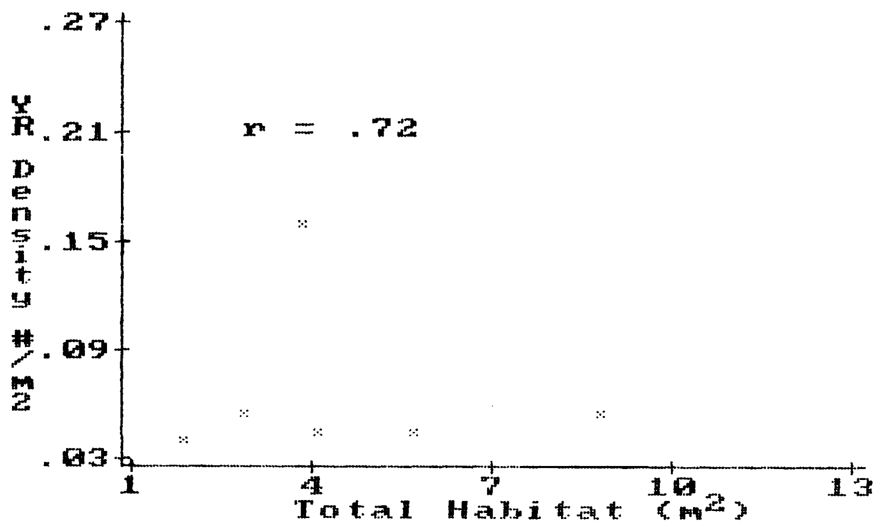


Figure 32. Relation between yearling rainbow-steelhead trout density and total habitat at the lower study area on Bedrock Creek from May to December, 1984.

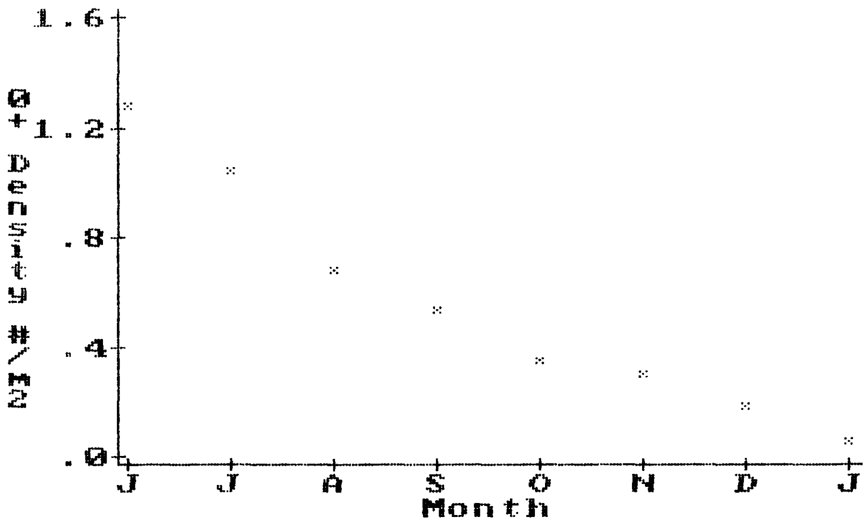


Figure 33. Subyearling rainbow-steelhead trout density at the lower study area on Bedrock Creek from June, 1983 to January, 1984.

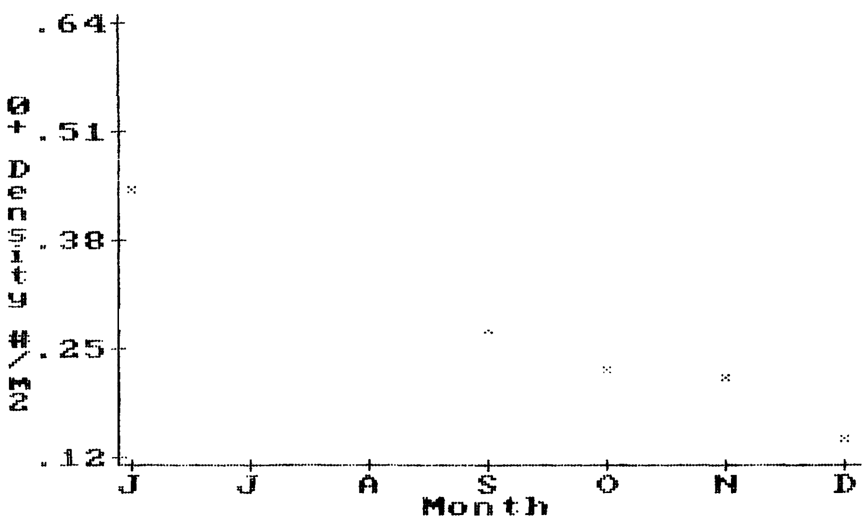


Figure 34. Subyearling rainbow-steelhead trout density at the lower study area on Bedrock Creek from June to December, 1984.

Table 17. Monthly va lues of stream area and stream volume sampled and average density and biomass (standard deviation in parenthesis) of subyearLing rainbow-steethead trout collected in the lower study area on Bedrock Creek in 1983 and 1984.

Month	Stream Area Sampted (m2)	Stream Vo l ume Sampled (m3)	Dens i ty Number/m2	Dens i ty Number/m3	Biomass Grams/m2	Biomass Grams/m3
1984 a						
May	911.4	129.8				
June	789.3	80.8	0.445 (.14)	4.27 (.81)	0.60 (.17)	5.75 (.99)
July	583.8	33.1	0,625 (.22)	10.91 (3.34)	1.99 (.66)	34.82 (11.04)
August	485.4	21.9	0,410 (.22)	9.22 (5.23)	1.45 (.76)	31.78 (17.48)
Sep t ember	603.3	44.3	0,280 (.11)	3.78 (1.50)	1.14 (.47)	15.50 (6.30)
October	705.0	75.7	0,230 (.07)	2.21 (.84)	1.26 (.47)	12.01 (5.18)
November	765.0	105.6	0,220 (.09)	1.52 (.62)	1.17 (.51)	8.25 (3.48)
December	799.5	125.1	0.150 (.04)	0.97 (.32)	0.84 (.29)	5.44 (2.08)
1983 b						
May	643.0	68.7				
June	552.8	31.4	1 ,320 (.94)	22.91 (15.65)	2.04 (1.46)	2.04 (1.46)
July	492.0	22.7	1,090 (.24)	23.90 (7.0)	2.50 (.03)	54.43 (4.62)
August	45614	22.5	0.730 (.25)	15.05 (6.23)	1.86 (.83)	38.52 (19.84)
September	434.0	21.0	0,585 (.15)	12.09 (3.82)	2.14 (.37)	44.45 (10.39)
October	474.4	26.3	0,400 (.10)	7.51 (3.26)	1.87 (.48)	35.20 (15.50)
November	598.8	58.2	0.345 (.007)	3.52 (.17)	2.39 (.17)	24.69 (2.66)
December	558.6	42.9	0.225 (.02)	2.96 (.59)	1.64 (.22)	21.61 (5.07)
January	603.6	89.5	0.105 (.007)	0.70 (.09)	0.81 (.02)	5.59 (1.19)

a Aveage of three 50 meter sample stat i ons,
b Average of two 50 meter sample stat ions,

1984 estimates (.15 fish/m^2), suggesting a December carrying capacity of this magnitude. Subyearlinq fish accounted for 79.3 to 94.4 percent of the total salmoid density present in 1983 and 63.6 to 89 percent of the total in 1984.

Subyearling biomass estimates in 1983 ranged from 2.04 g/m^2 in June (Table 17) to a peak of 2.5 in July, fluctuated up and down from Auqust to November, and declined to .81 g/m^2 in January of 1984. No distinguishable trends in biomass were evident in 1983. Biomass values in 1984 ranged from a low of 60 m/^{2} in June to a maximum of 1.99 in July and generally declined in the fall to 84 g/m^2 in December. Subyearling biomass and density, unlike the middle and upper study areas, was not significantly associated during either year. Biomass of age 0+ rainbow-steelhead trout in 1983 contributed 35.6 to 75 percent of the total.

Production of subyearling steelhead (Table 6) at the lower study area ranged from 1.57 g/m^2 (1984) to 5.33 g/m^2 in 1983. Annual production of age 0+ fish was estimated in 1983. In 1984, data from November to May was not available and thus some of the cohort production was missed. Monthly production estimates indicated that accumulation of fish flesh was positive during most months except in November of 1983 and Julv of 1984 (Table 6). Estimated production was highest in June of both years with a decreasing production from Auqust to October of 1984. Higher levels of weight qain were observed durinq August to October of 1983. Difference in subyearling production between the study areas was small, in 1984, varying from 1.53 to 1.82 g/m^2. Accumulation s-f age 0+ biomass in 1983 was more variable ranging from 3.2 s/m' at the upper study area to 5.33 q/m^2 at the lower area.

Correlation matrices between subyearling steelhead density and biomass and habitat variables indicated a significant relation existed between density and average water temperature during both years (Figures 35 and 36). Abundance of age 0+ fish would only increase up to a point where lethal temperatures were approached, at which point the graph would truncate. Summer average water temperatures reached 19.5 C in 1983 and 18 C during 1984 which is at the upper range of optimum water temperature of 12 to 18 C for rainbow trout (Raleigh et al. 1984). Subyearling production was positive through the summer months except for July of 1983 (Table 6). The largest decline in subyearling density occurs from July to August, during both years, durinq the period of low flows and high water temperature. Subyearlinq biomass and stream discharge was significantly neqatively correlated in 1983 (r=-.69), but not in 1984 (r=-. 69) indicating an inverse relationship. Density of subyearling versus yearling fish was not significantly correlated in either 1983 (r=.71) or 1984 (r=.66). This differed from the other two study areas where a

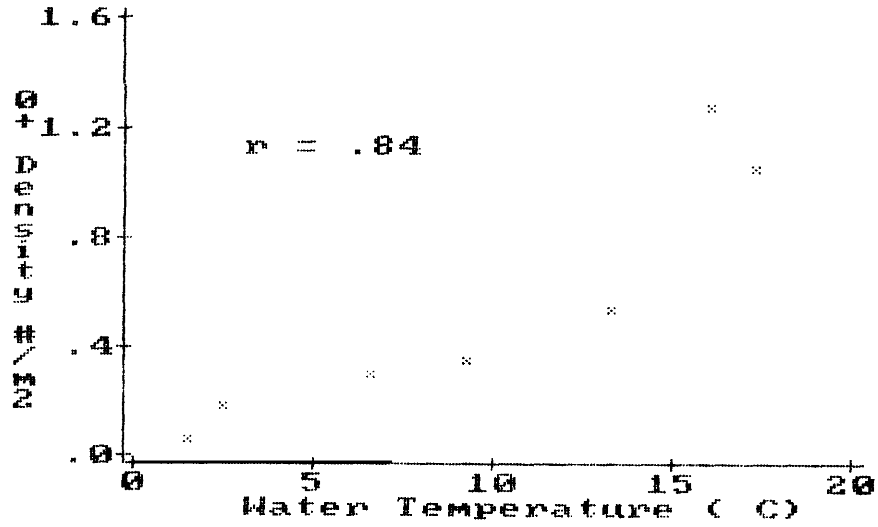


Figure 35. Relation between subyearling rainbow-steelhead trout density and average water temperature at the lower study area on Bedrock Creek from June, 1983 to January, 1984.

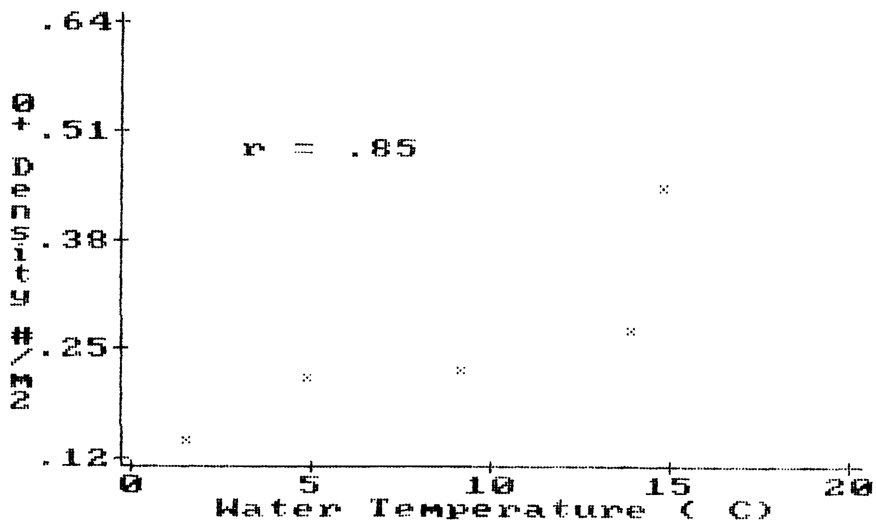


Figure 36. Relation between subyearling rainbow-steelhead trout density and average water temperature at the lower study area on Bedrock Creek from June to December, 1984.

significant relationship existed and generally higher densities of yearling fish. When a significant relationship exists between density of yearling and subyearling fish, it is difficult to explain the association as being intraspecific predation. Further research into the interspecific competition, food habits and feeding ecology of the rhinichthys-Cottus-Salmo species complex is needed.

Substrate sampling showed that adequate spawning gravels existed for adult steelhead. Estimated available spawning substrate in 1983 was 28.3 percent of the total stream bottom area and in 1984 was 27.6 percent. Spawning substrate was present in patches or pocket areas as opposed to large continuous expanses of gravels. The percentage of each substrate classification present is given below with 1983 information presented first and the 1984 data in parenthesis: boulder 18 (23); large cobble 34.1 (24.7); small cobble 29.2 (36); very coarse gravel 13.7 (7.45); coarse gravel 0 (2.2): medium gravel 3.7 (3.7); fine gravel 0 (.8); pea gravel 0 (.4); sand .6 (.2) and silt .3 (.8) percent. Cobble embeddedness was estimated to have been 38.2 percent in 1983 and 26.6 percent in 1984.

Juvenile Steelhead Outmigration

Juvenile rainbow-steelhead trout outmigration was monitored during the study period while density and biomass estimates were made. Generally, small pulses in downstream movement were seen (Figure 24). The only exception was the tail-end of the spring 1984 smolt outmigration that was sampled, and smolt movement ceased by mid June of 1984. No small pre-smolt (age I+) fish were captured during this latter portion of the smolt outmigration which is similar to the movement patterns in Cottonwood Creek. Smaller pulses in movement were evident in the fall of 1983 and 1984 but the numbers of fish sampled were low. Very little movement was evidenced during summer low flow stream conditions. Stream flow goes sub-surface at the stream mouth during the summer and early fall period thus precluding fish movement into the Clearwater River. The number of smolts migrating out of the Bedrock Creek system, based on December population estimates, were projected to be 5,290 fish in 1984 and 4,339 fish in 1985. This estimate assumed that no mortality took place after December of each year. Smolt estimates calculated using population estimates obtained during base flows (August), were twice the above estimates and were misleading.

Juvenile Steelhead Age and Growth

A total of 255 juvenile steelhead were aged via the scale method to separate age groups for density, biomass and production estimates. For this report two groups of fish were recognized: yearlings (age I+, age II+

and older) and subyearlings (age 0+). During the study period yearling rainbow-steelhead ranged in size from 74 to 304 mm in total length and 4 to 221 g in weight. The largest fish sampled (304mm-221g) was the only age II+ individual collected in Bedrock Creek. Over 90 percent of the yearling rainbow-steelhead trout examined were age I+ fish. These fish varied in size from 74 to 190 mm in length and 4 to 67 g in weight. Subyearling fish ranged up to 127 mm in lenqth and 13 Q in weight during their first growing season. Annulus formation was completed by March at which time fish were assigned to the next older age group.

The average length of yearling rainbow-steelhead (Tables 18 to 20) was very similar between the same month, study area and year (generally + 10 mm). Average length and weight of yearling steelhead in May of 1984 ranged from 108 to 119 mm and 11.6 to 15.3 g; for all three study areas. Fish size fluctuated up and down over the summer and fall and varied from 129 to 142 mm in lenqth and 16.5 to 20 g in weight during the overwintering period (Tables 18 to 20). The largest increase in weight observed in 1984, occurred from May to June with a small increase from June to July. During summer low flow conditions (.0096 m^3/s in August), average weight decreased but then increased slightly in October. Average fish condition factors during 1984 did not bottom out during the summer low flow period but during the winter at a value of between .74 to .77; condition factors ranged from .89 to .74. Yearling fish in 1983 ranged from about 120 mm in length and 16.7 to 18.6 g in weight in May and fluctuated up and down during the summer and fall. Fish varied in length from 137 to 141 mm and in weiqht from 19.3 to 21.1 g in January, 1984. Average yearling weight attained vascillated more in 1983 at the lower study area (Table 20) than the upper area (Table 18). Condition factors in 1983, unlike the 1984 data, reached a low point during late summer (.57 to .62) and then increased slightly in the winter and ranged from .71 to .75. Net growth occurs during May and June with some growth occurring durinq the fall. Small increments in growth that are realized in late spring and in the fall are partially vegated by weight loss durinq summer low flow conditions and in the winter period. The growth that occurred in early spring was missed because no sampling was conducted due to water turbidity and higher stream flows.

Progression in the average length and weight of subyearling rainbow-steelhead was similar between study areas in 1984 (Tables 18 to 20). Subyearling fish increased in size during the year and attained a lenqth and weight of about 83 mm and 5 g in December. Average condition

Table 18. Average total length, weight and condition factor (standard deviation in parenthesis) of yearling and subyearling rainbow-steelhead trout sampled from the upper study area on Bedrock Creek in 1983 and 1984.

Month	Yearling Total Length (mm)	Yearling Weight (g)	Yearling Condition Factor	Subyearling Total Length (mm)	Subyearling Weight (g)	Subyearling Condition Factor
1984						
May	107.7	11.60	0.86	-		
	(17.0)	(6.15)	(.09)			
June	125.2	19.30	0.89	48.2	0.70	0.57
	(21.2)	(15.74)	(.07)	(4.6)	(.39)	(.23)
July	131.2	21.55	0.85	65.8	2.75	0.93
	(23.0)	(17.14)	(.09)	(6.3)	(.86)	(.12)
August	130.3	20.10	0.81	70.5	3.15	0.87
	(21.5)	(14.90)	(.07)	(5.7)	(.87)	(.12)
September	127.6	18.65	0.83	74.3	4.05	0.97
	(16.9)	(9.36)	(.09)	(6.3)	(1.02)	(.09)
October	135.8	23.95	0.89	80.0	5.15	0.97
	(18.0)	(12.15)	(.15)	(8.0)	(1.50)	(.11)
November	137.7	23.20	0.80	81.0	4.70	0.85
	(22.2)	(15.38)	(.07)	(8.4)	(1.38)	(.10)
December	141.7	20.0	0.77	83.0	5.0	0.84
	(29.8)	(23.80)	(.07)	(8.9)	(1.50)	(.10)
1983						
May	120.1	18.60	0.91	-		
	(27.4)	(19.23)	(.14)			
June	128.5	18.65	0.71	53.6	1.35	0.90
	(29.0)	(25.60)	(.10)	(4.5)	(.24)	(.28)
July	131.0	19.30	0.76	65.3	2.20	0.79
	(24.1)	(14.97)	(.12)	(5.2)	(.63)	(.25)
August	131.8	16.55	0.64	70.6	2.10	0.58
	(22.9)	(13.97)	(.12)	(7.2)	(.63)	(.17)
September	134.3	16.65	0.57	74.5	3.65	0.85
	(25.6)	(16.65)	(.12)	(6.6)	(1.11)	(.10)
October	138.3	21125	0.68	84.3	4.55	0.77
	(25.6)	(18.12)	(.14)	(8.5)	(1.21)	(.24)
November	137.1	20.20	0.74	84.6	5.35	0.85
	(15.8)	(8.26)	(.09)	(9.9)	(1.91)	(.12)
December	138.3	20.10	0.71	87.4	5.70	0.89
	(16.7)	(9.17)	(.10)	(11.2)	(1.45)	(.30)
January	137.4	19.30	0.71	91.0	5.70	0.79
	(12.9)	(7.64)	(.12)	(9.9)	(.93)	(.27)

Table 19. Averge total lengh weitht and condition factor (standard deviation in parenthiseis) of yearling and subyearling rainbow-steelhead trout sampled from the middle study area on Bedrock Creek in 1984,

Month	Yearling Total Length (mm)	Yearling Weight (g)	Yearling Condition Factor	Subyearling Total Length (mm)	Subyearling Weight (g)	Subyearling Condition Factor
1984						
May	111.6	12.95	0.87	..		
	(16.1)	(6.04)	(.10)			
June	126.9	19.30	0.88	63.0	2.30	0.88
	(19.1)	(10.40)	(.08)	(5.9)	(.75)	(.15)
July	131.2	20.95	0.85	68.0	3.0	0.93
	(21.8)	(14.36)	(.11)	(5.7)	(.81)	(.12)
August	127.0	18.20	0.81	71.7	3.25	0.85
	(19.6)	(10.87)	(.06)	(6.1)	(.96)	(.12)
September	132.3	20.65	0.82	75.8	4.10	0.92
	(20.2)	(12.14)	(.07)	(6.9)	(1.18)	(.10)
October	135.2	21.10	0.80	77.8	4.30	0.88
	(20.2)	(10.58)	(,073	(8.1)	(1.33)	(.09)
November	138.4	21.70	0.75	79.7	4.50	0.86
	(20.0)	(11.62)	(.07)	(8.4)	(1.43)	(.08)
December	128.7	16.50	0.74	81.0	4.95	0.90
	(15.3)	(5.50)	(.05)	(9.1)	(1.55)	(.09)

Table 20. Average total length, weight and condition factor (standard deviation in parenthesis) of yearling and subyearling rainbow-steelhead trout sampled from the lower study area on Bedrock Creek in 1983 and 1984.

	Yearling			Subyearling		
Month	Total Length (mm)	Weight (g)	Condition Factor	Total Length (mm)	Weight (g)	Condition Factor
1984						
May	118.7	15.35	0.84	..		
	(21.5)	(9.28)	(.10)			
June	132.6	22.30	0.88	55.8	1.35	0.75
	(19.7)	(12.29)	(.07)	(5.0)	(.42)	(.17)
July	137.6	23.65	0.83	68.6	3.20	0.96
	(21.6)	(15.50)	(.11)	(5.9)	(.91)	(.14)
August	127.6	18.0	0.83	72.7	3.50	0.88
	(12.1)	(5.07)	(.07)	(6.2)	(.94)	(.12)
September	130.1	19.15	0.82	78.0	4.10	0.82
	(17.4)	(8.11)	(.12)	(7.9)	(1.38)	(.12)
October	135.1	21.60	0.82	81.8	5.40	0.96
	(17.8)	(8.93)	(.05)	(8.6)	(1.63)	(.10)
November	131.8	19.25	0.79	84.5	5.40	0.87
	(19.3)	(8.24)	(.06)	(9.5)	(1.62)	(.10)
December	130.8	18.80	0.77	82.9	5.25	0.88
	(21.3)	(10.23)	(.06)	(9.7)	(1.75)	(.09)
1983						
May	121.5	16.75	0.88	-		
	(18.1)	(8.29)	(.12)			
June	134.4	20.30	0.76	54.2	1.55	1.02
	(19.9)	(13.13)	(.14)	(7.3)	(.42)	(.39)
July	127.1	15.90	0.75	68.1	2.50	0.81
	(12.3)	(5.54)	(.14)	(7.2)	(.64)	(.24)
August	126.5	12.95	0.62	71.0	2.40	0.67
	(10.7)	(4.99)	(.12)	(6.6)	(.74)	(.18)
September	133.4	18.10 a	0.76	76.0	3.90	0.86
	(14.3)			(7.7)	(1.17)	(.13)
October	140.5	20.90 a	0.75	86.2	4.70	0.75
	(19.3)			(8.1)	(.94)	(.22)
November	139.9	22.0	0.72	94.8	7.10	0.81
	(23.9)	(14.36)	(.08)	(10.4)	(2.0)	(.13)
December	139.3	20.45	0.72	96.3	7.25	0.83
	(16.9)	(7.85)	(.10)	(11.4)	(1.70)	(.26)
January	141.1	21.15 a	0.75	100.4	7.90	0.80
	(9.9)			(11.4)	(1.92)	(.23)

a Weight derived from the log length-log weight regrssion equation.

factors during the sampling period generally ranged between .84 and .97 and were .84 to .90 in December during the overwintering period. Age 0+ steelhead, in 1983, followed a similar pattern of growth but fish were larger going into the winter period. Larger size has been shown to be important in the overwintering survival of wild subyearling brook trout (Salvelinus' fontinalis) by Hunt (1969). Subyearling fish in December varied from 87 to 96 mm in length and 5.7 to 7.25 g in weight compared to 83 mm in length and 5 g in weight in 1983. Average condition factors in 1984 ranged between .75 and .96 in most cases.

The length-weight relationship for juvenile steelhead from Bedrock Creek is presented in Figure 37. A non-linear least squares regression was run and the length-weight equation showed that growth slightly exceeded the cubic relationship resulting in allometric growth (Tesch 1971) during natal stream habitation. The log length-log weight relationship was log W = -11.1957 + 2.9018 log L (R^2 =.98).

Information on total length and fork length for juvenile steelhead was collected in 1984. Conversion factors between total length and fork length for subyearling fish (n=305) 57 to 102 mm is TL = .1295 +.9477(FL) and for 168 yearling fish (99-207 mm) is TL = -.4152 + .9495(FL). The coefficient of determination (R^2) for the simple model of total length and fork length was .99 for both groups.

Enhancement Strategy

Enhancement recommendations for the Bedrock Creek system have previously been made by Kucera et al. (1983), Fuller et al. (1984) and Fuller et al. (1986). Results from these studies and the current survey will be used to address anadromous salmonid enhancement potential. Where direct support from the sample data is not available, through regression or correlation, support from the literature is used. Problems identified were a lack of yearling habitat, low summer stream discharge and concurrent elevated water temperatures and extreme annual streamflow variation.

Lack of instream cover for yearling fish is a limiting factor to anadromous salmonid production in Bedrock Creek as has been found in other studies (Everest and Sedell 1984). Total measured instream cover never exceeded 10 percent of the available area at any study area, with the remainder being riffle or riffle-run

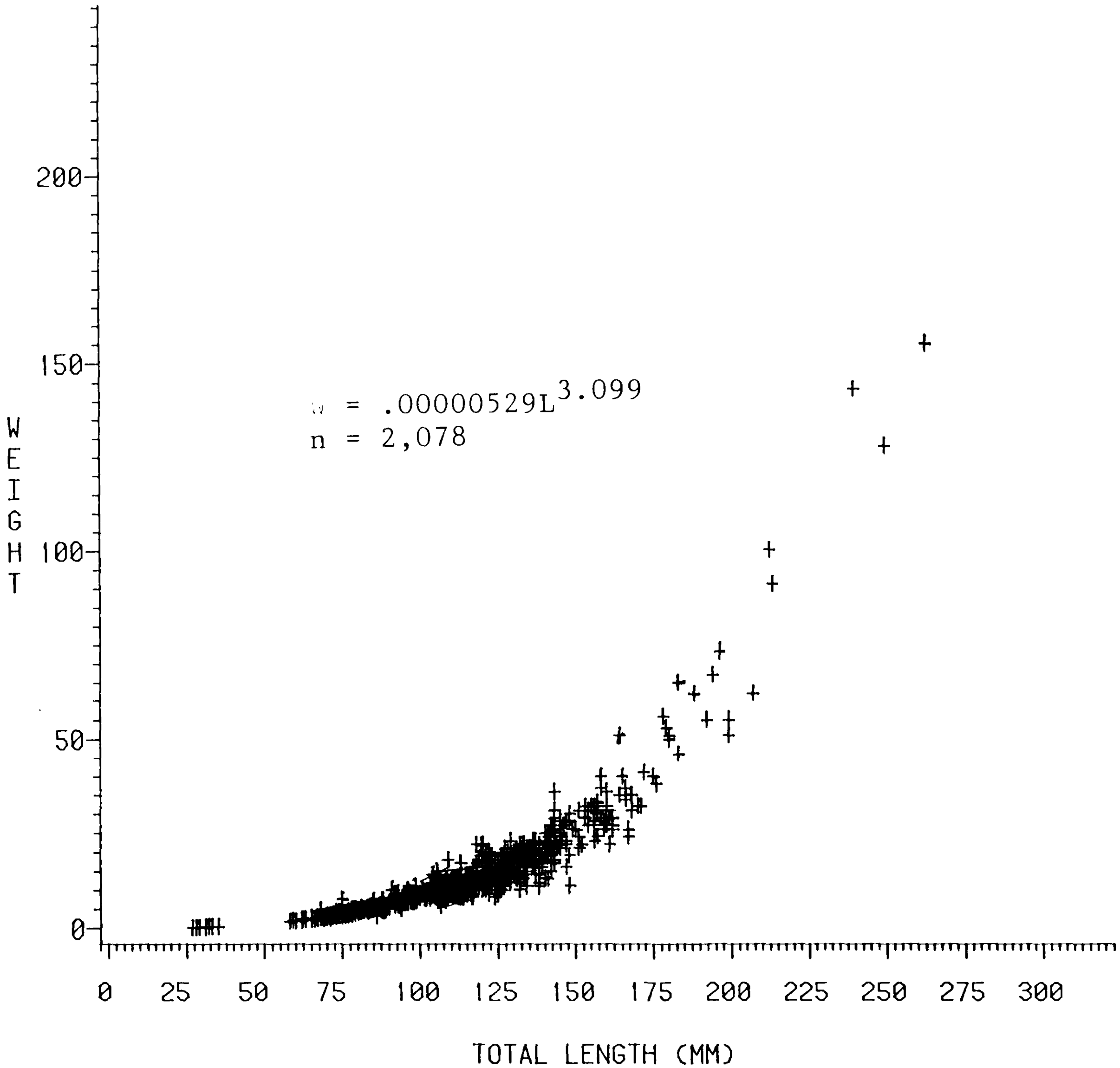


Figure 37. Length-weight relationship for juvenile rainbow-steelhead trout from Bedrock Creek.

habitat. The upper study area supported the highest summer and winter yearling steelhead densities (Table B.l) and also contained the highest percent instream cover during the two year study period. The upper study area contained more pool habitat, the middle study area more run habitat and the lower study area mainly surface turbulence and overhanging vegetation as instream cover. Yearling steelhead density was significantly correlated (PcO.05) with total yealing habitat at the lower study area only. Few significant correlations existed that provided a biological basis to relate yearling density or biomass information to habitat data. Therefore, regression analysis was not a useful tool in delineating factors that limit steelhead densities. However, other investigators (Burns 1.971; Gordon and MacCrimmon 1982) have found significant relationships between yearling steelhead densities and living space variables. Some habitat enhancement measures in the Clearwater Basin are also based on the premise that improving instream habitat will increase steelhead density.

Average stream depths during the summer and early fall were less than 12 cm and water velocities averaged less than 15 cm/s. These depths and velocities are at a minimum level in terms of probability-of-use data for juvenile steelhead (Rovee 1978). Yearling rainbow trout (Wesche 1980) and steelhead trout (Everest and Chapman 1972) are reported to utilize depths more often as depth exceeds 15 centimeters. Preferred depths (>15 cm) are generally found in pool habitats2 Yearling densities at the pool sites ranged up to 1.5 fish/m and were three to ten times the densities observed at the sample stations. High pool steelhead densities indicated that pool habitat provided crucial cover during summer low flow conditions and during the winter. Placement of instream structures such as boulders, root wads, gabions, boulder clusters and woody debris would help increase the amount of pool habitat. It is estimated that with such limited yearling cover (<l0%), that placement of instream habitat structures could substantially increase the smolt yield. Placement of instream structures should take place as part of an overall. enhancement/restoration plan. For example, Jester and McKirdy (1966) reported that water temperature increased 60 percent in 16 reaches improved by log dams. Water temperature in Bedrock Creek averages nearly 20 C during the summer period (maximum of 25.1 C) which is not within the optimum range of 12 to 18 C for rainbow trout (Raleigh et al. 1984).

Annual stream flow variation, low summer stream flows and high summer water temperatures are variables that also need improvement in this lowland valley stream. Bedrock

Creek, hydrologically, is highly variable. Stream discharge during the sampling period varied from .003 to 4.25 m^3/s; a 1,417 fold difference. Stream discharge measured on a descending flow in the spring of 1986 was 22 m^3/s. Raleigh et al. (1984) state that there is a definite relationship between annual flow regime and quality of trout habitat with the most important period being base flows. Peak spring runoff has reduced the channel stability by creating wider flood plains in the lower 4 to 5 km of stream. Stream channels within these wider flood plain areas, may be completely altered from year to year which would leave some instream structure enhancement unavailable to trout. Spring runoff also inhibits riparian vegetation establishment in these areas. However, where well-developed riparian vegetation and overhead canopy exist, there is usually better channel stability. Placement of instream structures such as woody debris not only creates high quality pools (Platts and Rinne 1985) but also helps control channel stability (Heede 1981). conditiosn in the lower one to two kilometers of stream may require rechannelization into a meandering path and revegetation of the stream banks. Placement of instream deflectors to help dissipate energy during periods of high runoff needs to be evaluated further.

Low summer stream flows and high summer water temperatures also are of concern in the Bedrock Creek system. Stream discharge was as low as .003 m^3/s (.10 cfs). Stream discharge was significantly positively correlated with yearling steelhead habitat and at summer base flows severely limited the available yearling cover. Available yearling habitat was lacking ((10%) under low flow conditions as the majority of habitat present (90%) were riffles or riffle-run habitat. Consistent declines in yearling populations (numbers of fish) were observed during the summer over the two year study period. A period of population regulation apparently occurs during the summer low flow period. Low summer flows, high water temperatures and lack of yearling habitat all occur during the summer. One specific limiting factor that regulated yearling numbers could not be identified but, rather, the time of population decline was. Flow augmentation, either through spring enhancement or construction of a small. storage reservoir, would alleviate summer low flow, increase yearling habitat and help reduce water temperatures. Average water temperatures in Bedrock Creek reach 20 C during the summer with maximum temperatures up to 25.1 C for short periods of time. Yearling steelhead growth and production during this time is negative as the summer low flow period is reached and water temperatures are elevated. Platts and Rinne (1985) state that summer solar radiation accounts for about 95% of the heat input in Rocky Mountain streams during midday. A moderate overhead canopy is therefore, essential to shade the stream and keep water temperatures at acceptable levels for salmonid production. Raleigh et al. (1984) report that the optimum range in water temperature for rainbow trout is between 12 to 18 degrees Centigrade. Riparian vegetation is needed on the Bedrock system (Fuller et al. 1986) to help shade the stream, thus reducing water temperature. It would also stabilize banks and, in the upper watershed, would decrease the rate of water runoff in the spring. Good riparian development may also enhance channel stability and increase stream flow. Riparian enhancement would also be required in the vicinity of Louse Creek. Water temperature and yearling density are generally positively significantly correlated in Bedrock Creek. The data did not indicate that increased water temperature decreased yearling densities. However, increase in density along with temperature could only occur up to the point that lethal limits were approached and then the relationship would truncate. The upper limit in optimum water temperature (Raleigh et al. 1984) has been exceeded and yearling steelhead populations decline during the summer period. Yearling fish density may remain positively correlated with higher water temperature but at a physiological cost of negative growth and production and a notable increase in incidence of parasitism by black grub.

An enhancement/restoration plan of riparian revegetation, placement of instream structures and channel stabilization would substantially increase smolt yield in Bedrock Creek. Riparian revegetation is important to help shade the stream, thus reducing water temperature, and stabilize banks. It may also aide in stabilizing the channel and increasing stream flow during low flow periods. Placement of instream structures will improve the amount of yearling habitat present and may be placed to help channel stability. Channel stabilization is also an important enhancement goal. It is estimated (indirectly) that smolt yield would be doubled if these measures were undertaken. The current smolt yield was estimated to be 5,290 fish in 1984 and 4,339 smolts in 1985. The feasibility of flow augmentation, either spring enhancement or reservoir storage, and instream water deflectors requires further evaluation.

COTTONWOOD CREEK

Cottonwood Creek flows for 25.6 km, the lower 9.6 km having perennial flow, and is joined by two small perennial tributaries, Magpie Creek and Coyote Creek, in the lower stream section (Figure 38). The upper drainage is located in agricultural environs with poor riparian development and moderate to heavy grazing by cattle. From skm 22.4 the stream flows about 7.6 km through a relatively steep canyon area, which provides limited grazing, and the canyon widens about skm 14.8 where grazing pressure is heavy down to skm 10. Flooding in this section has created a wider flood plain and prevented revegetation of the stream banks. From skm 9.6 to about skm 4 there is good riparian development and little grazing activity. Numerous residences are present in the lower 4 km of stream where very little overhead canopy is present and grazing is generally heavy. Logging has taken place in the drainage and several old logging roads remain.

Stream discharges varied 376 fold, from .02 to 7.52 m^3/s over the two year study period (Figure 39). The stream flow variability has created wider flood plains in certain areas and has reduced channel stability. Peak spring runoff inhibits riparian revegetation, in the wider flood plain areas, which helps shade the stream and stabilize banks. Stream channels were more stable in areas of good riparian vegetation and overhead canopy. Discharge during the fish population sampling period ranged from .0166 to ,197 m^3/s. Monthly average water temperatures (Figure 39) fluctuated from 2.5 to 18.8 C with summer maximum temperatures up to 26.4 degrees Centigrade. Thermograph placement in 1983 was in the upper study area about 1 km below where subsurface water flow re-entered the stream channel, which kept water temperatures cooler than the lower study area. Because of this phenomena the 1983 water temperature data was used for the upper studv area only. In 1984, the thermograph was moved to the lower study area and the data used only for this area. Stream gradient ranged from one to five percent and averaged 2.5 percent. Water quality analysis (Table 21) showed Cottonwood Creek to be moderately productive with a pH of 8 and total dissolved solids (TDS) level of 138 to 148 mg/l. Water quality did not appear to be limiting to fish production. Fish species inhabiting Cottonwood Creek are: rainbow-steelhead trout, cutthroat trout, speckled dace, northern squawfish, chiselmouth, redside shiner, bridgelip sucker and paiute sculpin. Crayfish are also moderately abundant in the stream. Adult steelhead in spawning condition have been sampled in Cottonwood Creek in the spring. Large numbers of adult bridgelip sucker ascend the creek from the Clearwater River, each spring, to spawn along with lesser numbers of adult northern squawfish and chiselmouth. Due to the presence of adult steelhead spawners and the low number of age II+ and older rainbow-steelhead (<l0%), we believe the fish

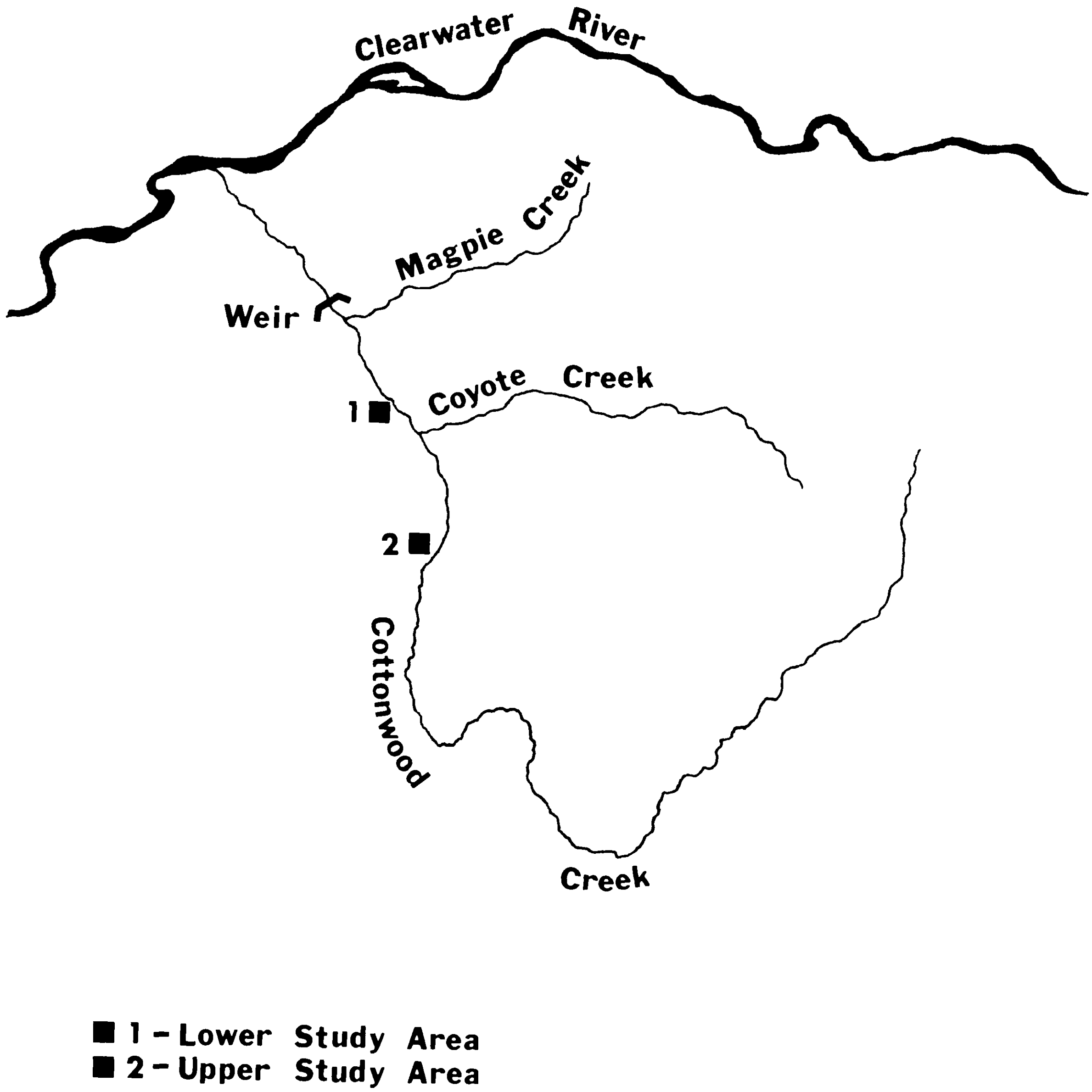


Figure 38. Map of Cottonwood Creek indicating the two study areas sampled in 1983 and 1984 and the fish weir location.

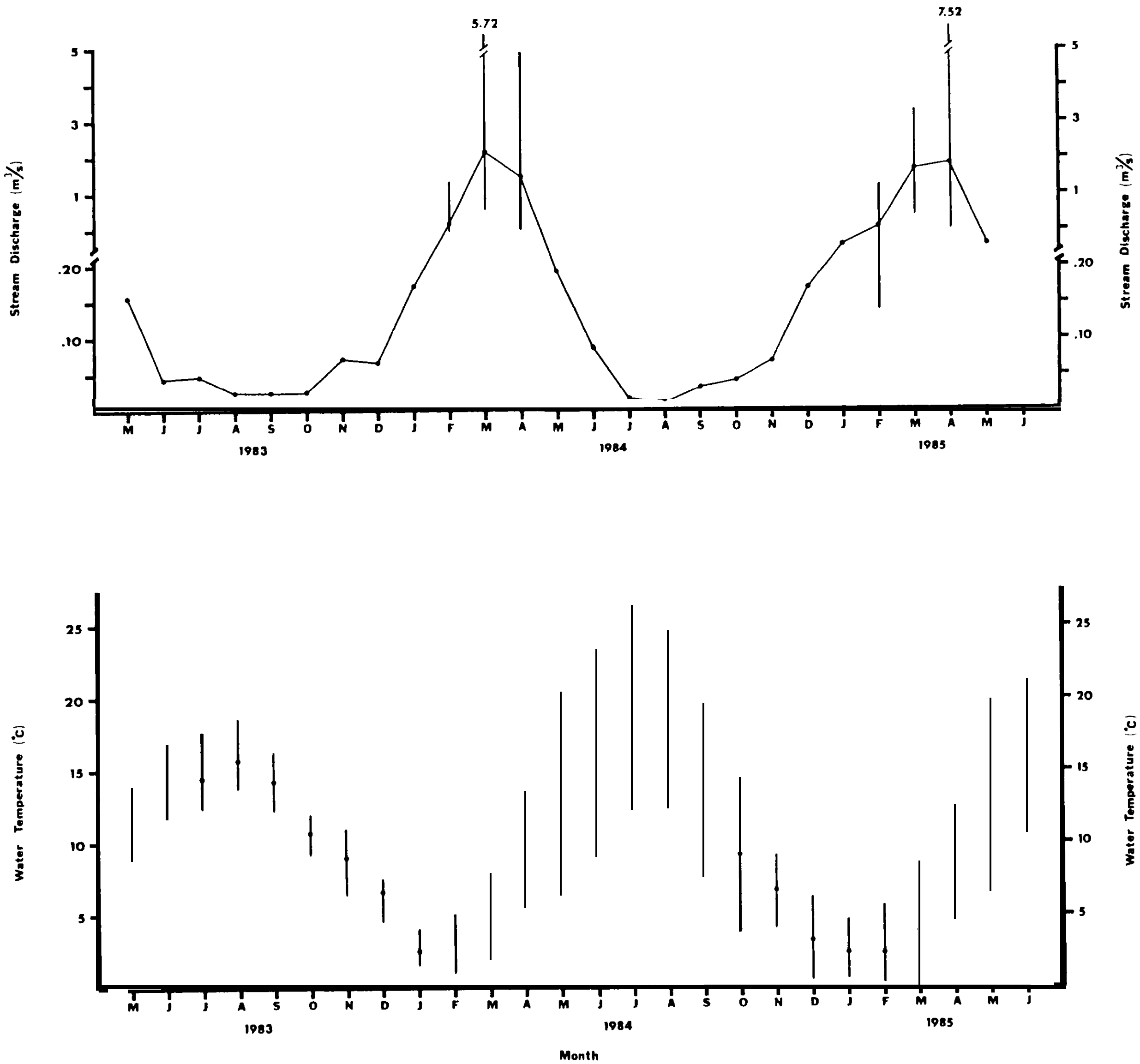


Figure 39. Monthly range and average water temperature (lower graph) and average monthly discharge (upper graph) in Cottonwood Creek from May, 1983 to June, 1985. Ranges in stream discharge are during the spring runoff period.

Table 21. Chemical analysis of water collected from Cottonwood Creek on August 4, 1983, and September 14, 1984.

Constituent	Year 1983	1984
pH	8.01	7.92
Calcium, Ca, mg/l	20.28	22.43
Magnesium, Mg, mg/l	7.40	9.13
Sodium, Na, mg/l	9.15	10.67
Potassium, K, mg/l	2.65	3.52
Chloride, Cl, mg/l	0.35	3.19
Carbonate, CO3, mg/l	9.89	Nil
Bicarbonate, HCO3, mg/l	99.39	134.15
Sulfate, SO4, mg/l	1.0	2.0
Nitrate, NO3, mg/l	0.39	0.072
Orthophosphate, PO4, mg/l	0.07	0.07
Total Residue, mg/l	142.0	150.0
Non-Filtered Residue, mg/l	4.0	2.4
Total Dissolved Solids, TDS	138.0	147.6

to be steelhead and not a population of resident rainbow trout. Cottonwood Creek steelhead, electrophoreticallv, were not siqnificantlv different from the Hiq Canyon Creek population in a pairwise comparison and were in a cluster of other A-run populations (Appendix A). Fishing mortality was not quantified on the juvenile steelhead but fishing pressure was believed to be ligh.

Upper Study Area

Rainbow-steelhead trout was the only anadromous salmonid sampled in this area during the study period. Yearling density during 1983 (Fiqure 40) was .18 fish/m^2 in May and increased to a hiqh of ,315 fish/m^2 in June. Densities remained around .24 fish/m^2 from July to October and then decreased to .095 fish/m^2 in January, 1984 (Table 22). The increase in fish density from 18 fish/m^2 in May to 315 fish/m^2 in June occurred while stream discharqe decreased from .1417 m^3/s to 0395 m^3/s (Table 23) which constricted fish into smaller available stream area. The largest decrease in numbers of fish transpired from November to December. Densities in 1984 ranged from .205 fish/m^2 in May, with a pointed increase from June (.295 fish/m*) to 435 fish/m^2 in July. This was followed bv a steady decrease from July to December at which time an estimated .155 fish/m^2 were present (Fiqure 41 and Table 22). The marked increase in fish abundance from June to July coincided with a decrease in stream discharge from .0761 m^3/s in June to .0154 m^3/s in July (Table 23), thereby concentratins fish into reduced available habitat. The largest decline in fish numbers (not densities) occurred from Auqust to September and from November to December. However, unlike the 1983 density decreases, as stream discharge remained low thru October the 1984 yearling densities decreased constantly forming a straight, descendinq riqht limb on the qraph (Figures 40 and 41). Winter density of fish in December of 1983 (.125 fish/m^2) was very similar to the 1984 estimate of .155 fish/m^2. This suggests that the carrvinq capacity of vearlinq rainbow-steelhead trout, durinq this time of year, may be near these densities. Actual numbers of yearling fish, as opposed to densities, declined from November to December of both years (Appendix-Table R.4.) which coincided with the timing of yearling downstream movement at the fish weir (see outmigration section). Yearling steelhead, presumably, are seeking overwinering habitat and/or are moving out of the stream systme. Yearling fish accounted for 20 to 36 percent of the total saslmonid density in 1983 and from 50 to 60.8 percent of the total in 1984. Subyearling steelhead comprised the remaining percentae in each year, respectively.

Yearling biomass and density was highly correlated durinq both years of study (P<0.05). Subsequently, biomass and density exhibited similar relationships with the physical habitat

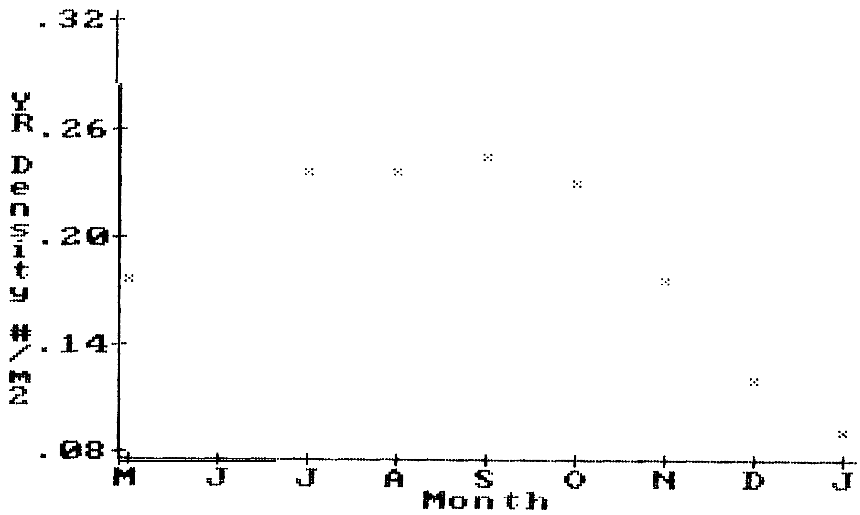


Figure 40. Yearling rainbow-steelhead trout density at the upper study area on Cottonwood Creek from May, 1983 to January, 1984.

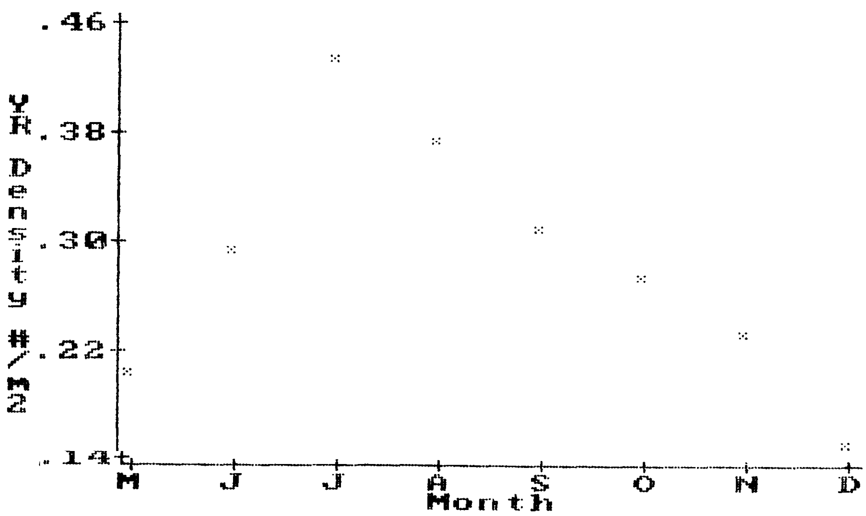


Figure 41. Yearling rainbow-steelhead trout density at the upper study area on Cottonwood Creek from May to December, 1984.

Table 22. Monthly values of stream area and stream volume sampled and average density and biomass (standard deviation in parenthesis) of yearling rainbow-steelhead trout collected in the upper study area on Cottonwood Creek in 1993 and 1984,

Moth	Stream Area Sampled (m2)	Stream Volume Sampled cm31	Density		Biomass	
			Number/m2	Number/n3	Gr ams/m2	Grams/m3
1984 a						
May	684.3	143.6	0.205	0.95	2.56	11.85
			(.05)	(.16)	(1.02)	(3.57)
June	619.5	98.5	0,295	1.84	4.42	27.42
			(.03)	(.24)	(1.33)	(6.35)
July	482.1	63.7	0.435	3.23	7.0	51.59
			(.14)	(.71)	(3.51	(20.03)
August	526.5	60.0	0.375	3.20	6.42	55.47
			(.13)	(.35)	(3.15)	(16.78)
September	531.0	76.7	0,310	2.07	5.40	36.09
			(.13)	(.40)	(3.19)	(14.93)
October	555.0	93.6	0.275	1.60	4.56	26.23
			(.09)	(.36)	(2.56)	(12.16)
November	567.9	118.3	0.235	1.12	4.05	19.36
			(.07)	(.26)	(1.62)	(7.52)
December	633.6	132.2	0.155	0.73	2.17	10.13
			(.04)	(.13)	(1.20)	(4.13)
1983 b						
May	459.4	94.1	0.180	0.90	3.70	18.0
			(.01)	(.003)	(1.12)	(4.88)
June	394.4	60.8	0.315	2.03	6.87	44.13
			(.06)	(.31)	(2.83)	(16.11)
July	407.0	61.7	0,240	1.73	5.21	34.72
			(.03)	(.60)	(.22)	(4.73)
August	377.4	62.2	0.240	1.46	3.85	23.81
			(.01)	i.18)	i.68)	(5.80)
September	367.4	54.8	0,250	1.69	5.75	38.0
			(.03)	(.08)	(2.49)	(14.03)
October	353.4	62.3	0.235	1.29	4.55	25.01
			(.09)	(.40)	(3.14)	(15.39)
November	39514	76.0	0.180	0.93	4.27	21.77
			(.04)	(.15)	(1.73)	(6.81)
December	402.8	71.9	0.125	0.70	2.97	16.81
			(.05)	(.31)	(1.91)	(11.12)
January	466.6	105.7	0.095	0.43	2.30	10.29
			(.02)	(.04)	(.33)	(2.15)

a Average of three 50 meter sample stations,
b Average of two 50 meter sample stations+

Table 23. Average monthly physical characteristics, standard deviation in parenthesis, of the upper study area on Cottonwood Creek sampled in 1983 and 1984.

Month	Stream Disch. (m3/s)	Stream Veloc. (cm/s)	Stream Width (cm)	Stream Depth (cm)	Aver. Water Temp. (C)	Depth >30cm (m2)	Undercut Bank (m2)	Overhang. Vegetatn. (m2)	Surface Turb. (m2)	Subm. Rock (m2)	Total Habitat (m2)
<u>1984</u> a											
May	0.1923	21.9	456.4	21.2	-	43.61	2.17	2.43	3.12	0.95	52.29
	(.02)	(.9)	(56.9)	(2.3)		(8.09)	(2.21)	(3.10)	(2.12)	(1.64)	(10.35)
June	0.0761	12.1	412.9	16.1	-	22.70	1.37	3.78	1.71	0.71	30.28
	(.01)	(2.2)	(54.7)	(2.3)		(8.03)	(1.20)	(3.16)	(1.69)	(.67)	(8.44)
July	0.0154	4.0	321.4	13.3	-	14.02	1.51	2.04	0.40	0.62	18.61
	(.001)	(.9)	(37.9)	(2.0)		(4.22)	(1.22)	(1.90)	(.27)	(.65)	(5.76)
August	0.0106	3.1	350.9	11.7	-	13.31	1.31	2.90	0.15	0.63	18.31
	(.0008)	(.8)	(37.1)	(3.9)		(3.60)	(1.60)	(1.99)	(.04)	(1.10)	(6.25)
September	0.0262	6.7	353.9	14.7	-	16.55	1.85	3.09	0.30	0.52	22.32
	(.005)	(1.9)	(43.7)	(3.8)		(5.26)	(1.34)	(1.69)	(.09)	(.65)	(6.90)
October	0.0273	6.4	370.1	17.0	-	18.53	2.37	3.28	0.32	0.57	25.09
	(.003)	(1.1)	(53.0)	(2.2)		(5.94)	(1.91)	(1.01)	(.14)	(.65)	(6.16)
November	0.0492	9.8	378.6	20.9	-	19.61	2.17	4.69	0.47	0.43	27.39
	(.003)	(1.1)	(55.9)	(1.5)		(6.65)	(2.11)	(.70)	(.13)	(.60)	(7.26)
December	0.1168	16.5	422.3	21.3	-	30.47	2.06	6.44	0.59	0.54	40.11
	(.003)	(2.2)	(70.2)	(5.2)		(13.22)	(1.87)	(1.59)	(.66)	(.58)	(13.73)
<u>1983</u> b											
May	0.1417	16.3	459.9	20.5	11.1	-	-				
	(.02)	(4.6)	(9.3)	(.7)							
June	0.0395	6.4	394.6	15.4	14.1	21.75	3.49	20.28	0.72	1.58	47.83
	(.006)	(1.4)	(30.5)	(.8)		(1.18)	(3.26)	(16.77)	(.26)	(2.41)	(18.72)
July	0.0349	6.6	407.0	15.2	14.5	20.60	3.79	9.98	0.34	2.54	37.25
	(.0008)	(.3)	(6.4)	(2.7)		(4.84)	(4.0)	(8.55)	(.49)	(3.29)	(4.93)
August	0.0202	4.2	377.5	16.3	15.7	21.55	5.26	5.37	0.10	1.41	33.70
	(.002)	(.1)	(88.5)	(1.1)		(3.46)	(4.22)	(2.97)	(.15)	(1.62)	(2.25)
September	0.0152	3.3	367.6	14.9	14.3	20.57	3.59	5.01	0.23	2.11	31.52
	(.0009)	(.03)	(26.2)	(1.1)		(4.41)	(2.49)	(1.70)	(.01)	(2.82)	(3.05)
October	0.0150	2.8	353.7	17.7	10.6	18.80	3.70	5.78	0.27	1.31	29.87
	(.002)	(.1)	(26.5)	(1.7)		(4.81)	(3.29)	(3.62)	(.18)	(1.86)	(.05)
November	0.0521	8.2	395.6	19.3	9.0	24.44	3.74	2.60	0.81	0.75	32.34
	(.007)	(1.0)	(45.9)	(1.9)		(4.33)	(1.78)	(1.58)	(.15)	(1.06)	(2.18)
December	0.0444	7.3	402.9	17.8	6.6	31.26	3.99	3.80	1.20	0.67	40.93
	(.01)	(1.9)	(45.7)	(.4)		(5.49)	(.79)	(1.82)	(.54)	(.80)	(3.14)
January	0.1634	19.4	466.5	22.5	2.5	-					
	(.10)	(9.0)	(64.1)	(1.4)							

a Average of three 50 meter sample stations.
b Average of two 50 meter sample stations.

variables examined. Biomass varied from 3.7 g/m^2 in May 1983, to a high of 6.87 in June (Table 22) and decreased to 2.3 g/m^2 in January, 1984. Biomass estimates in 1984 ranged from 2.56 g/m^2 in May to a peak of 7 g/m^2 in July, gradually decreasing to 2.17 g/m^2 in December. The estimated biomass present in December of both years was essentially the same. Yearling biomass represented the maiority of total salmonid biomass present, comprising 70.3 to 86.4 percent of the total in 1983 and 83 to 97 percent of the total in 1984.

Yearling steelhead production at the upper study area (Table 24) was .59 g/m^2 in 1984 and 1.54 g/m^2 during 1983. Some production from this cohort was missed since sampling occurred from May to December or January. Monthly production estimates did not follow a similar pattern between years (Table 24). In 1984, yearling production was positive from May thru July and in October and was negative during late summer and in the winter. Estimated accumulation of fish flesh in 1983 was positive during May, August and from October thru December. Negative values were obtained for June, July and September. Fish emigration is a factor that can affect production estimates. Negative production (-1.07 g/m^2) was estimated from July to August of 1983 as a minimum of 32 percent of the population were new fish that moved into the area; determined by yearling fish marking experiments. Average fish weight also declined from 20.35 g to 16 g during this time. Fish production from July to August of 1984 was positive (.39 g/m^2 as only 13 percent of the population had moved into the area during the month. Fish were also smaller in weight in 1984, increasing from 15.6 to 16.85 grams. Yearling steelhead were larger in weight during 1983 and weight varied more between months than during 1984 (see age and growth section, Table 33). Juvenile steelhead production for Cottonwood Creek, averaged over the two study areas, was 2.13 g/m^2 in 1984 and 6.78 g/m^2 during 1983. The 1983 information reflects subyearling production estimates from November to May (1984) which the 1984 estimates lack. Cottonwood Creek steelhead production values fall into a low to middle range of rainbow trout production reported by Neves et al. (1985) for fluvial systems in the United States. Neves reported production values ranging from 2.4 to 13.2 g/m^2. Production estimates for two Idaho streams ranged from 2.4 g/m^2 for the Lemhi River up to 10.4 g/m^2 in Pig Springs Creek (Goodnight and Bjornn 1971).

Survival estimates for yearling steelhead were calculated from May to December during 1983 and 1984. Since yearling fish could emigrate at will, the estimates are considered rough approximations only. Computation of survival estimates was not the main focus of the present study. Estimated survival in 1984 ranged from 34.8 percent (lower study area) to 47 percent (upper study area). In 1983 these values varied from 26 percent at the lower area to 39.3 percent at the upper area. Lower study area survival estimates were consistently about

Table 243 Production estimates of yearling and subyearling rainbow-steelhead trout from two study areas on Cottonwood Creek in 1983 and 1984,

Month	Upper Study Area Production (g/m2) Yearling	Upper Study Area Production (g/m2) Subyearling	Lower Study Area Production (g/m2) Yearling	Lower Study Area Production (g/m2) Subyearling
1984				
May	.62	--	1.87	--
June	.26	.08	- .85	.73
July	.39	.4[illegible]	- .32	.22
August	0	.10	- .01	.[illegible]2
September	- .23	.01	- .08	.23
October	.08	0	.09	- .06
November	- .53	- .02	.11	.02
December				
TOTALS	.59	.62	.81	1.66
1983				
May	1.32	--	- .79	--
June	- .41	1.0	.72	1.63
July	-1.07	.39	- .11	.59
August	2.07	.25	.12	1.98
September	-1.20	.08	.61	1.41
October	.67	.49	- .23	.94
November	.03	- .04	- .12	.04
December	.13		- .18	
January				
Nov-May a		1.55		1.70
TOTALS	1.54	3.72	.02	8.29

a - Age 0+ steelhead only+

14 percent lower than upper studv area values. Survival from age I+ to smolt outmigrant (age II) could not be estimated due to pre-smolt outmigration of the age I+ individuals and fish movement in general. Bjornn (1978) reported the survival of yearling steelhead migrants from stocked fry to range from .4 to 1.2 percent over a 12 year period in Big Springs Creek, Idaho.

The upper study area on Cottonwood Creek was characterized by excellent riparian development, with both overhead canopv shading the stream and abundant grasses overhanging the stream bank. Instream cover was mainly pool and run habitat with some overhanging vegetation also being present. The pools had undercut banks. Cobble embeddedness was estimated to be at least 35 percent with silt comprising 10 percent of the total bottom substrate. salmonid production can be affected as the percent fines reach about 20 percent (Bjornn et al. 1977). Total measured yearling habitat (Table 23) was never less than 10 percent of the available stream area and generlaly ranged between 12 to 20 percent. Total yearling habitat was more abundant during the summer of 1983 than in 1984. The instream cover component of depth greater than 30 cm made up the majority of habitat present. Average stream depths during the summer and fall ranged between 10 to 16 cm and water velocities were less than 12 cm/s. Depths less than 15 cm and velocities less than 15 cm/s are at a minimum level in terms of probability-of-use for juvenile steelhead (Bovee 1978). Everest and Chapman (1972) and Wesche (1980) reported that yearling steelhead and rainbow trout utilize the depth component more as it exceeds 3.5 to 20 centimeters. If our criterion for instream cover had been depth greater than 20 cm, considreably more vearling habitat would have been estimated.

Correlation matrices between vearlinq steelhead density and biomass and habitat variables were calculated. No significant correlations existed that provided a consistent biological basis to relate yearling steelhead density to habitat data. Therefore, regression analysis was not a useful tool in delineating factors that limit steelhead densities. The discussion is supported by the literature when possible. A significant association between density and stream discharge also existed (Figures 42 and 43). During both years there was a significant ($P<0.05$) negative correlation between these variables, indicating an inverse relationship. Reduced stream discharge concentrated fish into a smaller available area but increased flow did not cause a reduction in yearling density. Average water temperature, data available only in 1983, and yearling density (Figure 44) also had a significant relationship. Density of yearin fish would continue to increase only until lethal temperature was approached and the relationship would truncate. Average water temperature reached a high of 15.7 C in August of 1983 with a maximum temperature of

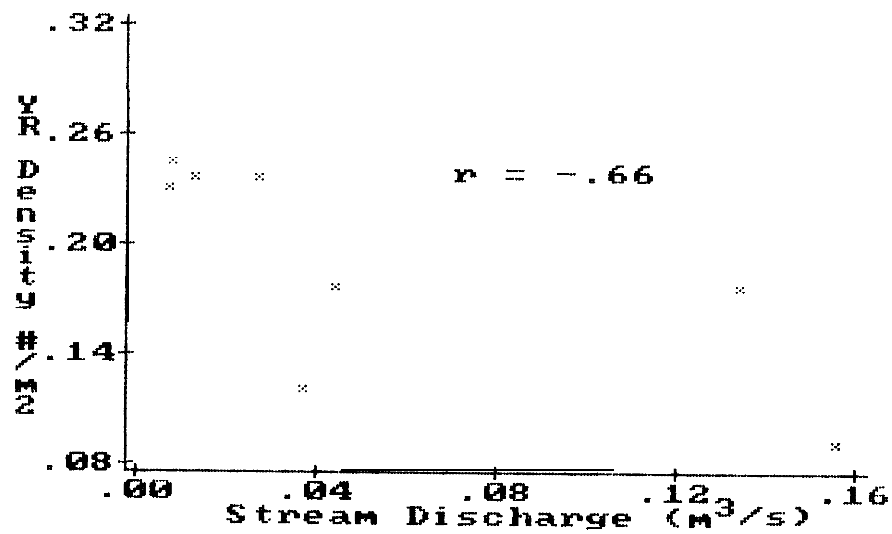


Figure 42. Relation between yearling rainbow-steelhead trout density and stream discharge at the upper study area on Cottonwood Creek from May, 1983 to January, 1984.

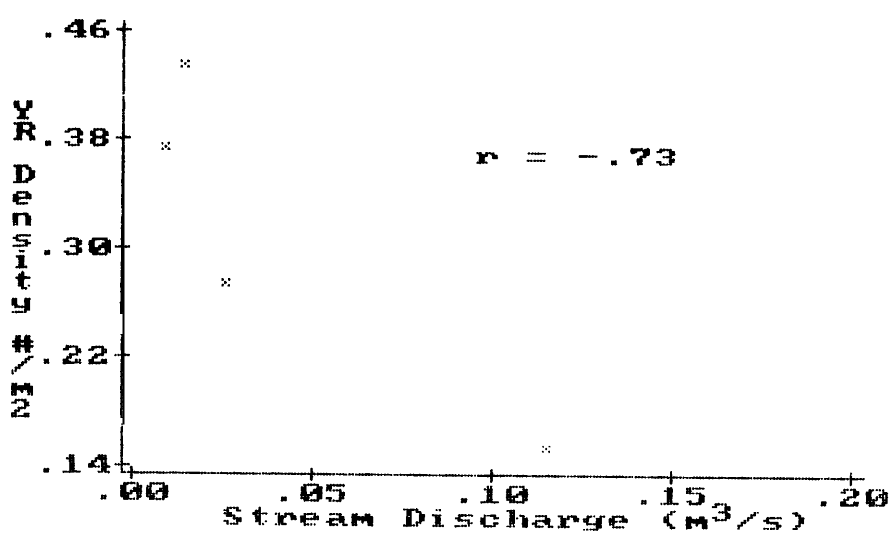


Figure 43. Relation between yearling rainbow-steelhead trout density and stream discharge at the upper study area on Cottonwood Creek from May to December, 1984.

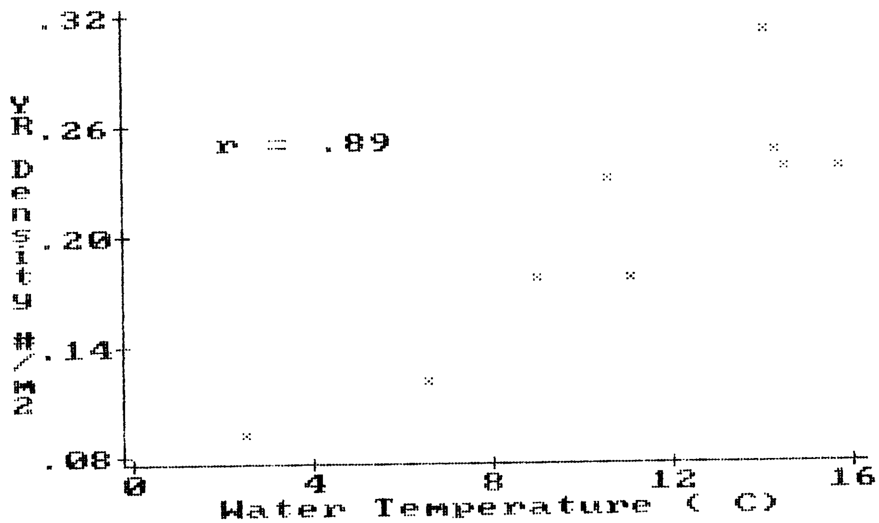


Figure 44. Relation between yearling rainbow-steelhead trout density and average water temperature at the upper study area on Cottonwood Creek from May, 1983 to January, 1984.

18.6 degrees Centigrade. These higher temperatures were generally within the optimum range of 12 to 18 C reported for rainbow trout (Raleigh et al. 1984). A significant association between yearling density and overhanging vegetation (r=.77) was observed in 1983 but in 1984 a significant negative correlation existed (r=-. 71) which is not clearly understood. overhanging vegetation as instream cover was almost twice as abundant in 1983 as during 1984 (Table 23), as more grasses hung over the stream edge. Also, patterns in stream discharge were different between years (Figure 39) with higher flows occurring in May, June and December of 1984 as compared to 1983. Fish density and total yearling instream cover had a positive (r-=.24) relationship in 1983 but a significant negative correlation (r=-.79) in 1984. Different factor(s) that affect densitv must have been present between years during the study period.

Subyearling rainbow-steelhead densities in 1983 fluctuated from .915 fish/m^2 in June, with a sharp decrease occurring from .96 fish/m^2 in July to .64 fish/m^2 in August. Densities further declined to .505 fish/m^2 in September and to .225 fish/m^2 in January, 1984 (Figure 45 and Table 25). The sharp decrease from July to August did not correspond to a concurrent drop in stream discharge. Density of subyearling fish in 1984 ranged from .19 fish/m^2 in June to a high of .395 fish in July and declined to .15 fish/m^2 in December (Figure 46 and Table 25). The increase from .19 fish/m^2 in June to .395 fish/m^2 in July occurred as more fish were recruiting to the gear and as stream discharge dropped from .0761 m^3/s to .0154 m^3/s, thus concentrating fish. Peak densities of age 0+ fish in 1983 was twice that during 1984, as density was generally higher throughout the year. Catch per unit of effort of adult steelhead indicated a larger escapement in 1983 (2 fish/man day) than in 1984 (1 fish/man day). The December 1983 density (.27 fish/m^2) was almost double the subyearling density in December of 1984 (.15 fish/m^2). Density of subyearling fish comprised 64 to 80 percent of the total salmonid density in 1983 and 39 to 50 percent of the total in 1984.

Estimated subyearling biomass in 1983 varied from 1.08 g/m^2 in June up to 2.2 in July and then decreased to .88 g/m^2 in January, 1984. Biomass of subyearling fish in 1984 was generally lower ranging from .14 g/m^2 in June to a high of 1.13 in August which declined to .51 g/m^2 in December. Subyearling density and biomass was not significantly correlated in 1983 (r=.50) or in 1984 (r=.64). Subyearling biomass made up only a small portion of the total salmonid biomass present in 1983 (13.6 - 30%) and in 1984 (3 - 17%).

Subyearling steelhead production (Table 24) in the upper study area was .62 g/m^2 in 1984 and 3.72 g/m^2 during 1983. Production in 1983 was calculated from May to May of 1984, which

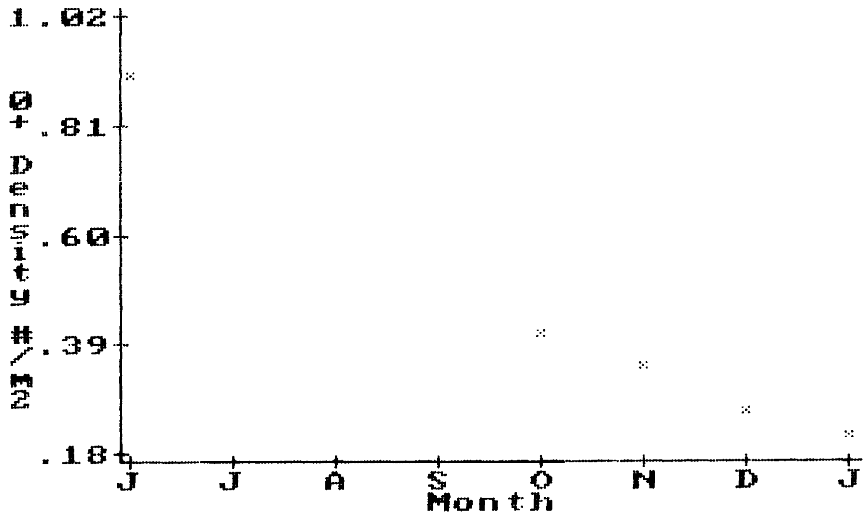


Figure 45. Subyearling rainbow-steelhead trout density at the upper study area on Cottonwood Creek from June, 1983 to January, 1984.

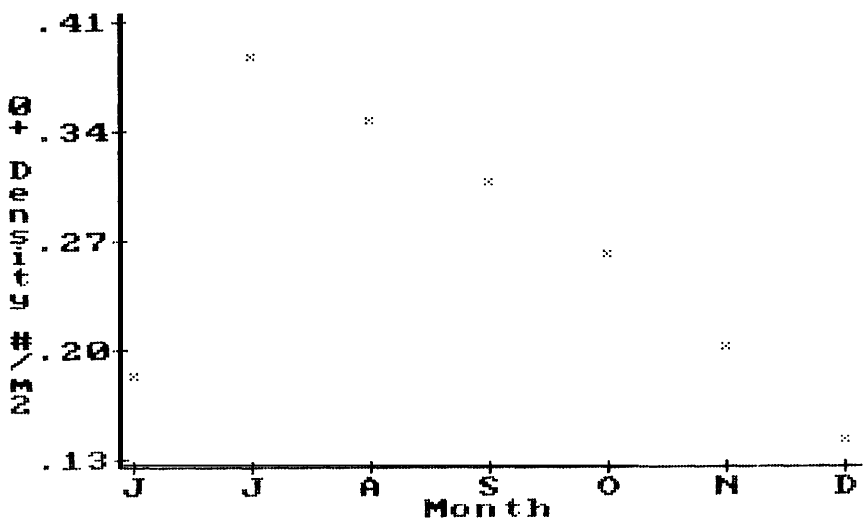


Figure 46. Subyearling rainbow-steelhead trout density at the upper study area on Cottonwood Creek from June to December, 1984.

Table 25. Honthly values of stream area an? stream volume s3mp led and average density and biomass (standard deviation in parenthesis) of subyearling rainbow-steelhead trout collected in the upper study area on Cottonwood Creek in 1983 and 1984.

Month	Stream Area Sampled (m2)	Stream Volume Sampled (m3)	Density		Biomass	
			Number/m2	Number/m3	Grams/m2	Grams/m3
1984 a						
May	684.3	143.6	-	-	-	-
June	619.5	98.5	0.190	1.24	0.14	0.96
			(.09)	(.76)	(.07)	(.62)
July	482.1	63.7	0.395	3.07	0.72	5.63
			(.04)	(.87)	(.09)	(1.64)
August	526.5	60.0	0.355	3.45	1.13	11.06
			(.05)	(1.91)	(.16)	(6.09)
September	531.0	76.7	0.315	2.36	1.09	8.23
			(.11)	(1.49)	(.40)	(5.15)
October	555.0	93.6	0.270	1.63	0.95	5.82
			(.08)	(.72)	(.30)	(2.67)
November	567.9	118.3	0.210	1.02	0.75	3.65
			(.03)	(.23)	(.09)	(.69)
December	633.6	132.2	0.150	0.73	0.51	2.51
			(.03)	(.23)	(.07)	(.59)
1983 b						
May	459.4	94.1	-	-	-	-
June	394.4	60.8	0.915	6.0	1.08	7.09
			(.40)	(2.93)	(.33)	(2.53)
July	407.0	61.7	0.960	6.56	2.20	15.11
			(.27)	(2.96)	(.63)	(6.81)
August	377.4	62.2	0.640	3.95	1.55	9.57
			(.18)	(1.38)	(.08)	(1.13)
September	367.4	54.8	0.505	3.41	1.63	10.99
			(.01)	(.28)	(.03)	(.55)
October	353.4	62.3	0.420	2.39	1.44	8.19
			(0)	(.21)	(.03)	(.62)
November	395.4	76.0	0.355	1.86	1.59	8.28
			(.06)	(.49)	(.01)	(.77)
December	402.8	71.9	0.270	1.49	1.22	6.83
			(.05)	(.29)	(.04)	(.08)
January	466.6	105.7	0.225	0.99	0.88	3.91
			(.06)	(.21)	(.19)	(.61)

a Average of three 50 meter sample stations.
b Average of two 50 meter sample stations.

provided the best estimate of annual production. Computations in 1984 lacked the November to May estimate, and thus some of the cohort production was missed. Monthly production estimates showed that subyearling fish accumulated biomass during all months except during the late fall (November) of 1983 and 1984 (Table 24). Lower study area production was two times greater than that estimated for the upper study area during both years. Annual subyearling production in 1983 ranged between 3.72 and 8.29 g/m^2 between the two study areas.

Survival estimates for subyearling steelhead were computed from July to December in 1983 and 1984. Fish emigration precluded estimating survival from December to the following May (1984). Estimates are considered to be too high as survival was calculated from when the first population estimate could be made. Initial numbers of age 0+ fish were unknown. Subyearling fish survival ranged from 36.5 to 50 percent in 1984 and from 21.5 to 27.7 percent during 1983. Lower survival values were always observed at the lower study area. Subyearling densities at the lower study area (1983) were two to six times higher than upper study area densities. Survival estimates, however, did not vary widely between the upper area (27.7%) and lower study area (21.5%). Wentworth and LaBar (1984) estimated the overwinter survival of subyearling steelhead to average 16 percent (range 13-44%). They also report an average survival of four percent from stocking of fry to age I.

Correlation matrices between subvearling density and biomass and habitat variables indicated significant. relation between density and average water temperature (Figure 47). Subyearling density would only increase with water temperature until lethal temperatures were approached and then the relationship would truncate. Average water temperature reached 15.7 C in August which was within the optimum range of 12 to 18 C reported by Raleigh et al. (1984) for rainbow trout. Water temperature data was not available in 1984 to analyze the relationship. In 1983 there was a significant positive association (r= 79) between density and the cover component of overhanging vegetation. However, as with the yearling fish, there was a high negative correlation (r=-.89) between the two variables in 1984. Stream discharge was significantly negatively correlated with subyearling density in 1984 (r=-.90), but was not in 1983 (r=-.44). Low stream discharge does concentrate a higher number of fish per unit area. High discharge occurs in the spring as fish are just recruiting to the sampling gear and in the late fall when populations have already declined. Thus, higher discharge does not cause lower subyearling densities. Subyearling densitv was siqnificantlv associated with yearling densitv in 1983 (r=.81) and in 1984 (r=.91). Whether this is indicative of intraspecific predation of yearling rainbow-steelhead on the smaller subyearling fish may only be determined through a thorough food habits investigation.

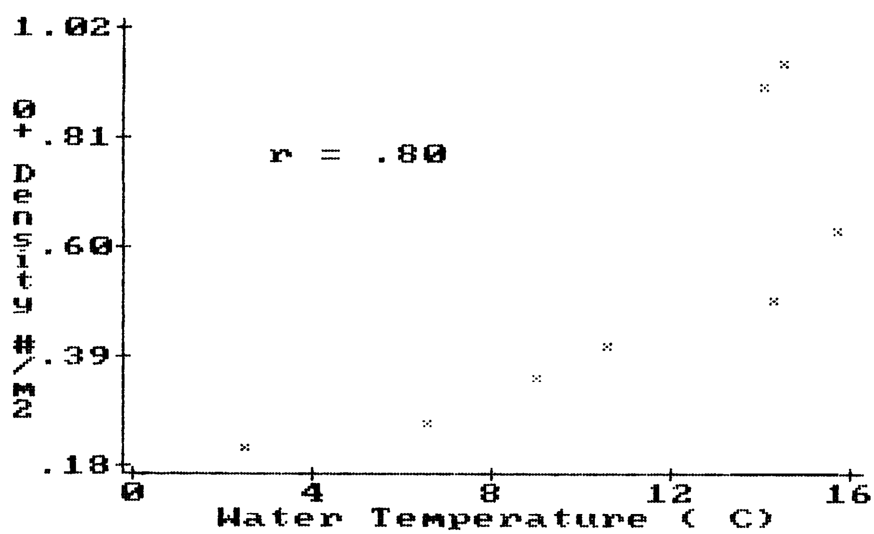


Figure 47. Relation between subyearling rainbow-steelhead trout density and average water temperature at the upper study area on Cottonwood Creek from June 1983 to January, 1984.

Substrate sampling during the study period indicated that there was adequate spawning gravel present for adult steelhead. Estimated available spawning substrate in 1983 was 32.1 percent of the total available stream area and in 1984 was 24.4 percent. The cobble embeddedness was estimated to be 35 percent during both years of study. Percentage of each substrate size is as follows, with 1983 data presented first and 1984 values in parenthesis: boulder 9.1 (10.7); large cobble 30.1 (30.4); small cobble 34.3 (35.8); very coarse gravel 15 (5); coarse gravel 0 (1.5); medium gravel 2.2 (1.5); fine gravel 0 (.03); pea gravel 0 (.2); sand 0 (.l) and silt 9.2 (11.8) percent.

Lower Study Area

Rainbow-steelhead trout was the only anadromous salmonid collected in the lower study area. Density of yearling rainbow-steelhead in 1983 was low, ranging from .10 to . 11 fish/m^2 from May to August, declining to .05 fish/m^2 in January, 1984 (Figure 48 and Table 26). Yearling density in 1984 (Figure 49 and Table 26) was similar in magnitude, fluctuating from .15 to 17 fish/m^2 from May to July and decreasing to .06 fish/m^2 in December. A small increase in density from .lO fish/m^2 in October to .125 fish/m^2 in November, shortly preceeded the fall 1984 yearling pulse in downstream movement (see juvenile steelhead outmigration section). Winter density of fish in December of 1983 (.03 fish/m^2) was similar to the December 1984 value of .06 fish/m^2, but was only one-half of the upper study area winter density. The relative constancy of yearling density in December of both years, suggests that the carrying capacity may be approached for this time of year. Estimated density of fish at the upper study area was almost twice that of the lower study section (Table 22 and 26) during the study period. Yearling fish made up 4 to 9 percent of the total salmonid density in 1983 and 17.3 to 34 percent of the total in 1984.

Estimated yearling biomass (Table 26) in 1983 varied from a high of 3.47 g/m^2 in May, fluctuated up and down thru the summer and fall, and was 1.77 g/m^2 in January of 1984. Biomass estimates in 1984 reflected a high of 3.83 s/m^2 in June, decreasing to 1.37 g/m^2 in December. Biomass generally fluctuated very little and only in association with water temperature in 1984 (r=.70). Yearling density and biomass was significantly correlated during both 1983 and 1984 ($P<0.05$). In 1983 yearling biomass constituted 22 to 34.3 percent of the total salmonid biomass present and in 1984, composed 50 to 89.5 percent of the total.

Production of yearling steelhead at the lower study area ranged from .02 g/m^2 in 1983 to .81 g/m^2 during 1984 (Table 24). Some production from this cohort was missed as sampling was not conducted in the early spring. Monthlv production

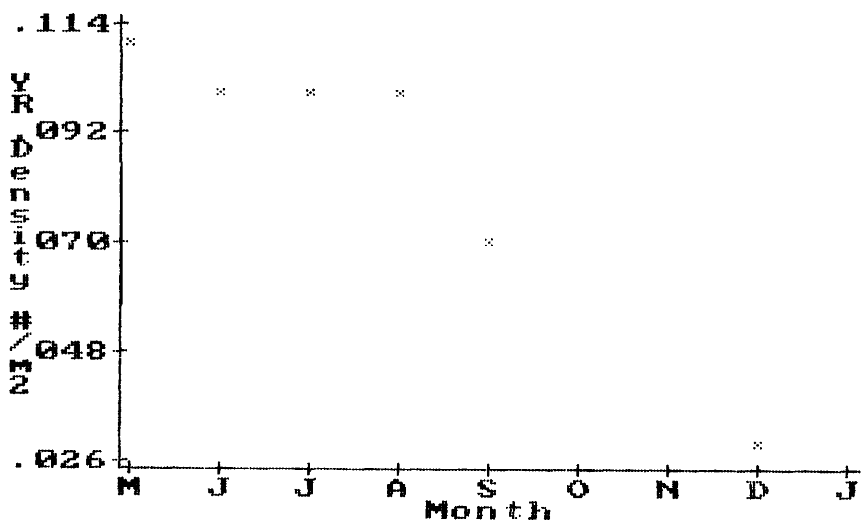


Figure 48. Yearling rainbow-steelhead trout density at the lower study area on Cottonwood Creek from May, 1983 to January, 1984.

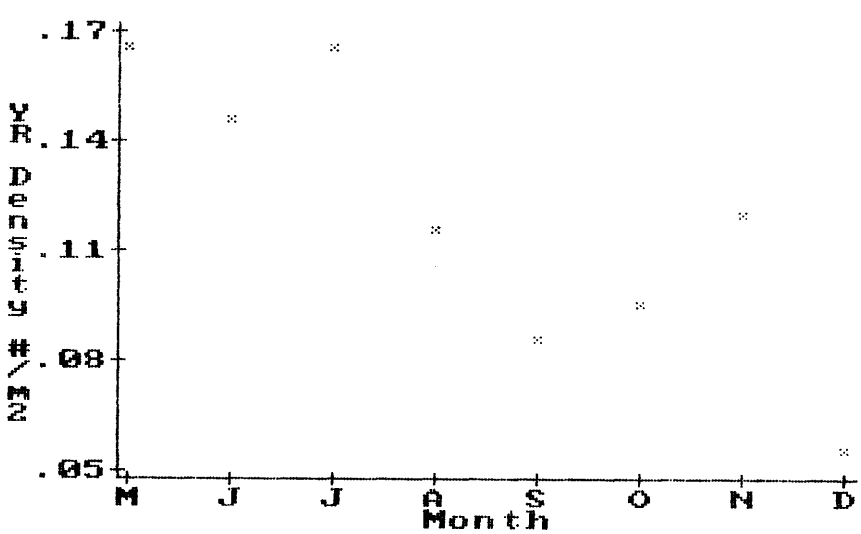


Figure 49. Yearling rainbow-steelhead trout density at the lower study area on Cottonwood Creek from May to December, 1984.

Table 26. Monthly values of stream area and stream volume sampled and average density and biomass (standard deviation in parenthesis) of yearling rainbow-steelhead trout collected in the lower study area on Cottonwood Creek in 1983 and 1984.

Month	Stream Area Sampled (m2)	Stream Volume Sampled (m3)	Density Number/m2	Density Number/m3	Biomass Grams/m2	Biomass Grams/m3
1984 a						
May	795.3	128.3	0.170 (.03)	1.07 (.33)	2.78 (.48)	17.26 (3.92)
June	717.3	100.4	0.150 (.05)	1.07 (.35)	3.83 (1.89)	26.58 (10.40)
July	569.4	74.0	0.170 (.06)	1.33 (.50)	3.70 (1.39)	28.57 (9.81)
August	565.5	62.5	0.120 (.06)	1.19 (.73)	2.60 (1.58)	25.73 (18.26)
September	603.6	76.3	0.090 (.03)	0.76 (.33)	2.05 (.61)	16.47 (6.01)
October	637.8	76.5	0.100 (.06)	0.85 (.47)	2.20 (.89)	18.12 (6.45)
November	678.0	115.1	0.125 (.09)	0.71 (.45)	2.71 (1.57)	15.45 (7.64)
December	770.4	152.7	0.060 (.02)	0.30 (.09)	1.37 (.44)	6.81 (1.61)
1983 b						
May	489.0	78.4	0.110 (.02)	0.69 (.19)	3.47 (1.31)	21.78 (8.92)
June	436.4	52.2	0.100 (.14)	0.84 (1.19)	2.40 (3.39)	20.17 (28.52)
July	457.0	53.9	0.100 (.07)	0.90 (.64)	3.02 (2.18)	26.16 (19.83)
August	385.4	41.5	0.100 (.04)	0.92 (.39)	2.72 (.63)	25.36 (6.32)
September	407.0	45.9	0.070 (.05)	0.66 (.53)	2.18 (1.65)	20.27 (16.92)
October	402.4	51.8	0.080 (.02)	0.69 (.22)	3.21 (1.31)	25.73 (13.04)
November	434.8	60.6	0.060 (.06)	0.48 (.50)	2.17 (2.47)	16.19 (18.65)
December	420.0	59.8	0.030 (.02)	0.23 (.15)	1.08 (1.01)	7.71 (7.41)
January	446.0	71.9	0.050 (.03)	0.31 (.22)	1.77 (1.41)	10.85 (8.46)

a Average of three 50 meter sample stations.
b Average of two 50 meter sample stations.

estimates did not follow a consistent pattern between years. In 1984, production was negative from June to September and most production (1.85 g/m^2) occurred in May. Production in 1983 was negative in May, July and October to December with most production taking place in June (.72 g/m^2) and in September (.61 g/m^2) (Table 34). Yearling fish sample size (1983) was somewhat small (<50) compared to the 1984 samples which ranged between 50 and 130 fish. Yearling steelhead were larger in size at the start of the sampling period during May of 1983 at 29.45 g, compared to 1984 when yearlings were 16.1 grams in weight (see age and growth section, Table 34). Juvenile steelhead production for Cottonwood Creek, averaged over the two study areas, was 2.13 g/m^2 in 1984 and 6.78 g/m^2 during 1983. Production estimates for 1984 lacked subyearling accumulation of biomass from November to May, which the 1983 estimates included. Cottonwood Creek steelhead production falls into a low to middle range of rainbow trout production in streams in the United States (Neves et al. 1985). Neves et al (1985) reported production values ranging from 2.4 to 13.2 g/m2.

This study area contained good overhead canopv which shaded the stream, but little vegetation on the stream banks as cattle grazing was moderate in this section. Pool/run habitat comprised the majority of yearling cover; with very few undercut banks present. The cobble embeddedness was conservatively estimated to be 25 to 30 percent. Measured yearling habitat (Table 27) comprised about 7 to 10 percent of the available stream area during both years and was relatively similar between years. The instream cover component of depth greater than 30 cm made up the bulk of the total habitat present. As discussed previously the upper study area contained almost twice the density of yearling rainbow-steelhead trout compared to the lower study area. Although not definitive, some observations can be made concerning this difference. The upper study area, beside being 3 km higher up in the drainage had about a two to three degree Centigrade cooler average water temperature. Raleigh et al. (1984) state that the optimum range in water temperature for rainbow trout is 12 to 18 C, which the upper study section usually is (Table 23). The upper study area also contained almost twice the amount of yearling cover (Table 23 and 27) and had higher quality pools with undercut banks which the lower section lacked. Stream depth averaged less than 13 cm from July to October of both years (Table 27). Stream velocity was less than 13 cm/s during the same period. These stream depths and velocities are at a minimum level in terms of probability-of-use for juvenile steelhead (Rovee 1978). Everest and Chapman (1972) also reported a higher density of age I+ steelhead in depths greater than 15 centimeters.

Correlation matrices between yearling density and habitat variables indicated a significant relationship with water temperature (Figure 50). Even though average water temperature

Table 27. Average monthly physical characteristics, standard deviation in parenthesis, of the lower study area on Cottonwood Creek sampled in 1983 and 1984.

Month	Stream Disch. (m3/s)	Stream Veloc. (cm/s)	Stream Width (cm)	Stream Depth (cm)	Average Water Temp. (C)	Depth >30cm (m2)	Undercut Bank (m2)	Overhang. Vegatatn. (m2)	Surface Turb. (m2)	Subm. Rock (m2)	Total Habitat (m2)
1984 a											
May	0.2017	23.9	530.4	16.6	12.1	20.51	1.07	0	5.86	0.17	27.62
	i.02)	(1.3)	(92.8)	(3.7)		(7.31)	(1.51)		(.47)	(.29)	(7.82)
June	0.1083	15.2	478.4	14.1	15.3	13.84	0.82	0	4.25	0.05	18.97
	i.01)	(3.2)	(69.9)	(2)		(4.18)	(1.42)		(1.87)	(.08)	(3.89)
July	0.0317	6.8	379.6	12.9	18.8	10.65	0.71	0	1.91	0.10	13.39
	(.004)	(1.2)	(30)	(1.5)		(3.62)	(1.24)		(.56)	(.18)	(3.93)
August	010226	4.9	377.3	11.2	18.2	9.59	0.74	0	1.20	0.02	11.55
	(.002)	(.9)	(39.4)	(2.7)		(3.31)	(1.14)		i.54)	(.03)	(3.38)
September	010450	8.5	402.4	12.7	13.4	11.75	0.97	0.09	2.07	0.01	14.89
	(.001)	(1)	(51.7)	(1.4)		(4.72)	(1.46)	(.16)	(.56)	(.02)	(5.87)
October	0.0613	9.9	425.3	12.1	9.1	13.23	0.94	0	1.76	0.03	15.97
	(.004)	(1.2)	(57.7)	(1.2)		(6.46)	(1.39)		(.54)	(.06)	(6.55)
November	0 . 0962	13.5	452.1	17.1	6.7	13.23	1.05	0	1.80	0	16.09
	(.011)	(1.1)	(48.9)	(2.7)		(6.04)	(1.59)		(.53)		(6.18)
December	0.2276	25.1	513.4	20.1	3.2	18.26	0.84	0.16	2.43	0	21.70
	(.003)	(1.5)	(89.6)	(3.1)		(6.19)	(1.21)	i.20)	(.82)		(6.70)
1483b											
May	0.1782	23.6	489.1	16.0		-	-				
	(.003)	(1)	(12.6)	(.5)							
June	0.0601	11.55	436.8	11.9		12.12	4.64	1.36	1.60	0.07	19.85
	(.002)	(1.4)	(27.6)	(.07)		(8.28)	(.68)	(1.14)	(1.36)	(.10)	(5.15)
July	0.0724	13.0	456.7	11.8		19.66	2.57	2.56	0.94	0.12	25.86
	(.005)	(1.2)	(23.8)	(.6)		(14.82)	(.39)	(2.89)	(0)	i.17)	(11.38)
August	0.0415	9.3	385.6	10.7		13.04	3.22	0.74	0.10	0.48	17.58
	i.001)	(.09)	(11.9)	(.2)		(8.47)	(1.47)	(1.04)	(.14)	(.28)	(5.53)
September	0.0458	9.4	407.0	11.3		12.28	2.02	0.24	0.35	0.32	15.22
	(.006)	(1.4)	(.3)	(1.3)		(6.55)	(2.56)	(.34)	(.16)	(.22)	(3.26)
October	0.0497	8.5	402.6	12.8		14.31	2.82	0.59	0.63	0.33	18.69
	i.01)	(2.5)	(11.3)	(1.4)		(6.90)	(.94)	(.83)	(.89)	i.11)	(4.13)
November	0.0977	13.6	434.8	13.9		15.62	2.91	0.31	1.00	0.40	20.26
	(.007)	(.5)	(.07)	(.8)		(6.25)	(1.69)	(.44)	(1.25)	(.57)	(2.29)
December	0.0894	13.5	419.9	14.2		12.62	3.23	0.43	1.65	0.45	18.40
	i.009)	(.9)	(1.5)	(.5)		(5.46)	(1.14)	(.61)	(.78)	(.20)	(2.73)
January	0.1881	22.8	446.0	16.1							
	(.002)	(0)	(17.6)	(.5)							

a Average of three 50 meter sample stations+
b Average of two 50 meter sample stations+

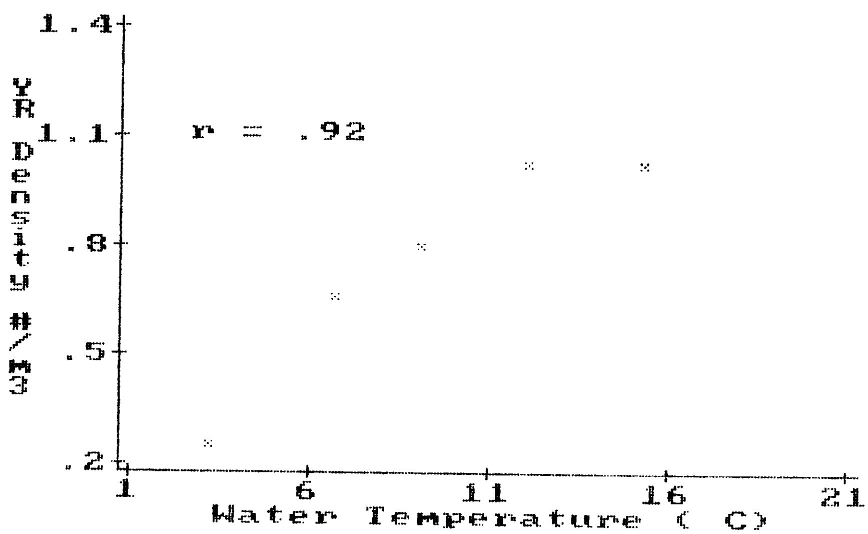


Figure 50. Relation between yearling rainbow-steelhead trout density and average water temperature at the lower study area on Cottonwood Creek from May to December, 1984.

reached 18.8 C (maximum temp.- 26.4 C) the data did not indicate that increased water temperature reduced yearling fish densities. In fact, yearling steelhead survived water temperatures between 17.4 to 26.4 C from July 27 to August 5, 1984. These temperatures surpassed the 12 to 18 C optimum range in water temperature reported by Raleigh et al. (1984). Water temperature data was not available for 1983 to examine the relationship. The highest correlation observed between density or biomass and instream cover components in 1983 was between yearling biomass (g/m^2) and depth greater than 30 cm (r=.46). However, in 1984, this association was negative (r=-.30). Consistent, significant relationships between yearling density and instream habitat were not observed which precluded regression analysis.

Subyearling rainbow-steelhead density in 1983 ranged from 2.34 $fish/m^2$ in June, the highest observed age 0+ density during the study period, down to .26 $fish/m^2$ in January 1984 (Figure 51 and Table 28). These high subyearling densities resulted from a larger adult escapement in 1983 and were observed generally from riffle areas, at a gradient of five percent, that contained large cobble substrate, higher stream velocities and a lot of surface turbulence. Chapman (1966) states that spatial isolation usually prevents competition in riffle areas, and Kalleberq (1958) found that visual isolation among Atlantic Salmon (Salmo salar) and brown trout led to reduced territorial size. Visual isolation appears to have been partially responsible for the high subyearling-densities in 1983 in lower Cottonwood Creek. Declines in subyearling abundance from 2.14 $fish/m^2$ in July to 1.75 $fish/m^2$ in August occurred as stream discharge decreased from .0724 m^3/s to the summer low flow of .0415 m^3/s (Table 27). Pointed decreases in density from October to November and December to January occur as rising stream discharge increases available stream area and during peak movement of subyearling fish in the fall on November 4 and December 12 (see juvenile steelhead outmigration section). Estimated density in 1984 (Figure 52 and Table 28) varied from .37 $fish/m^2$ in June to .54 fish in July and then decreased to .15 $fish/m^2$ in December. The June to July density increase occurs as subyearling fish fully recruited to the gear and as stream discharge dropped (Table 27) markedly from .1083 m^3/s in June to .0317 m^3/s in July, thereby concentrating fish into a smaller area. Average fish density decreased from July to August as average water temperature reached 18.8 C; maximum temperature of 26.4 degrees Centigrade. Raleigh et al. (1984) considered 25 C to be the upper limit suitable for rainbow trout and then only for short periods. Age 0+ rainbow-steelhead in this study area are surviving somewhat higher maximum temperatures for short periods of time. A small decrease in subyearling density from ,245 $fish/m^2$ in November to .15 $fish/m^2$ in December occurred as peak downstream movement takes place in late November and as stream discharge increases.

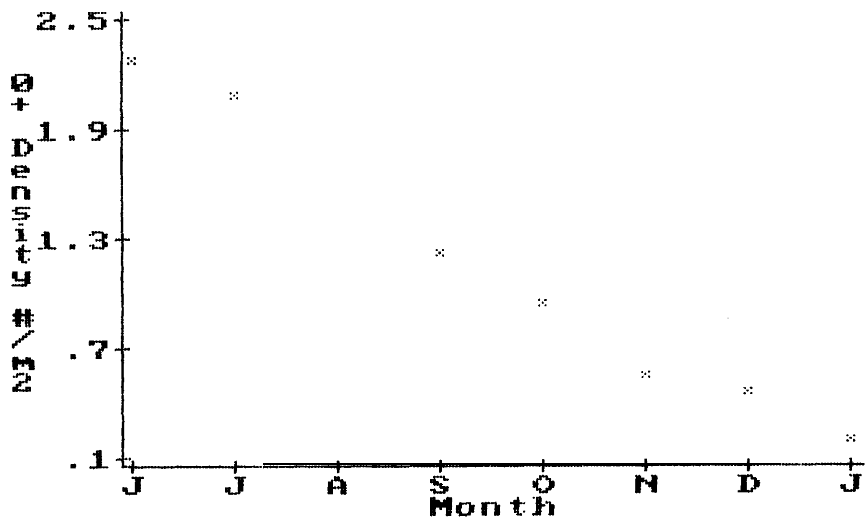


Figure 51. Subyearling rainbow-steelhead trout density at the lower study area on Cottonwood Creek from June, 1983 to January, 1984.

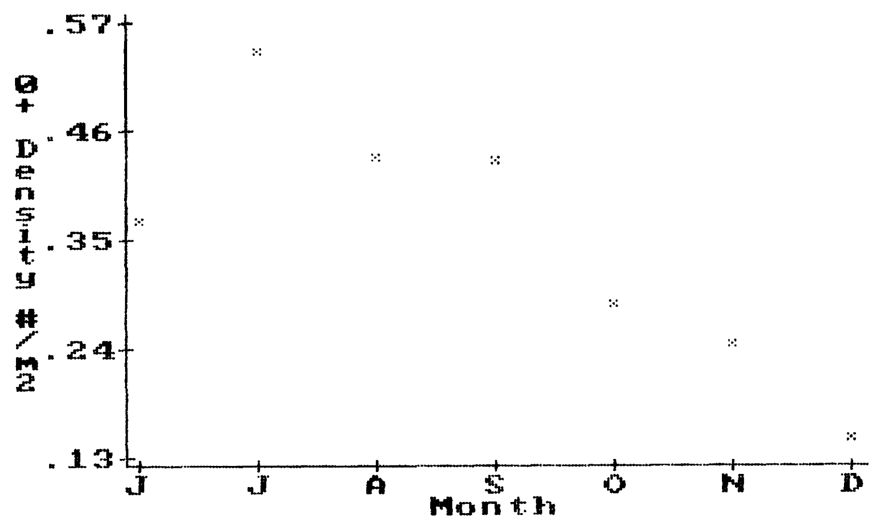


Figure 52. Subyearling rainbow-steelhead trout density at the lower study area on Cottonwood Creek from June to December, 1984.

Table 28. Monthly values of stream area and stream volume sampled and average density and biomass (standard deviation in parenthesis) of subyearling rainbow-steelhead trout collected in the lower study area on Cottonwood Creek in 1983 and 194.

Month	Stream Area Sampled (m2)	Stream Volume Sampled (m2)	Density Number/m2	Density Number/m3	Biomass Grams/m2	Biomass Grams/m3
1984 a						
May	795.3	120.3	-	-	-	-
June	717.3	100.4	0,370 (.08)	2.63 (.58)	0.45 (.07)	3.28 (.78)
July	569.4	74.0	0.540 (.22)	4.24 (1.97)	1.71 (.73)	13.56 (7.02)
August	565.5	62.5	0.435 (.16)	4.21 (2.17)	1.58 (.64)	15.39 (8.28)
September	603.6	76.3	0,430 (.20)	3.50 (1.85)	2.06 (1.11)	16.88 (9.92)
October	637.8	76.5	0.285 (.10)	2.37 (.89)	1.55 i.84)	12.92 (6.59)
November	678.0	115.1	0.245 i.05)	1.44 (.32)	1.26 i.44)	7.49 (2.44)
December	770.4	152.7	0.150 i.02)	0.76 i.21)	0.79 (.01)	4.03 (.72)
1983 b						
May	489.0	78.4	-	-	-	-
June	436.4	52.2	2,340 (.06)	19.61 (.46)	5.75 (.17)	48.05 (1.12)
July	457.0	53.9	2.140 (.58)	18.10 (4.08)	6.86 (1.88)	57.95 (13.06)
August	385.4	41.5	1,750 (.54)	16.23 (4.67)	6.12 (1.86)	56.83 (16.36)
September	407.0	45.9	1,280 (.34)	il.26 (1.81)	5.90 (1.60)	51.78 (8.33)
October	402.4	51.8	1.010 (.17)	7.83 (.50)	6.12 (1.07)	47.41 (3.06)
November	434.8	60.6	0,610 (.007)	4.43 (.37)	4.16 (.08)	29.90 (2.47)
December	420.0	59.8	0,520 (.007)	3.68 (.20)	3.82 (.08)	26.87 (1.50)
Jabuary	446.0	71.9	0.260 (.007)	1.64 (.05)	1.77 (.09)	10.97 (.28)

a Average of three 50 meter sample stations.

b Average of two 50 meter sample stations.

Higher age 0+ abundance in 1983 was due to a higher escapement of adults into the system as reflected by the catch per unit of effort for adult steelhead; 2 fish/man day in 1983 versus 1 fish/man day in 1984. Winter densities of age 0+ steelhead, after peak downstream movement, were almost twice as high in January 1984 (.26 fish/m^2) as in December of 1984 (.15 fish/m^2). Higher densities of subyearling rainbow-steelhead were present in 1983 along with a stronger fall pulse in movement and a spring pulse (1984) in pre-smolt (age I+ fish) outmigration. With lower age 0+ densities in 1984 the fall subyearling pulse in movement was reduced and a much smaller spring pre-smotl outmigration was noted. With the higher adult escapement in 1983, subyearling fish comprised 91 to 96 percent of the total salmonid density present but in 1984 made up 66 to 82.7 percent of the total.

Biomass estimates of subyearling fish in 1983 ranged from 5.75 g/m^2 in June to a high of 6.86 in July and decreased to 1.77 g/m^2 in January, 1984 (Table 28). Subyearling biomass in 1984 averaged less than one-half of the 1983 estimat5s, with a high of 2.06 g/m^2 in September decreasing to .79 g/m during the overwintering period in December. Age 0+ density and biomass was significantly correlated in 1983 (r=.81) but not in 1984. Biomass of subyearling steelhead accounted for the majority (65.6 to 78%) of the total salmonid biomass in 1983 but comprised 10.5 to 50 percent of the total. in 1984.

Estimated subyearling steelhead production at the lower study area varied from 1.66 g/m^2 in 1984 to 8.29 g/m^2 during 1983 (Table 24). Annual production of subyearling fish was estimated in 1983. During 1984, information from November to May was not available and some of the cohort production was missed. Adult escapement was also larger during the spring of 1983. Even with higher fish densities in 1983 the comparative monthly production was twice that of the 3984 estimates (Table 24). Monthly production estimates showed that accumulation of fish flesh was positive during all months except for October of 1984. Production slowed considerably during November of both years. Estimated age 0+ production at the lower study area was more than twice that which occurred at the upper studv area.

Correlation matrices between age 0+ density and biomass and habitat variables showed that stream discharge and subyearling biomass had a significant inverse relationship (Figures 53 and 54). Reduced stream discharge had the effect of concentrating fish into a smaller available area but higher stream flows did not act to reduce subyearling densities. Subyearling density was also significantly associated with water temperature in 1984 (Figure 55). Age 0+ density was not shown to decline with increasing water temperature. However, subyearling density also increased in response to reduced stream flow which concentrated fish. Density would only continue to increase with water

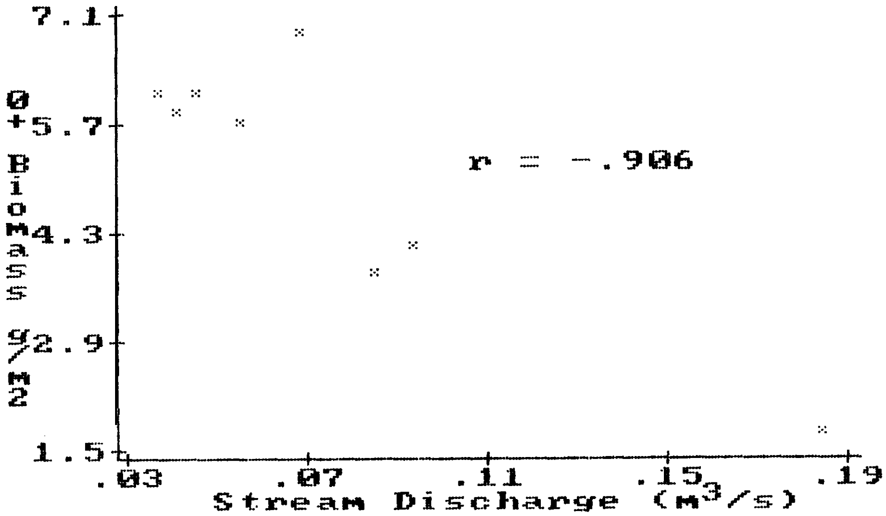


Table 53. Relation between subyearling rainbow-steelhead trout biomass and stream discharge at the lower study area on Cottonwood Creek from June, 1983 to January 1984.

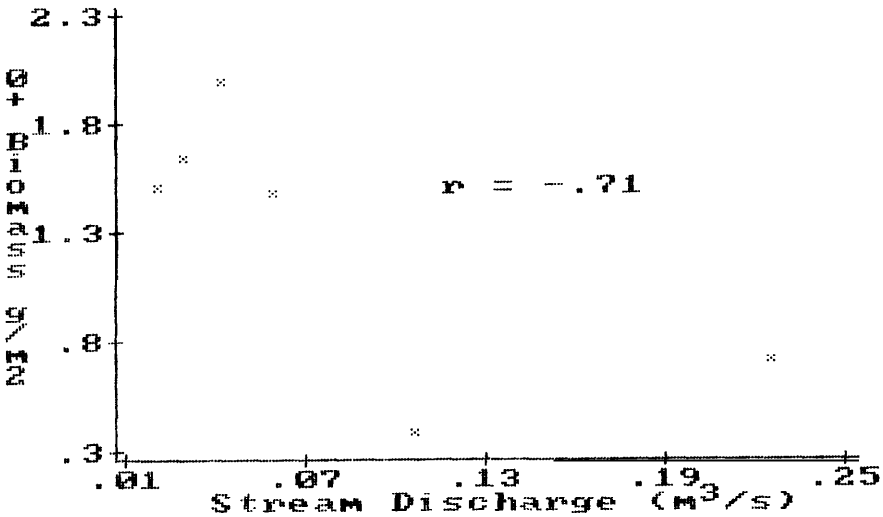


Table 54. Relation between subyearling rainbow-steelhead trout biomass and stream discharge at the lower study area on Cottonwood Creek from June to December, 1984.

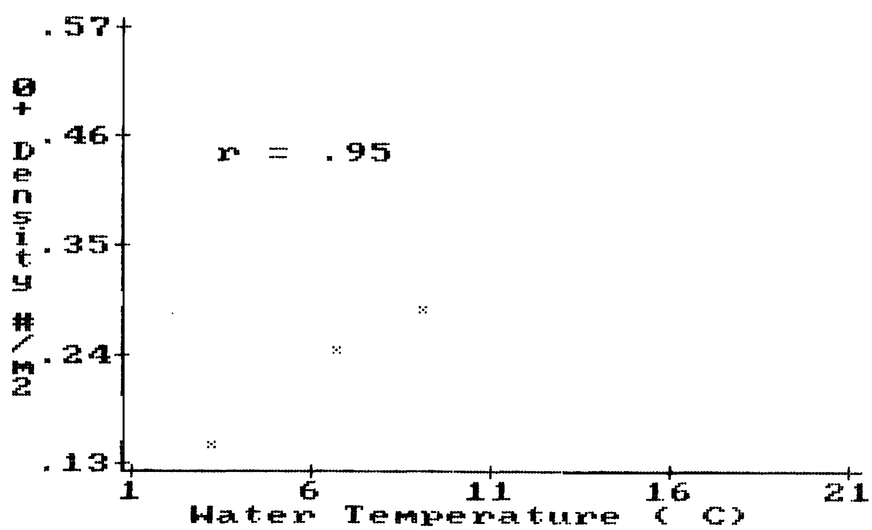


Figure 55. Relation between subyearling rainbow-steelhead trout density and average water temperature at the lower study area on Cottonwood Creek from June to December, 1984.

temperature as the upper lethal temperature was approached, at which point the relationship would truncate. The largest declines in subyearling numbers (not densities) occur from July to August during both years. This decrease, occurs as summer low flows are reached and water temperatures average 19 degrees Centigrade. In July and August, essentially no downstream movement is observed at the fish weir site. Subyearling fish either undergo mortality or emigrate from the sampling stations during this time. yearling biomass and subyearling biomass were significantly correlated during both years of study ($P<0.05$). Further study would have to be conducted to explore if this correlation indicated the possibility of intraspecific predation.

Substrate sampling indicated that the lower study area in Cottonwood Creek contained adequate spawning substrate for adult steelhead. Available spawning substrate in 1983 was estimated to be 35.3 percent of the total available stream area and in 1984, 29.6 percent of the stream area. Cobble embeddedness was visually estimated to be 31.5 percent in 1983 and 28 percent in 1984. The percent of each substrate category is given below, with the 1983 data presented first and 1984 percentages in parenthesis: bedrock 1.7 (0); boulder 12.4 (11.4); large cobble 24.7 (28.4); small cobble 34.9 (35.2); very coarse gravel 17.9 (9); coarse gravel 0 (3); medium gravel 5 (7); fine gravel .6 (1.5); pea gravel 0 (1); sand .2 (.3); and silt 2.4 (2) percent.

<u>Juvenile Steelhead Outmigration</u>

Water Temperature

Water temperature varied considerably in Cottonwood Creek (Figure 56). Temperatures recorded in 1983 appear to fluctuate less than those in 1984. The cause of this variation was due to placement of the 1983 thermograph site 1 km below where the subsurface stream flow resurfaced. The thermograph site was moved downstream, and closer to the trap for the 1984-1985 season. Maximum summer temperatures were as high as 26.4 C and minimum winter temperatures as low as 0.2 degrees Centigrade.

Stream Flow

Stream discharge fluctuated (Figure 56) from a high of 7.52 m^3/s in the spring (April 3, 1985) to a low of 0.02 m /s in the late summer (August 23, 1983). Maximum *flow* exceeded minimum flow by a ratio of 205 to 1 during 1984 when a more complete yearly range in flow measurement was available.

Precipitation

Cottonwood Creek stream flow is influenced by local precipitation throughout the year. There was a significant relationship between average daily precipitation depth at the

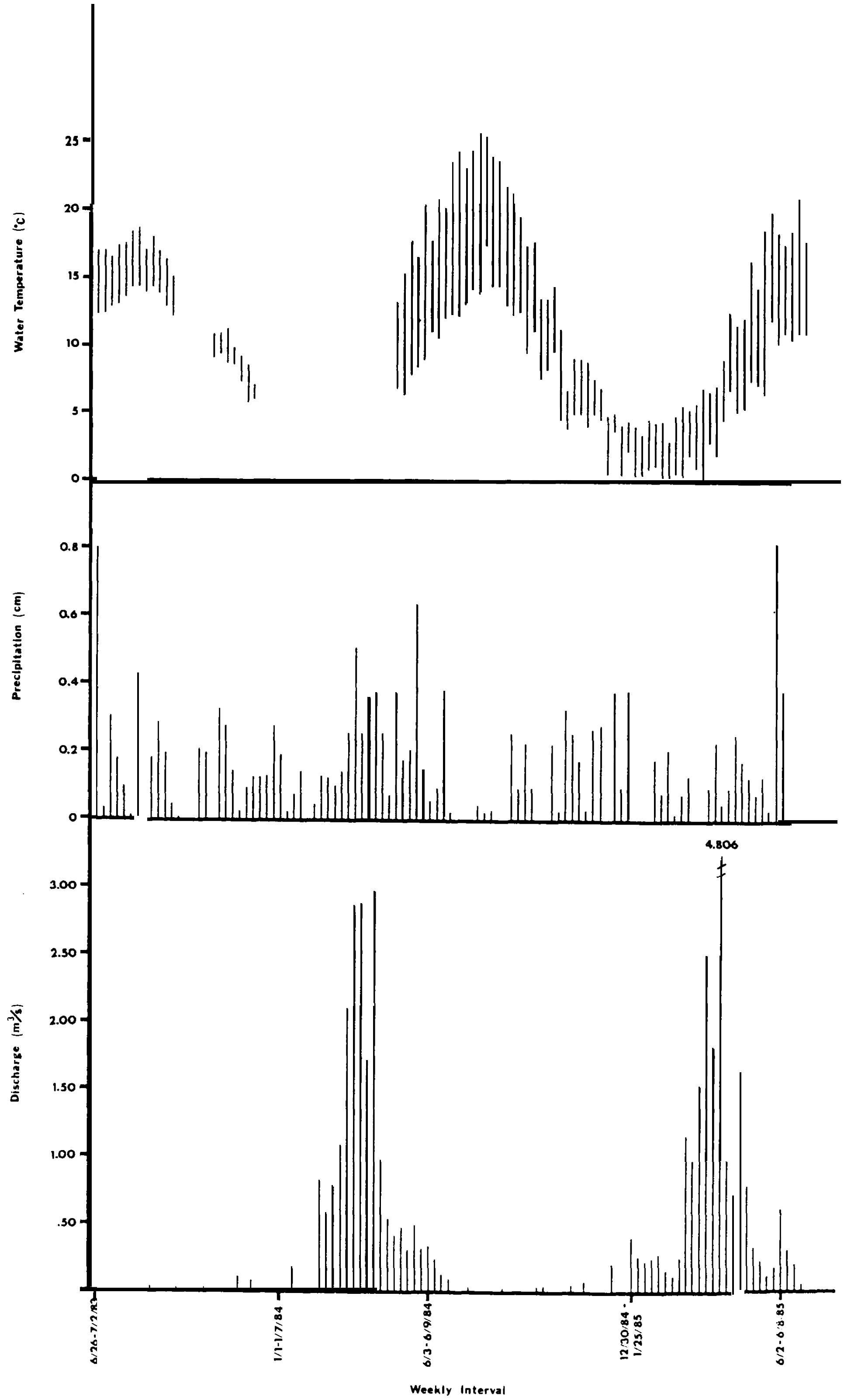


Figure 56. Weekly range in water temperature, mean precipitation depth, and mean stream discharge from June, 1983 to June, 1985 in Cottonwood Creek.

Craigmont and Winchester gage stations and daily discharge in Cottonwood Creek (r=.287, n=86), for the spring, 1984 period when both daily discharge and precipitation data were available. A significant correlation between precipitation and discharge was not observed for the spring of 1985 (r=.004, n=38). Neither was there a significant correlation between mean weekly precipitation depth and mean weekly discharge for both years as illustrated in Figure 56 (r=.18, n=59). However, when the highest weekly discharge and the highest weekly precipitation depth were dropped, the correlation was significant (r=.39, n=57). These results suggest that local precipitation depth does have some influence on stream discharge in Cottonwood Creek. It should be noted that precipitation data is recorded as inches of rainfall., and snowfall depth is converted to rainfall depth. However, data recorded at the trap site generally reflected rainy conditions when snow fell at the higher elevation gage stations. The relationship between precipitation and discharge was expected to be greater in the summer and early fall, than that in the winter and spring, when snowpack does not have as much influence on stream discharge.

Outmigration

There were four periods of rainbow-steelhead trout movement past the Cottonwood Creek trap (Figure 57). There was a fall pulse in 1983, a large spring pulse in 1984, a fall pulse in 1984, and a smaller spring pulse in 1985. Daily fluctuation within each movement period was also observed. Characteristics of each of the movement periods will be discussed below. The reader is directed to the methods section for explanation of YR/LG YR and YOY/SM YR categories.

Fall Outmigration, 1983

Movement began around the 4th of October and extended into late December (Figure 58). A total of 630 YOY and 17 YR rainbow-steelhead trout moved past the trap site during this time. A bimodal distribution indicated peak movement occurred on November 4 and December 1.2. The general trend in outmigration began as water temperature decreased from an average of 10.6 C in October to 6.6 C in December. Average stream discharge also increased during the period from .015 m^3/s in October to .0444 m^3/s in December.

Daily fluctuations in the number of fish moving past the trap were evident and the relationship that water temperature, precipitation and discharge had on daily movement was examined. The daily number of outmigrants (YOY and YR combined) correlated significantly with the daily mean water temperature (Table 29). Movement of subyearling fish also correlated significantly with water temperature. There was no significant relationship between movement of YR's and temperature; possibly due to the

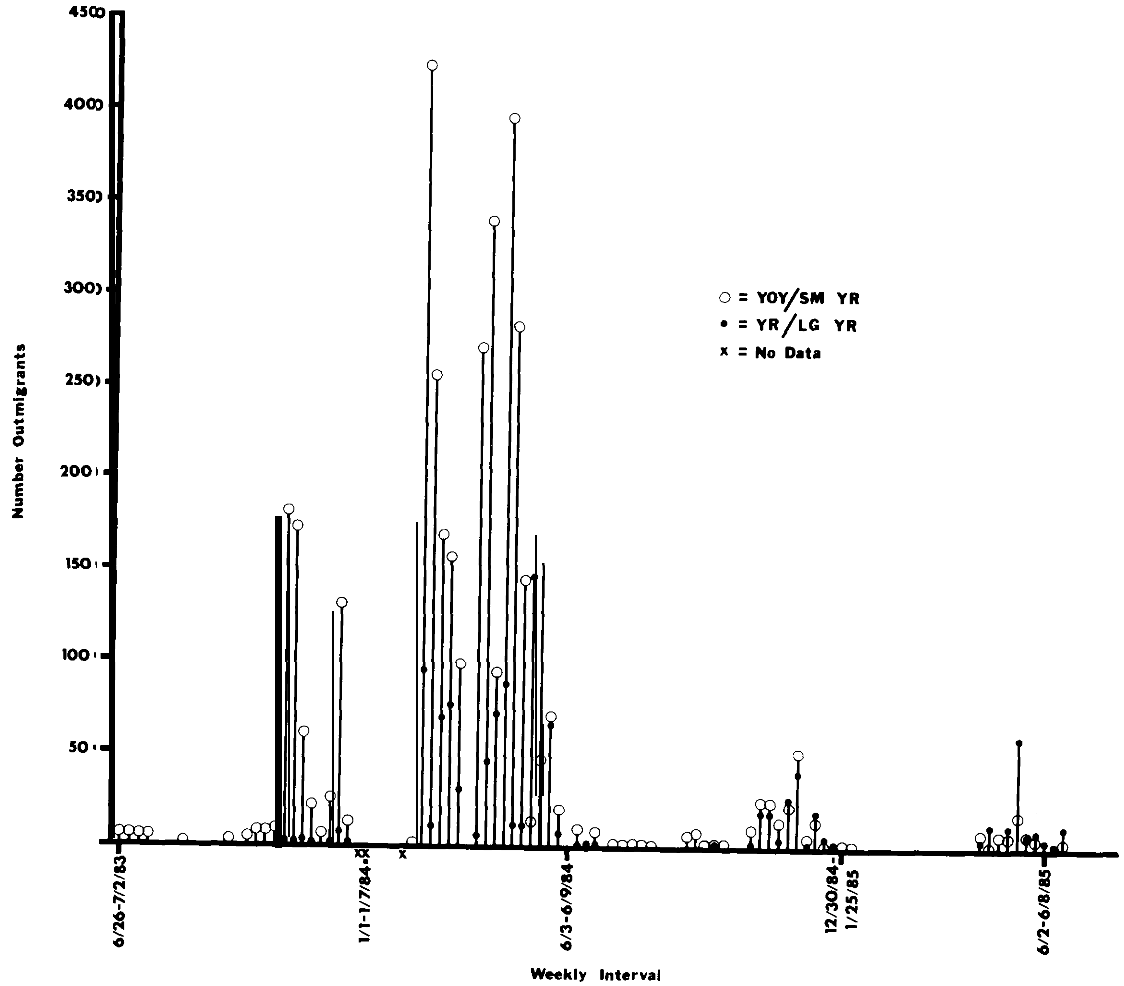


Figure 57. Estimated weekly number of rainbow-steelhead trout outmigrants that moved past the Cottonwood Creek trap site from June, 1983 to June, 1985.

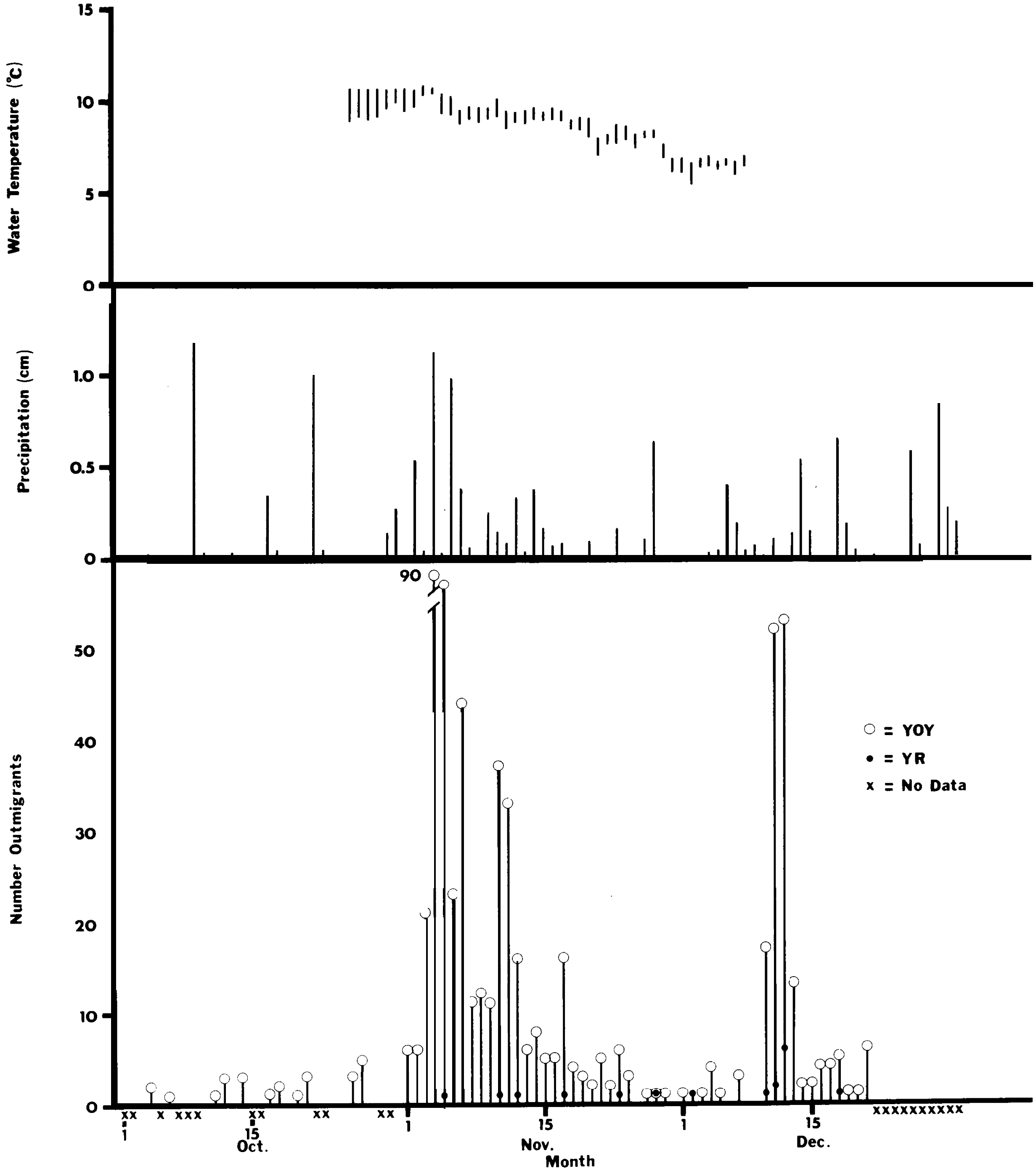


Figure 58. Daily range in water temperature, precipitation depth and number of rainbow-steelhead trout outmigrants that moved past the Cottonwood Creek trap site during the fall of 1983.

Table 29. Correlations between number of outmigrants and precipitation and temperature data for the fall period, 1983.

Dependent Variable (Y)	Independent Variable (X)	Sample Size (n)	Correlation Coefficient (r)	Significance Level
#YOY	Precipitation	69	0.426	0.05
# YR	Precipitation	69	0.002	NS
#TOTAL	Precipitation	69	0.416	0.05
#YOY	Temperature	42	0.479	0.05
# YR	Temperature	42	0.023	NS
#TOTAL	Temperature	42	0.477	0.05

low number of yearling migrants (n=17). The daily number of outmigrants (YOY and YR combined) also correlated significantly with average precipitation depth at upper watershed gauge stations (Table 29). Bjornn (1971) suggested that small freshets which occur during the fall increase the number of fish outmigrating. Our data also indicates this effect.

The length of the outmigrants appeared to be fairly consistent throughout the movement period (Figure 59). A few larger individuals moved out in December, but a distinct shift in size distribution was not evident. The mean total length of subyearling migrants in the fall was 90.3 mm, and mean total length of yearling migrants was 142.8 millimeters.

Spring Outmigration, 1984

The spring pulse in outmigration began on February 13 and extended through June 12 (Figure 60), with a peak occurring during the week of May 13th. Steelhead passage at Lower Granite Dam, in 1984, peaked about May 15th (McConnaha et al. 1985). Of the estimated 3706 rainbow-steelhead moving past the Cottonwood trap, 2741 were YOY/SM YR and 965 were YR/LG YR. Generally, migration began as water temperatures increased.

During the spring period, two fishing traps were employed. The fish weir was utilized until February 14, and the fyke net from February 15 through May 7. The weir was reinstalled on May 7 and fished throughout the remainder of the year.

The number of outmigrants passing the weir is more accurate than the estimate of those passing the fyke net. An estimated 2601 YOY/SM YR and 522 YR/LG YR moved past the fyke net. A total of 140 YOY/SM YR and 443 YR/LG YR moved past the fish weir. This difference in accuracy became important in evaluating environmental. influences on daily outmigration.

There was no significant correlation between the number of outmigrants and precipitation, discharge, or temperature, with the exception of number of YOY/SM YR and temperature (Table 30). When the weir data was considered alone, a significant negative correlation was found between temperature and number of outmigrants (YOY/SM YR and YR/LG YR, combined, and separately) . A higher, but non-significant relationship was noted between number of YR/LG YR and discharge from the fyke net data, and between number of YOY/SM YR and precipitation from the fish weir data.

A shift in length frequency of the outmigrants occurred during the spring period (Figure 61). Larger fish predominated as the outmigration period progressed. In May, the number of YF/LG YR steelhead (smolts) surpassed that of the smaller fish

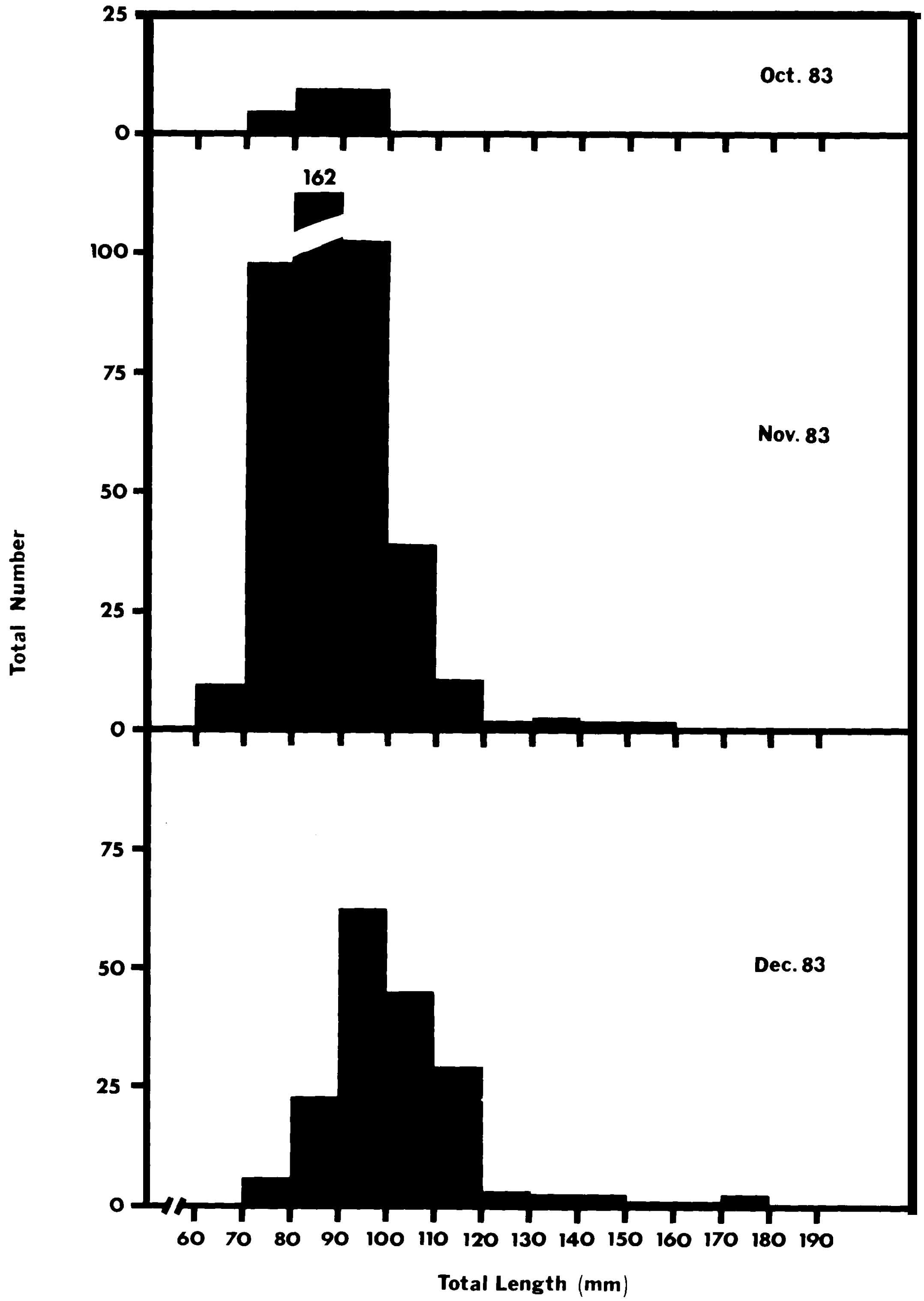


Figure 59. Length frequency of rainbow-steelhead trout that moved past the Cottonwood Creek trap site during the fall of 1983.

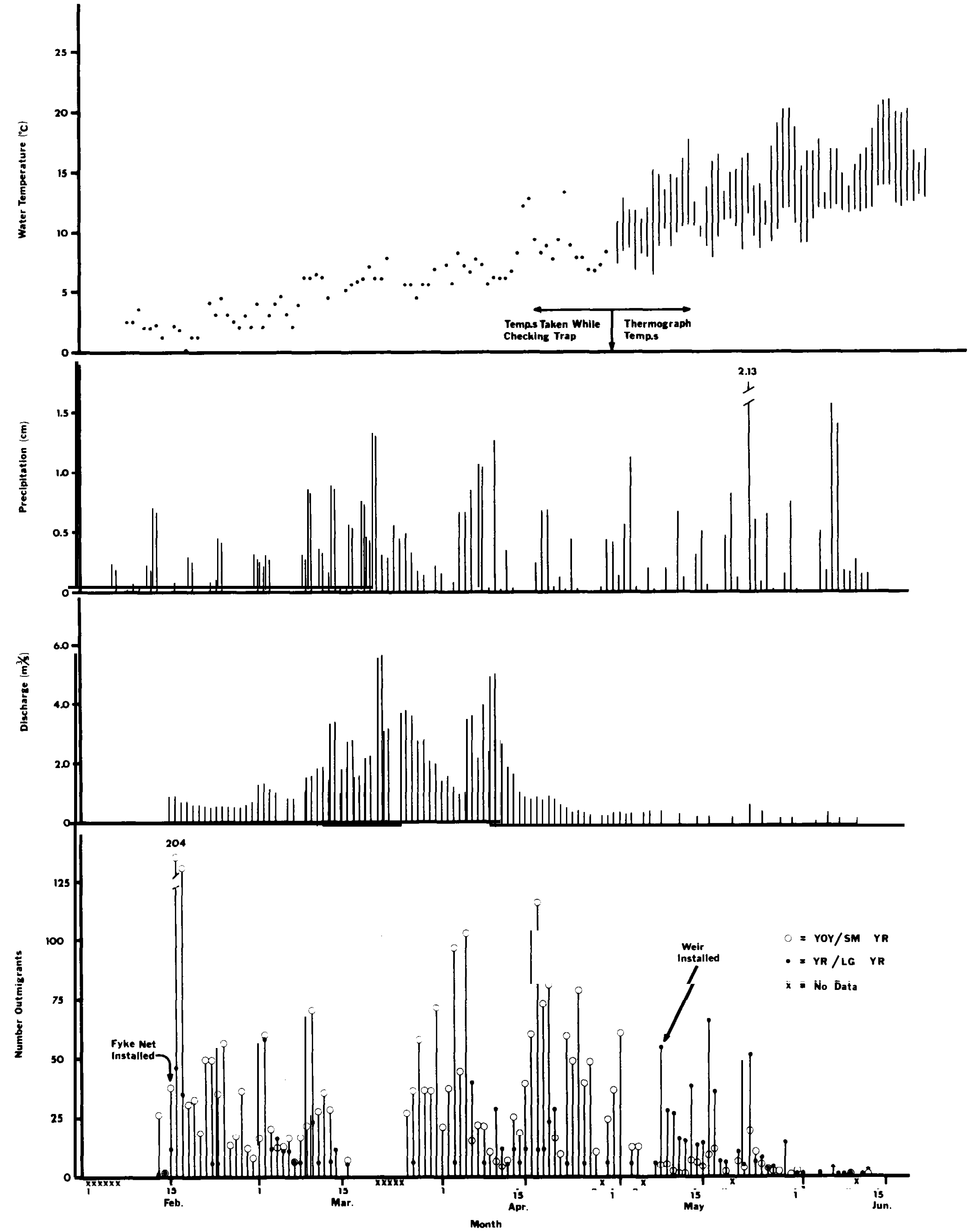


Figure 60. Daily water temperature, precipitation depth, stream discharge and number of rainbow-steelhead trout that outmigrated past the Cottonwood Creek trap site during the spring of 1984.

Table 30. Correlations between number of outmigrants and precipitation, discharge and temperature data on Cottonwood Creek during the spring, 1984.

Dependent Variable (Y)	Independent Variable (X)	Sample Size (n)	Correlation Coefficient (r)	Significance Level
#YOY/SM YR	Precipitation	111	-0.062	NS
#YR/LG YR	Precipitation	111	0.146	NS
#TOTAL	Precipitation	111	0.008	NS
#YOY/SM YR	Discharge	84	-0.038	NS
#YR/LG YR	Discharge	84	0.133	NS
#TOTAL	Discharge	84	0.007	NS
#YOY/SM YR	Temperature	37	-0.373	0.05
#YR/LG YR	Temperature	37	-0.166	NS
#TOTAL	Temperature	37	-0.228	NS
#YOY/SM YR	Precipitation	78	-0.035	NS
#YR/LG YR a	Precipitation	78	0.187	NS
#TOTAL a	Precipitation	78	0.022	NS
#YOY/SM YR a	Discharge	71	-0.177	NS
#YR/LG YR a	Discharge	71	0.211	NS
#TOTAL a	Discharge	71	-0.092	NS
#YOY/SM YR b	Precipitation	33	0.304	0.10

Table 30. Continued

Dependent Variable (Y)	Independent Variable (X)	Sample Size (n)	Correlation Coefficient (r)	Significance Level
#YR/LG YR b	Precipitation	33	0.059	NS
#TOTAL b	Precipitation	33	0.114	NS
#YOY/SM YR b	Discharge	14	0.251	NS
#YR/LG YR b	Discharge	14	0.022	NS
#TOTAL b	Discharge	14	0.091	NS
#YOY/SM YR b	Temperature	33	-0.338	0.05
#YR/LG YR b	Temperature	33	-0.361	0.05
#TOTAL b	Temperature	33	-0.360	0.05

a = Data during fyke net period only.

b = Data during Weir net period only.

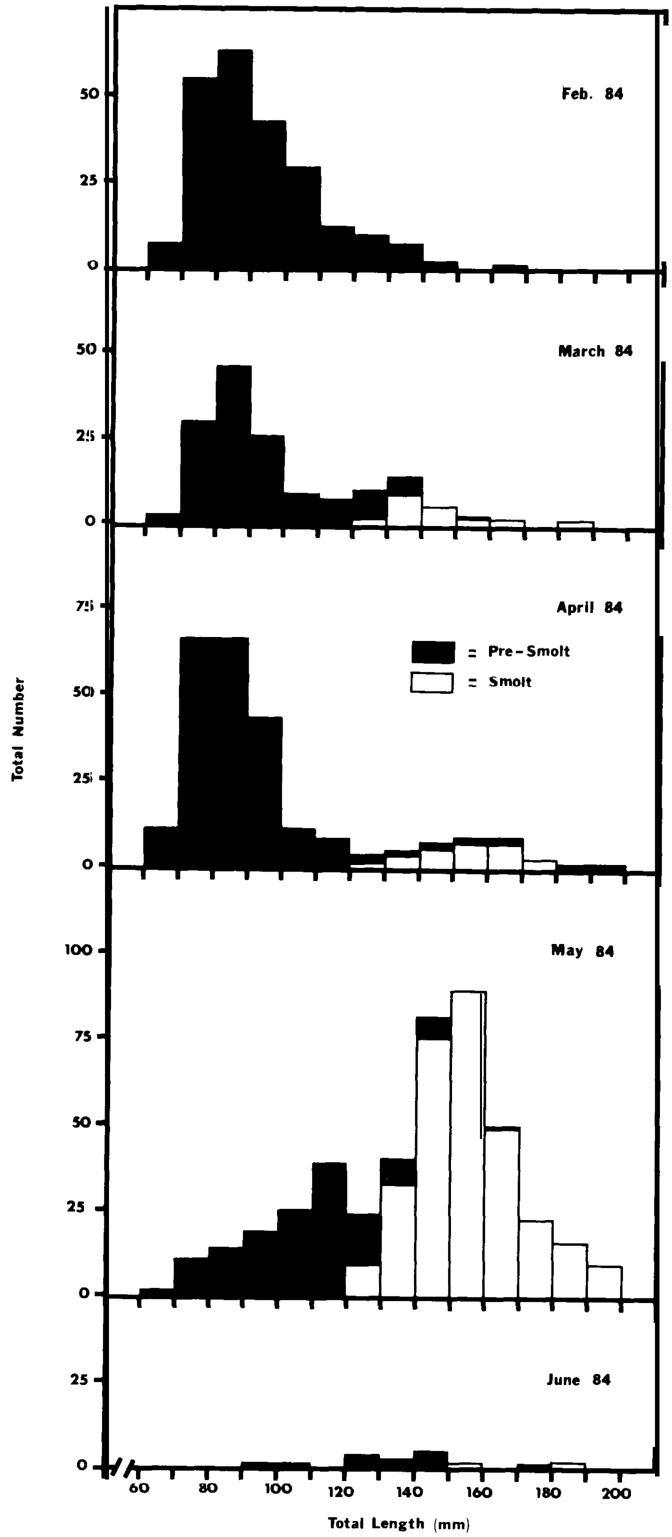


Figure 61. Length frequency of rainbow-steelhead trout that migrated past the Cottonwood Creek trap site during the spring of 1984.

(pre-smolts). We believe this reflects the reduced efficiency of the fyke net in trapping steelhead smolts under lower flow conditions. These conditions existed prior to replacement of the fyke net with the fish weir in early May (Figure 60). Mean length of YOY/SM YR fish during the spring was 88.4 mm and mean length of YR/LG YR fish was 150.5 millimeters.

During the spring period, smoltification became evident in the outmigrants. Smolts had the typical silvery appearance, elongated body and deciduous scales of steelhead smolts. The first distinguishable smolts were observed on March 2, 1984. Not all of the large yearling (LG YR) fish that migrated downstream had the "silvery" coloration of a smolt, but it was assumed that they were indeed smolts. Of 522 large yearling fish estimated to have passed the fyke net 50 percent were visually distinguishable as smolts; and of 443 fish sampled from mid-April on, approximately 82.8 percent appeared to be smolts. The mean length of the distinguishable smolt fish (154.5 mm) was similar to the length of YR/LG YR fish mentioned above (150.5 mm). The average length of Cottonwood Creek smolts is smaller than the mean length of wild steelhead smolts (181 mm) collected in the lower Clearwater River (Scully et al. 1984).

Fall Outmigration, 1984

Downstream movement in the fall began on October 22 and ended December 26, (Figure 62) with the peak occurring in late November. The number of subyearling fish outmigrating in 1984 (156) was only one-fourth that of the 630 fish that moved downstream in the fall of 1983. A total of 139 yearling rainbow-steelhead moved past the Cottonwood trap in 1984 compared to 17 fish in the fall of 1983. Bjornn (1978) surmised that yearling (age I+) fish that left Rig Springs Creek in the fall and winter did so because of a lack of overwintering habitat. As seen in 1983, movement coincided with decreasing water temperatures. Several reporters have shown steelhead to enter substrate chambers at water temperatures of 4-6 C where, presumably, they overwinter (Chapman and Bjornn 1969; Bjornn 1971; Bustard and Narver 1975). Some subyearling fish were still moving downstream in Cottonwood Creek at water temperatures below 4 degrees Centigrade.

Daily movement was tested for correlation with temperature and precipitation (Table 31). Number of outmigrants, YOY, YR and both classes combined, were significantly correlated with precipitation. A higher, but non-significant correlation was also observed with all groups and water temperature.

No major shift in outmiqrant length frequency occurred during the fall pulse in downstream movement (Figure 63). It was evident, however, that considerably more yearling fish moved downstream in 1984 versus 1983. Yearling densities were

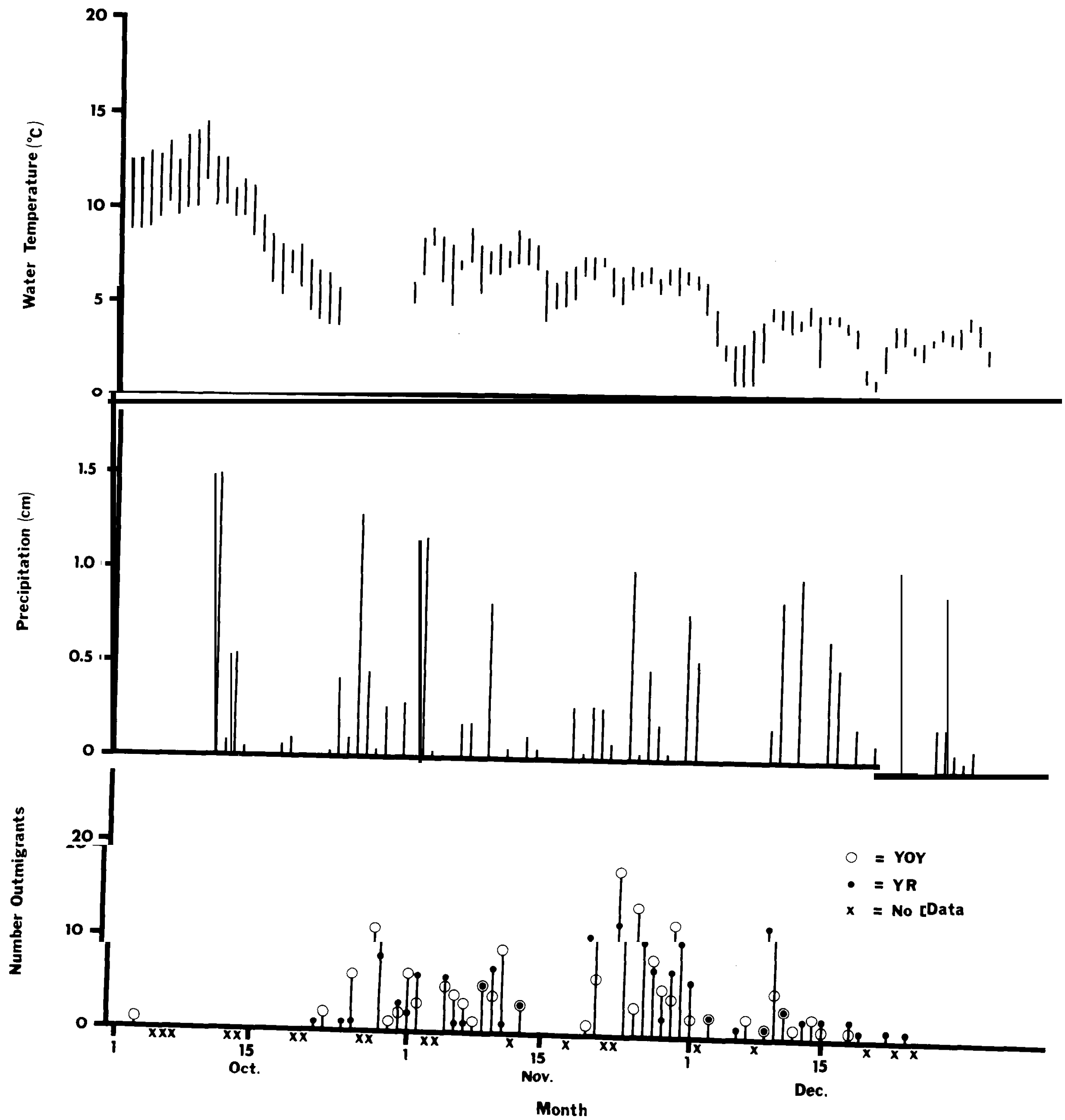


Figure 62. Daily range in water temperature, precipitation depth and number of rainbow-steelhead trout that moved past the Cottonwood Creek trap site during the fall of 1984.

Table 31. Correlations between number of outmigrants and precipitation, and number of outmigrants and water temperature in Cottonwood Creek, during the fall, 1984.

Dependent Variable (Y)	Independent Variable (X)	Sample Size (n)	Correlation Coefficient (r)	Significance Level
#YOY	Precipitation	51	0.452	0.05
#YR	Precipitation	51	0.474	0.05
#TOTAL	Precipitation	51	0.493	0.05
#YOY	Temperature	51	0.263	0.10
#YR	Temperature	51	0.254	0.10
#TOTAL	Temperature	51	0.277	0.10

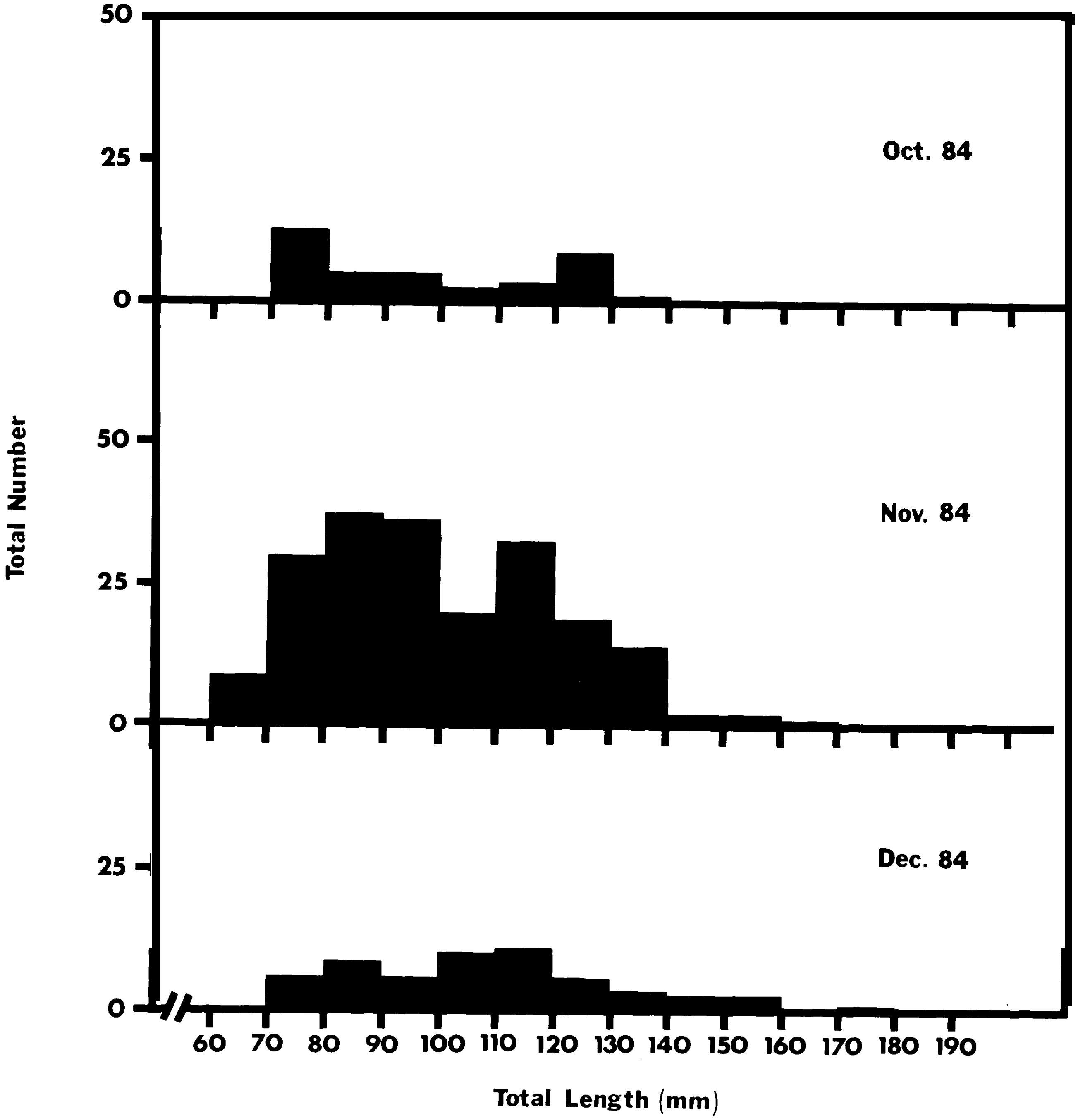


Figure 63. Length frequency of rainbow-steelhead trout that moved past the Cottonwood Creek trap site during the fall of 1984.

slightly higher at the upper study area in 1984 (Table 22) than in 1983, but lower study area densities were more similar between years (Table 26). Mean length of age 0+ outmigrants was 83.0 mm and mean length of yearling outmigrants was 119.4 millimeters.

Spring Outmigration, 1985

A minor pulse of outmigrant movement occurred in the spring of 1985 from April 17 until June 3. Only 22 YOY/SM YR and 154 YR/LG YR rainbow-steelhead moved past the trap (Figure 64).

The fyke net was fished from February 28 to April 16 and during this time, 16 YOY/SM YR and 24 YR/LG YR fish were captured. No fish were recaptured and therefore a trap efficiency was not available to estimate the number of outmigrants. It is believed that the low number of captured fish is partly the result of stream conditions which affected trap placement (see methods) but also may reflect a limited outmigrant movement.

No significant correlations existed between daily number of outmigrants and temperature, discharge or precipitation (Table 32). Outmigrant length shifted somewhat as the spring period progressed (Figure 65). The mean length of YOY/SM YR fish was 86.1 mm, and YR/LG YR mean length was 146.8 mm. Average length of fish that had the typical silvery appearance of a smot was 159.8 millimeters. Of the 154 yearling fish that moved past the trap site, 46 percent were visually distinguishable as smolts; all yearling fish were assumed to be smolts.

Outmigration Discussion

The spring 1984 data indicated that a large number of small yearling (age I+) and young-of-the-year fish migrated past the trap early in the season followed by a pulse of larger, smolt-size fish later in the season. The larger yearling (LG YR) fish were smolts, age II+ fish, as indicated by scale analysis. The majority of steelhead smolts (90% plus) were age II+ fish with the remainder being age I+ individuals. The peak of outmigration in 1984 occurred during the week of May 13th, and smolt passage at Lower Granite Dam peaked about May 15 (McConnaha et al. 1985). Steelhead smolts comprised only 26 percent of the fish moving past the trap site in 1984, with pre-smolt fish making up the remaining 74 percent. The initial movement of younger fish (age 0+ and small I+) in Cottonwood Creek is contrary to results reported on steelhead trout (Stauffer 1972; Kwain 1983) in which older and then younger fish move as the spring migration period progressed. This might be attributed to variations in fyke netting efficiency in capturing large versus smaller fish; or perhaps the smaller fish naturally outmigrate and rear in the mainstem river prior to outmigrating the following spring.

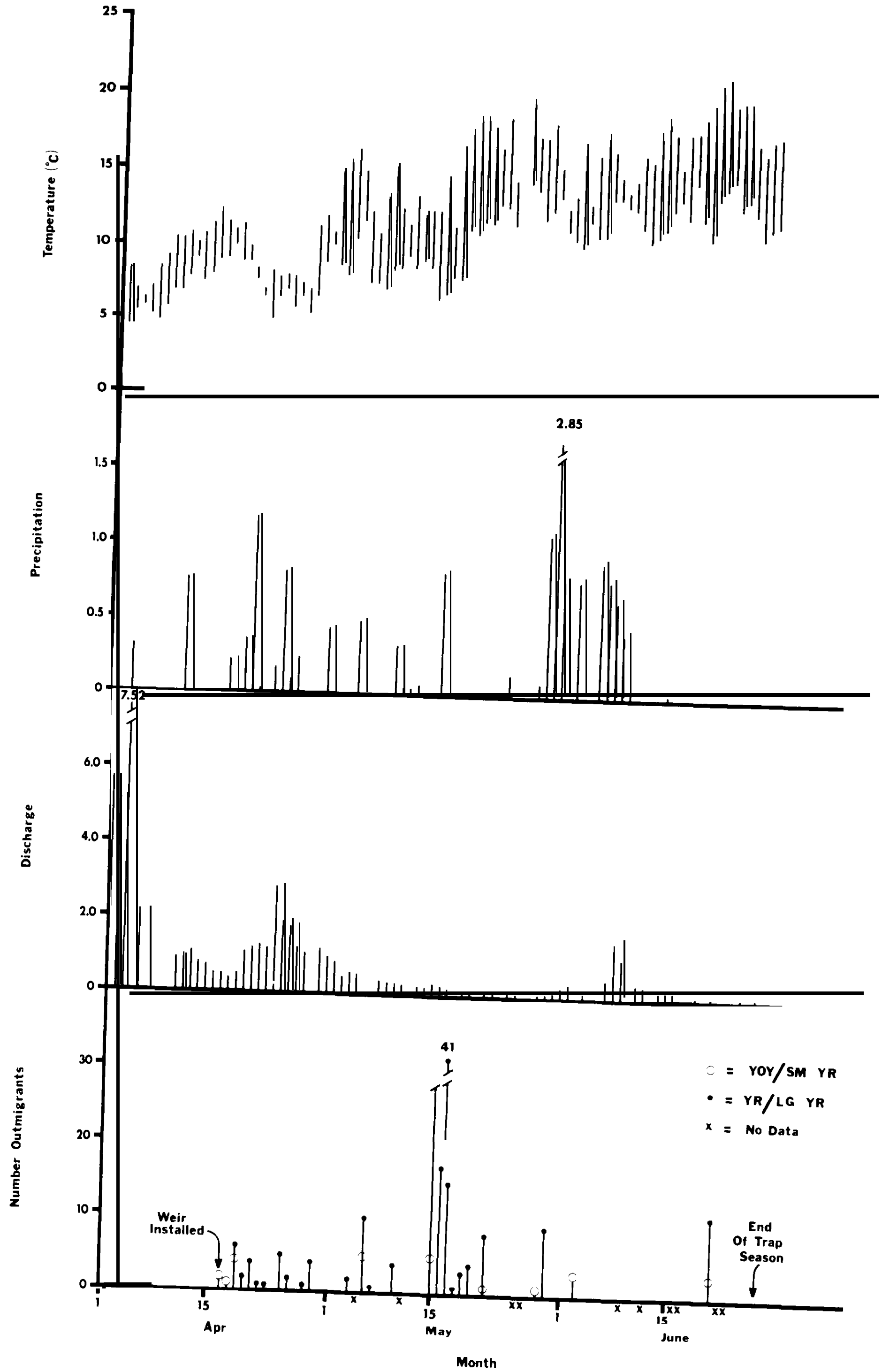


Figure 64. Daily range in water temperature, precipitation depth, stream discharge and number of rainbow-steelhead trout that migrated past the Cottonwood Creek trap site during the spring of 1985.

Table 32. Correlations between number of outmigrants and precipitation, discharge and temperature data on Cottonwood Creek during the spring, 1985.

Dependent Variable (Y)	Independent Variable (X)	Sample Size (n)	Correlation Coefficient (r)	Significance Level
#YOY/SM YR	Precipitation	44	0.164	NS
#YR/LG YR	Precipitation	44	-0.115	NS
#TOTAL	Precipitation	44	-0.074	NS
#YOY/SM YR	Discharge	38	-0.021	NS
#YR/LG YR	Discharge	38	-0.098	NS
#TOTAL	Discharge	38	-0.091	NS
#YOY/SM YR	Temperature	44	-0.165	NS
#YR/LG YR	Temperature	44	0.097	NS
#TOTAL	Temperature	44	0.058	NS

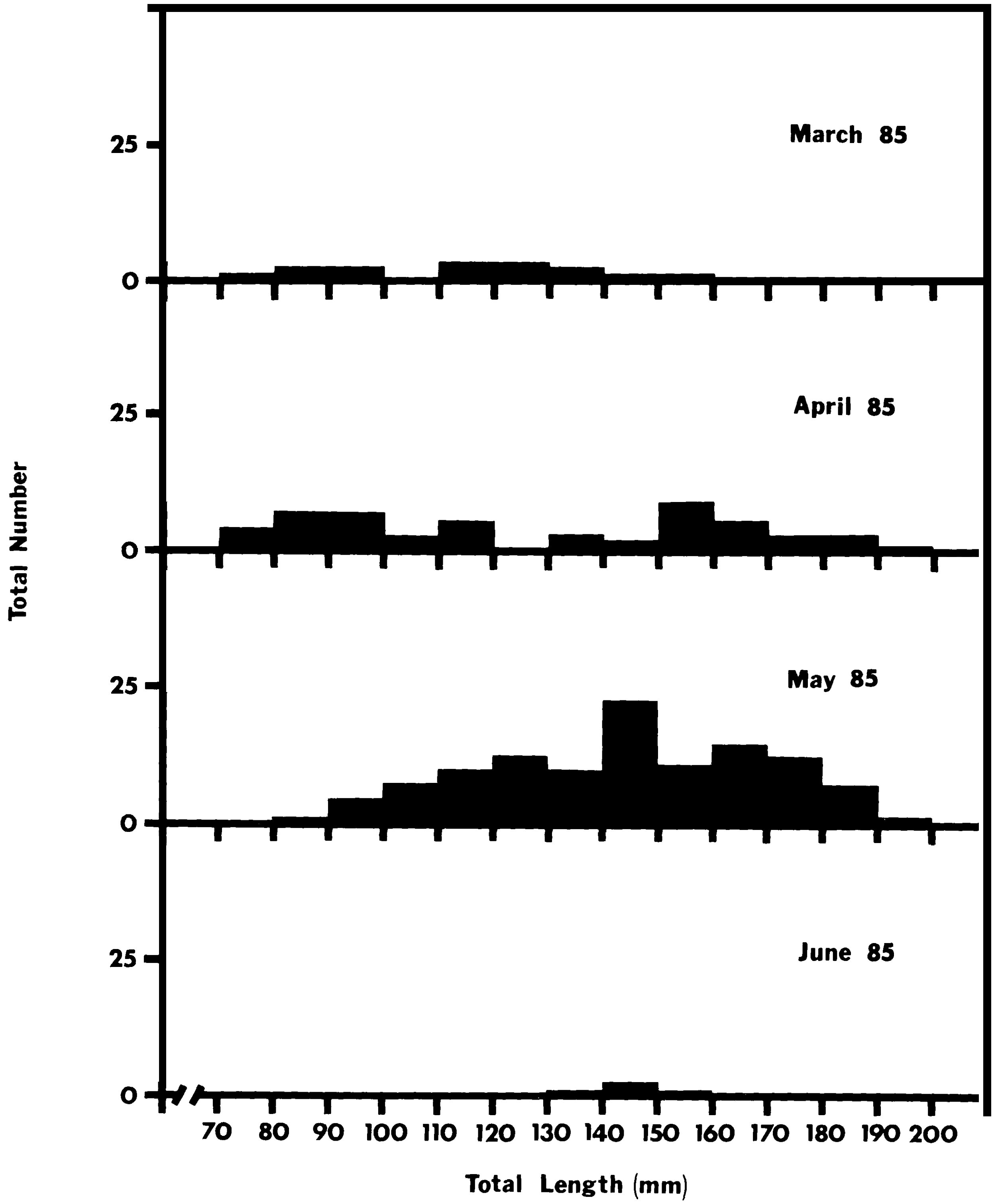


Figure 65. Length frequency of rainbow-steelhead trout that migrated past the Cottonwood Creek trap site during the spring of 1985.

Higher densities of age 0+ steelhead in the stream in 1983 evidently contributed to the 1983 fall pulse in subyearling outmigration. In 1984, when lower densities of subyearling fish were present in the stream, a smaller fall pulse in movement was observed. Bjornn (1978) reported a fall migration of subyearling rainbow-steelhead trout in Big Springs Creek, Idaho which he attributed to lack of overwintering habitat. Bjornn also noted that some fish may have an innate motivation to move downstream in the fall, regardless of fish density or available winter habitat. Bjornn (1971) reported that in Big Springs Creek, a tributary similar in size to Cottonwood Creek, subyearling migrants outnumbered the smolt migrants. In the Lemhi River, however, the number of smolts moving in the spring outnumbered all other age groups. Whether the subyearling and smaller yearling fish from Cottonwood Creek and other lower Clearwater tributary streams utilize the Clearwater or Snake Rivers as an additional rearing area or move back into tributary streams is poorly understood. The lower Snake River reservoirs do not provide adequate salmonid habitat during the summer period due to elevated water temperatures (David Bennett- personal communication).

Daily movement of smolt and pre-smolt fish during the spring was not related to discharge, precipitation or temperature. Other researchers (Eales 1965; Bagqerman 1960) have suggested that photoperiod might induce smoltification and hence movement of juvenile salmonids. The effect of photoperiod on migration was not tested in this study. Our results show that migration coincides with an increase in water temperature, but this should not be perceived to be a causal relationship. Bjornn (1971) cited evidence that salmonid migration occurs even under constant temperature regimes. The 1984 weir data indicates an inverse relationship between outmigration and temperature. However, the number of smolts moving past the Cottonwood Creek trap increased abruptly following the placement of the weir trap on May 7. This suggests that the more efficient weir trap sampled some portion of the outmigration and that the ineffective fishing of the fyke net during lower flows, before transition to the fish weir, may mask any relationship between temperature and outmigration.

The limited number of fish moving past the trap in the spring of 1985, was not completely understood. Most data on steelhead smolts document that the primary movement period occurs during the spring or early summer. It was believed that the low number of smolts trapped was partly the result of stream conditions which affected trap placement, but also may reflect a low number of outmigrants. Winter densities of yearling fish were very similar in 1983 and 1984, suggesting that the carrvinq capacity was being approached. The 1985 smolt yield should have been similar in magnitude to the 1984 outmigration. However, this was not observed.

Cottonwood Creek smolts are relatively small as compared with other Snake River basin steelhead smolts. Scully et al. (1984) reported that the average length of wild steelhead smolts collected in the lower Clearwater River was 181 mm. Those migrating out of the Cottonwood system were somewhat smaller, ranging in length from 154 to 160 mm over the two year study period.

In the spring of 1984, 965 smolts were estimated to have migrated past the weir site. This represents the smolt yield from about 5.2 kilometers of stream; as the weir was located at skm 4.4. Since the lower 4.4 km of stream was of lesser quality, we estimated that approximately 1,500 smolts, total, outmigrated in 1984. The projected smolt yield, from December population estimates, was 2,074 fish. This level of smolt yield is rather low if the system is dependent on adult returns, to seed the stream, from this number of smolts. However, 4,533 pre-smolt fish were estimated to have migrated in the spring of 1984 (for the entire 9.6 km) and another 630 subyearling fish moved past the weir during the fall of 1983. During the spring of 1985, 154 smolts were estimated to have moved past the trap site and a total of 255 smolts outmigrated out of the stream. The 1985 smolt yield, projected from December population numbers, was estimated to be 3,371 fish. Although problems were encountered in effectively fishing the fyke net in 1985, if a large number of outmigrants had moved downstream the fyke net would have sampled more fish. When the fyke net was replaced with the fish weir there was not a large immediate increase in number of fish caught which would indicate ineffective sampling by the fyke net. Therefore, it appears that smolts moved earlier and/or a smaller number of fish outmigrated during the spring of 1985. This magnitude of smotl yield, 1,500 fish in 1984 and 255 fish in 1985, pose questions in terms of what factors or combination of factors may be important to the continued survival of steelhead runs into Cottonwood Creek and other lower Clearwater River tributary streams. The following discussion is presented to utilize the present data to postulate scenarios in the survival of these steelhead runs, and to point out where "knowledge gaps" exist.

Based on the data from two years of outmigrant trapping on Cottonwood Creek one can hypothesize that: 1.) adult steelhead returns are dependent on the smolt yield from the stream, or 2.) adult steelhead returns are not dependent on the smolt yield from the stream. If the adult steelhead return in Cottonwood Creek was dependent on a smolt yield of 1,500 fish (1984), the smolt to adult survival would have to be at least two percent which would return 30 adults to seed 9.6 km of stream. This number of adults would not fully seed the stream based on a male to female sex ratio of 1:2.36 fish (n=47); based on adult collections over the two year study period. Length of ocean residence could affect these estimates in terms of the year of adult return, but 90 percent plus of the outmiqrating smolts represented one age group (age II+ fish). If adult steelhead returns were dependent on a smolt yield of 255 fish (1985) there would not be a viable spawning population. To the authors knowledge, there is no available information on smolt to adult survival on upriver wild or natural steelhead runs. This information needs to be gathered to effectively manage upriver steelhead stocks.

If adult steelhead returns are not entirely dependent on smotl yield from Cottonwood Creek other factors may influence adult returns: 1.) outmigrating pre-smolt fish may rear in the Clearwater or Snake Rivers or return to tributary streams and make a contribution to the adult returns; 2.) lower Clearwater River tributary streams may depend on adult strays from other streams or Dworshak hatchery, and 3.) some combination(s) of the above factors may occur.

It is unknown whether or not the 4,533 pre-smolt fish (x length-88.4 mm) that outmigrated in the spring of 1984, reared in the mainstem rivers, moved into tributaries and migrated the following spring or underwent mortality. What contribution these spring pre-smolts and the fall subyearling outmigrants make to the percent of returning adult steelhead or the distribution and survival of these fish in mainstem habitats is poorly understood. As mentioned previously, lower Snake River reservoirs apparently do not provide adequate summer salmonid habitat. Secondly, adult straying from other streams and from Dworshak National Fish Hatchery, into Cottonwood Creek, is difficult to analyze. Electrophoretically, Cottonwood Creek steelhead were most similar to the Big Canyon Creek population among Reservation streams (Appendix A). During adult steelhead collections in Cottonwood Creek, no identifiable hatchery fish were sampled. Bedrock Creek steelhead, however, were the only population not significantly different from Dworshak Hatchery Fish (Appendix A). Adult fish marked at the Dworshak facility and released have been collected in Bedrock Creek. The Bedrock Creek and Mission Creek populations broke out together in a cluster analysis of genetic similarity, suggesting that Mission Creek fish may also have been influenced by Dworshak Hatchery fish. Finally, any combination of the factors discussed above may act together in the life history strategy of steelhead trout in lower Clearwater River tributary streams.

Juvenile Steelhead Age and Growth

A total of 198 juvenile rainbow-steelhead trout were aged by the scale method to separate age groups for density, biomass and production estimates and outmigration information. Two groups of fish were recognized during this study: yearlings (age I+, age II+ and older) and subyearling (age O+). Yearling rainbow-steelhead ranged in size from 70 to 305 mm in total length and varied in weight from 3 to 287 grams. The largest fish sampled was an age III+ individual and was 305 mm lonq and weighed 287 grams. About 90 percent of the fish examined were age I+ rainbow-steelhead which ranged in length from 70 to 199 mm and in weight from 3 to 70 grams. The few age II+ fish sampled varied in total length from 157 to 258 mm and in weight from 38 to 152 grams. Several smaller age II+ fish were collected that were marked fish from the previous years work. They were as small as 128 mm in length and 17 g in weight. Subyearlinq rainbow-steelhead varied up to 129 mm in length and 11.6 g in weight by January.

Average length of yearling fish at the upper study area (Table 33) was greater in 1983 than in 1984. Yearlinq rainbow-steelhead in May of 1983 were 120 mm in length, compared to 106 mm in 1984, and remained 10 to 20 mm longer and about 4 to 9 g heavier in weight. Yearling fish from the lower study area were similarly larger in 1983 compared to 1984 (Table 34). Average fish weight at the upper study area (1983) was more variable than the 1984 weights, with the lowest condition factor occuring in October (.59) durinq low summer stream flow (.015 m^3/s) and in January. Condition factors in 1984 ranged from .74 to . 88 with the lowest condition factor occuring in December (.71 during the overwintering period. Yearling rainbow- steelhead trout at the lower study area were generally larger in size than upper study area fish (Tables 33 and 34). Most fish growth in 1984, at both study areas occurred from May to June, with some growth continuing to August at the upper study area, and then leveling off or declining into the winter period. Yearling growth in weight in 1983 appeared sporadic at both study areas. Fish were also larger in length and weight in 1983 compared to 1984. Weights recorded at the lower study area were variable from June to October due to low sample size of fish ((45). Yearling weight recorded in August of 1983, at the upper study area, was affected by emigration as at least 32 percent of the fish were new fish that moved into the sample stations; as determined through marking experiments. Fish growth that occured before May was missed as no sampling was conducted.

The average length and weiqht of subyearlinq rainbow-steelhead trout was generally similar between years in the upper study area (Table 33). Fish in December of 1983 were 81 mm in length and weighed 4.5 g compared to 75 mm and 3.45 g in December of 1984. Average condition factors at the upper study area ranged between . 75 and 1.14 in 1983 and varied between .56 to .99 in 1984. Condition factors in December (of both years) ranged between .79 to . 93 during the overwintering period. Subyearling fish from the lower study area were larger than fish from the upper section (Tables 33 and 34) and age 0+ steelhead were larger in 1983 as compared to 1984. Fish in December of 1984 averaged about 84 mm and 5.3 g but in 1983 were larger in

Table 33. Average total length weight and condition factor (standard deviation in parenthesis? of yearlign and subyearlinq rainbow-steelhead trout sampled from the upper study area on Cottonwood Creek in 1983 and 1984.

Month	Yearling Total Lenqth (mm)	Yearling Weiqht (g)	Yearling Condition Factor	Subyearlinq Total Length (mm)	Subyearlinq Weiqht (g)	Subyearlinq Condition Factor
1984						
May	106.2	12.30	0.88	-	-	-
	(22.5)	(10.57)	(.12)			
June	116.2	14.85	0.84	48.8	0.75	0.56
	(22.7)	(11.03)	(.08)	(7.3)	(.45)	(.16)
July	117.6	15.60	0.83	62.7	1.85	0.70
	(25.6)	(15.72)	(.07)	(6.6)	(.70)	(.15)
August	119.9	16.85	0.83	68.1	3.20	0.99
	(27.4)	(16.86)	(.09)	(5.7)	(.79)	(.10)
September	121.7	16.85	0.77	72.8	3.50	0.87
	(28.4)	(18.34)	(.06)	(7.4)	(1.21)	(.13)
October	120.5	16.05	0.80	72.4	3.55	0.90
	(25.5)	(13.64)	(.07)	(6.9)	(.98)	(.11)
November	123.3	16.30	0.76	74.2	3.55	0.84
	(25.4)	(13.35)	(.06)	(7.5)	(1.10)	(.10)
December	117.3	13.55	0.74	74.8	3.45	0.79
	(23.5)	(12.44)	(.06)	(7.9)	(1.13)	(.09)
1983						
May	120.3	16.30	0.88	-	-	
	(17.1)	(7.72)	(.14)			
June	134.6	21.80	0.73	50.5	1.25	1.09
	(29.1)	(22.95)	(.13)	(10.1)	(.52)	(.68)
July	132.8	20.35	0.76	60.3	2.30	1.14
	(24.5)	(15.94)	(.14)	(9.8)	(.63)	(.51)
August	129.0	16.0	0.67	69.6	2.80	0.84
	(22.7)	(13.14)	(.11)	(9.9)	(.80)	(.30)
September	138.6	24.45	0.78	73.3	3.25	0.82
	(31.9)	(23.95)	(.24)	(9.6)	(1.03)	(.24)
October	139.3	19.40	0.59	77.3	3.40	0.75
	(28.5)	(20.69)	(.13)	(9.6)	(.97)	(.21)
November	140.7	22.75	0.72	82.3	4.65	0.78
	(27.1)	(17.42)	(.12)	(11.2)	(1.87)	(.05)
December	139.0	22.90	0.71	81.1	4.55	0.93
	(31.1)	(23.26)	(.08)	(11.8)	(1.39)	(.63)
January	146.2	24.10	0.59	82.1	3.95	0.79
	(34.7)	(27.52)	(.11)	(12.7)	(.58)	(.34)

Table 34. Average total lenth, weight and condition factor (standard deviation in parenthesis) of year ling and subyearlinq rainbow-steelhead trout sampled from the Lower study area on Cottonwood Creek in 1983 and 1984.

Month	Yearling Total Length (mm)	Yearling Weight (g)	Yearling Condition Factor	Subyearling Total Length (mm)	Subyearling Weight (g)	Subyearling Condition Factor
1984						
May	112.9	16.10	0.92		-	-
	(29.1)	(18.18)	(.09)			
June	133.2	27.70	0.90	53.1	1.25	0.78
	(37.8)	(33.74)	(.07)	(6.2)	(.52)	(.21)
July	131.1	22.40	0.85	67.7	3.15	0.97
	(27.0)	(19.33)	(.08)	(6.5)	(.97)	(.12)
August	128.6	20.30	0.84	72.4	3.60	0.92
	(24.5)	(17.61)	(.09)	(6.7)	(1.10)	(.10)
September	131.0	20.20	0.81	78.9	4.75	0.93
	(23.1)	(14.57)	(.08)	(8.1)	(1.42)	(.09)
October	130.0	19.45	0.82	82.8	5.40	0.91
	(19.2)	(9.27)	(.06)	(9.3)	(1.79)	(.10)
November	132.2	20.25	0.79	83.1	5.20	0.87
	(23.2)	(12.09)	(.06)	(8.0)	(1.61)	(.11)
December	134.7	21.60	0.78	83.9	5.30	0.87
	(20.0)	(16.51)	(.05)	(7.8)	(1.56)	(.12)
1983						
May	141.7	29.45	0.99	-	-	-
	(19.9)	(11.64)	(.16)			
June	142.8	21.85	0.73	65.0	2.45	0.96
	(17.3)	(7.28)	(.17)	(10.0)	(.83)	(.51)
July	150.3	29.25	0.80	75.8	3.20	0.73
	(22.8)	(15.99)	(.09)	(11.5)	(1.31)	(.29)
August	158.7	27.85	0.63	78.6	3.50	0.72
	(21.6)	(16.61)	(.10)	(10.8)	(1.18)	(.19)
September	155.2	29.50	0.74	82.2	4.80	0.81
	(18.7)	(13.61)	(.10)	(10.7)	(1.81)	(.06)
October	160.6	37.20	0.87	90.7	6.05	0.79
	(21.3)	(14.67)	(.14)	(10.8)	(2.28)	(.17)
November	160.7	34.20	0.73	95.4	7.25	0.80
	(22.7)	(24.02)	(.08)	(11.6)	(2.52)	(.08)
December	159.8	31.40[a]	0.76	97.2	7.30	0.84
	(29.2)			(12.5)	(1.49)	(.31)
January	159.4	27.10	0.59	96.0	6.70	0.78
	(21.8)	(15.08)	(.11)	(12.4)	(1.90)	(.27)

a Average weight derived from the log Length-log weiqht egression equation.

December at 97 mm in total length and 7.3 g in weight. Condition factors during 1983 varied between .72 to .96 and in 1984 ranged between .78 and . 97 at the lower study area. Condition factors during the overwintering period (December) of both years ranged from .84 to .87.

The length-weight relationship for juvenile steelhead from Cottonwood Creek (Figure 66) was calculated by a non-linear least squares regression. The length-weight equation showed that growth was about a cubic relationship indicating isometric growth (Tesch 1971) during natal stream habitation. The log length-log weight relationship was log w = -12.0118 + 3.0768 log L (R^2=.97). Data on total length and fork length for juvenile rainbow-steelhead was collected in 1984. Conversion factors calculated for 306 subyearling fish 53 to 103 mm was TL = -1.2717 + 0.9665(FL), with an R-squared of .99. A total of 213 yearling fish 90 to 259 mm in length had a conversion factor of TL = -0.411 + 0.9479(FL); R-squared=.997.

Enhancement Strategy

Enhancement recommendations for Cottonwood Creek have previously been made by Kucera et al. (1983) and Fuller et al. (1986). Results from these reports and the current studv will be utilized to address anadromous salmonid enhancement potential. Where direct support from the sample data is not available, through regression or correlation, support from the literature is used. Problems identified were a lack of perennial flow in the upper 16 km of stream, lack of yearling habitat, sedimentation, low summer stream discharge and elevated water temperatures and extreme variation in annual stream flow.

Lack of perennial stream flow occurs in the upper 16 km of Cottonwood Creek. Some steelhead production occurs in isolated stretches of stream but the amount is negligible. Instream flow improvement/augmentation would be needed to open up this stream section to steelhead production (Fuller et al. 1986). The feasibility of flow augmentation through spring enhancement or construction of a small reservoir for water storage needs to be evaluated. The problems discussed below would also have to be addressed in this section if flow improvement was implemented.

A lack of instream cover for yearling steelhead is a limiting factor, in the lower 7 km in Cottonwood Creek, as has been reported in other studies (Everest and Sedell 1984). Total measured yearling cover did not exceed 11 percent of the available area at the lower study area. The upper study area contained up to 20 percent vearling cover and supported twice the summer and winter density of fish (Table B.1) compared to the lower study section. Yearling steelhead density was significantly correlated with one of the instream cover components (overhanging vegetation) at the upper study area in

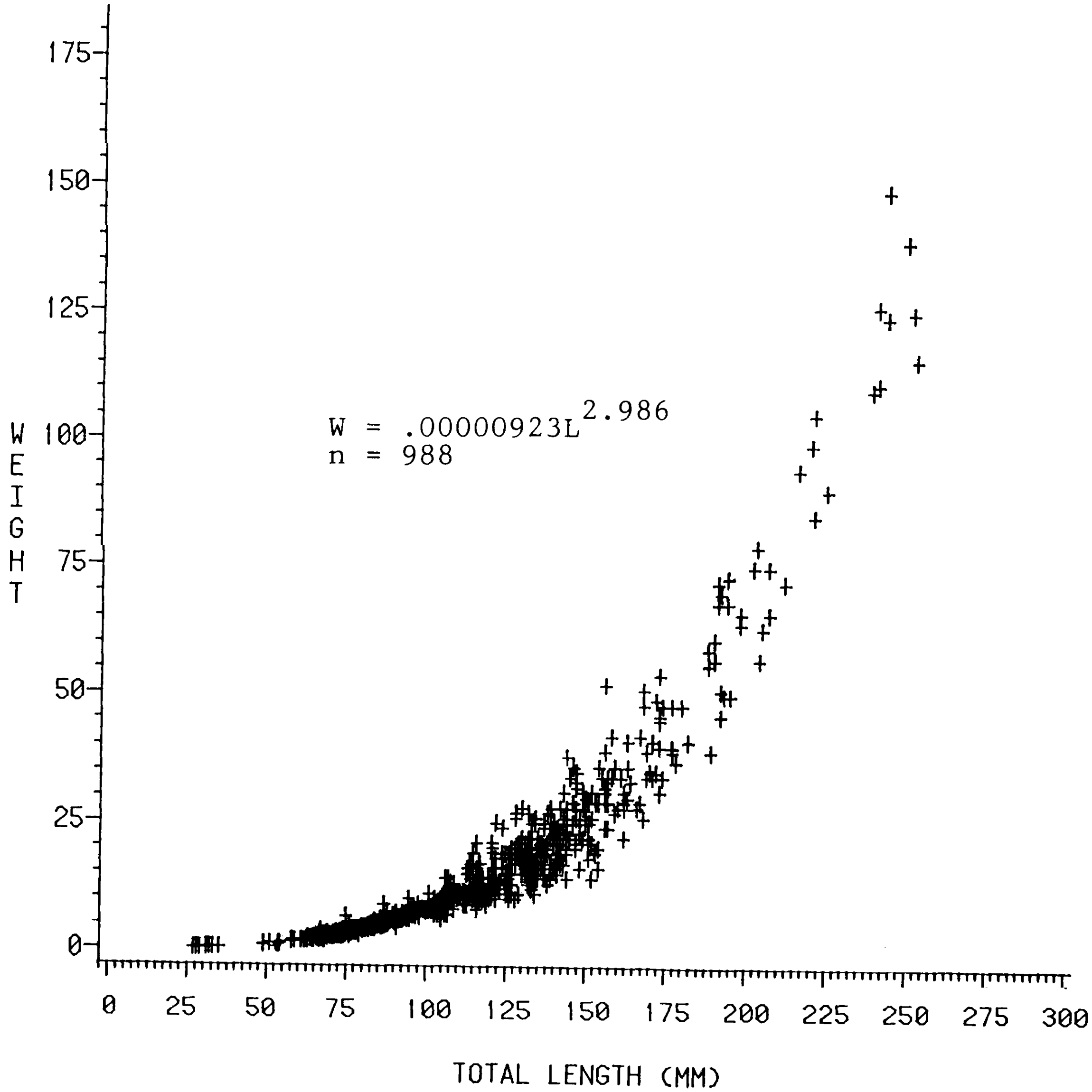


Figure 66. Length-weight relationship for juvenile rainbow-steelhead trout from Cottonwood Creek.

1983. Consistent significant correlations did not exist that would provide a biological basis to relate yearling steelhead density to instream habitat data. Regression analysis was, therefore, not a useful tool in delineating specific factors that limit fish densities. Other investigators (Burns 1971; Gordon and MacCrimmon 1982) have reported significant relationships between steelhead densities and living space variables. Some of the habitat enhancement measures in the Clearwater Basin are also founded on the premise that increasing instream cover will improve the density of anadromous salmonids.

Average stream depths at both study areas were less than 16 cm during the summer and early fall months. Water velocity was less than 13 cm/s during the same time period. These stream depths and velocities are at a minimum level in terms of probability-of-use data presented for juvenile steelhead (Bovee 1978). Yearling rainbow trout (Wesche 1980) and steelhead trout (Everest and Chapman 1972) are reported to utilize depths more often as depth exceeds 15 centimeters. These depths are available in pool and run habitat in Cottonwood Creek. Placement of instream structures such as woody debris, boulders, root wads, gabions and boulder clusters would increase the amount of pool habitat available to yearling fish. With such limited yearling cover present (<20%), it is estimated that placement of instream habitat structures could substantially increase the smolt yield. Instream structure placement should be one component of an overall enhancement/restoration plan for the Cottonwood system.

Sedimentation, although not directly studied during this project, may be one of the limiting factors to rainbow-steelhead trout production in Cottonwood Creek. Cobble embeddedness values during the study ranged from 25 to 35 percent and silt comprised 2 to 11.8 percent of the total bottom substrate. Rainstorm events in the drainage would occasion heavy sediment loads in the stream for several days. Bjornn et al. (1977) reported that fine sediment is a I.imiting factor to salmonid production. Fine sediment mav fill in or cover adult spawning substrate, reduce aquatic insect production on which fish feed, fill in interstices in the substrate which fish utilize as cover and may cause gill irritation. Riparian revegetation is necessary (Fuller et al. 1986) especially in the grazed headwater area and lower section of stream. Revegetation would help stabilize banks, decrease the rate of water runoff in the spring and thus incoming sediment, and would help shade the stream.

Low summer streamflows and high summer water temperatures are of cancern in Cottonwood Creek. Stream discharge reached a low of .011 m^3/s (.39 cfs). Stream discharge was generally significantly positively correlated with measured yearling steelhead habitat. At summer base flows the yearling cover was severely restricted. Available yearling cover was lacking ((20%) during most of the year as the majority of habitat present was riffle or riffle-run habitat. Average summer water temperatures in Cottonwood Creek reach 19 C in lower stream reaches with the maximum up to 26.4 degrees Centigrade. Yearling steelhead growth and production are negative during this time at the lower study area. Raleigh et al. (1984) state that the optimum range in water temperature for rainbow trout is between 12 to 18 degrees Centigrade. Water temperatures in the lower stream reaches exceeded this optimum range. Platts and Rinne (1985) report that summer solar radiation accounts for 95 percent of the heat input into streams during midday. Riparian revegetation is required in the upper watershed to stabilize banks, shade the stream and help decrease the rate of water runoff in the spring. Revegetation is also necessary in the lower 4 km of stream. Establishment of both streambank vegetation and overhead canopy may also enhance channel stability and increase stream flow. Average water temperature and yearling steelhead density are positively significantly correlated ($P<0.05$) in Cottonwood Creek. The data did not indicate that elevated water temperatures decreased yearling densities. Increase in fish density along with water temperature could only occur up to a point where upper lethal temperature was reached and then the relationship would truncate. Flow augmentation, through spring enhancement or construction of a small storage reservoir, would alleviate summer low flows, increase yearling habitat and help reduce water temperatures. Riparian revegetation would also help shade the stream, thus reducing water temperatures, and stabilize the stream banks.

Annual stream flow variation ranged from .02 to 7.52 m^3/s over the study period; a 376 fold difference. Raleigh et al. (1984) report that there is a definite relationship between annual flow regime and quality of trout habitat with the most important period being during base flows. Peak spring runoff and grazing has reduced the channel stability from skm 10 to 14.8 and in the lower 4 km of stream. Spring runoff also inhibits riparian vegetation establishment in these areas. However, where good overhead canopy and streambank vegetation exist there is normally a well defined channel. Placement of instream structures such as woody debris would help control channel stability (Heede 1981) and also create high quality pools (Platts and Rinne 1985). Re-establishment of riparian zones should also help stabilize the stream channel. Stream conditions in the lower-most section may require channelization into a meandering path.

An enhancement/restoration plan of riparian revegeation channel stabilization and placement of instream structures would substantially increase the steelhead smolt yield in Cottonwood Creek. Riparian revegetation is important to stabilize the banks to reduce water runoff and sediment input, and to help shade the stream thus reducing water temperatures. Good development of overhead canopy and streambank vegetation may also help stabilize the channel and increase stream flow. Placement of instream structures will improve the amount of yearling habitat quantity and diversity present and may be positioned to improve channel stability. It is estimated (indirectly) that the smolt yield would be doubled if these measures were implemented. The estimated smolt yield from the fish weir (1984) was 1,500 fish. Smolt yield, estimated from population projections, was 2,074 fish in 1984 and 3,371 smolts in 1985. The feasibility of flow augmentation through spring enhancement or reservoir storage needs to be evaluated further. If flow augmentation was determined to be feasible it would open up 16'kilometers of habitat to steelhead production. Currently about 9.6 km of stream has perennial flow and supports juvenile steelhead production.

BIG CANYON CREEK

Big Canyon Creek flows for approximately 48 km (Figure 67) with an 8 to 10 kilometer stretch of stream in the upper section having intermittent flow. Little Canyon Creek is the major tributary and discharges into Big Canvon Creek at skm 3.7. Several smaller streams and intermittent tributaries flow into the Big Canyon system throughout its length. The stream eminates in agricultural environs in the upper drainage and flows through a deep, relatively inaccessible U-shaped canyon that has steep canyon walls. The creek flows through the town of Peck and is paralleled by a highway for the lower three to four kilometers. Riparian vegetation is generally sparse consisting of scattered deciduous trees. Cattle grazing activity is moderate to heavy throughout the stream length. Flood damage has resulted in-localized severe degradation of fish habitat and the stream has been channelized in the lower section. Logging has occurred on the steep canvon slopes and side drainages.

During the 1983 study period stream discharge ranged from .0763 to .3833 m^3/s (Figure 68). Aerial and ground observations have indicated that severe flooding has occurred and stream flow variability appears high. The stream is located in a CT-shaped canyon and has a relatively wide flood plain area. Peak spring runoff and grazing inhibits riparian vegetation which helps shade the stream and stabilize the banks. Monthly average water temperatures (Figure 68) varied from 2 to 20.5 C, with summer maximum temperatures up to 23.2 degrees Centigrade. Stream gradient ranged from .5 to 4.5 percent. Water quality analysis (Table 35) indicated that with a total dissolved solids (TDS) level of 128 and a pH of 8.5 that Big Canyon Creek appeared to be moderately productive. High nutrient concentrations and fecal coliform bacteria violations have been reported in the past (Idaho Department of Health and Welfare 1980). Fish species inhabiting Big Canvon Creek include rainbow-steelhead trout, brook trout, speckled dace, chiselmouth, northern squawfish, redide shiner, bridgelip sucker and paiute sculpin. Adult steelhead have been collected in Rig Canyon over the study period. Due to the collection of adult steelhead and the low number (<13%) of age II+ and older rainbow-steelhead trout it is believed that the fish were steelhead and not a resident population of rainbow trout. The Pig Canvon Creek steelhead population, in pairwise comparisons and a cluster analysis of genetic similarity, broke out with the Cottonwood Creek population and other A-run populations. Big Canyon fish were significantly different from Dworshak Hatchery steelhead (Appendix A). Some hatchery smolts, however, have been collected in the lower reaches of Rig Canyon Creek (Kuccra et al. 1983). No stocking of Dworshak hatchery fish has been recorded in the Big Canyon system. Large numbers of adult bridgelip suckers from the Clearwater River ascend the creek each spring to spawn along with lesser numbers of adult northern squawfish and chiselmouth. Fishing mortality was not quantified

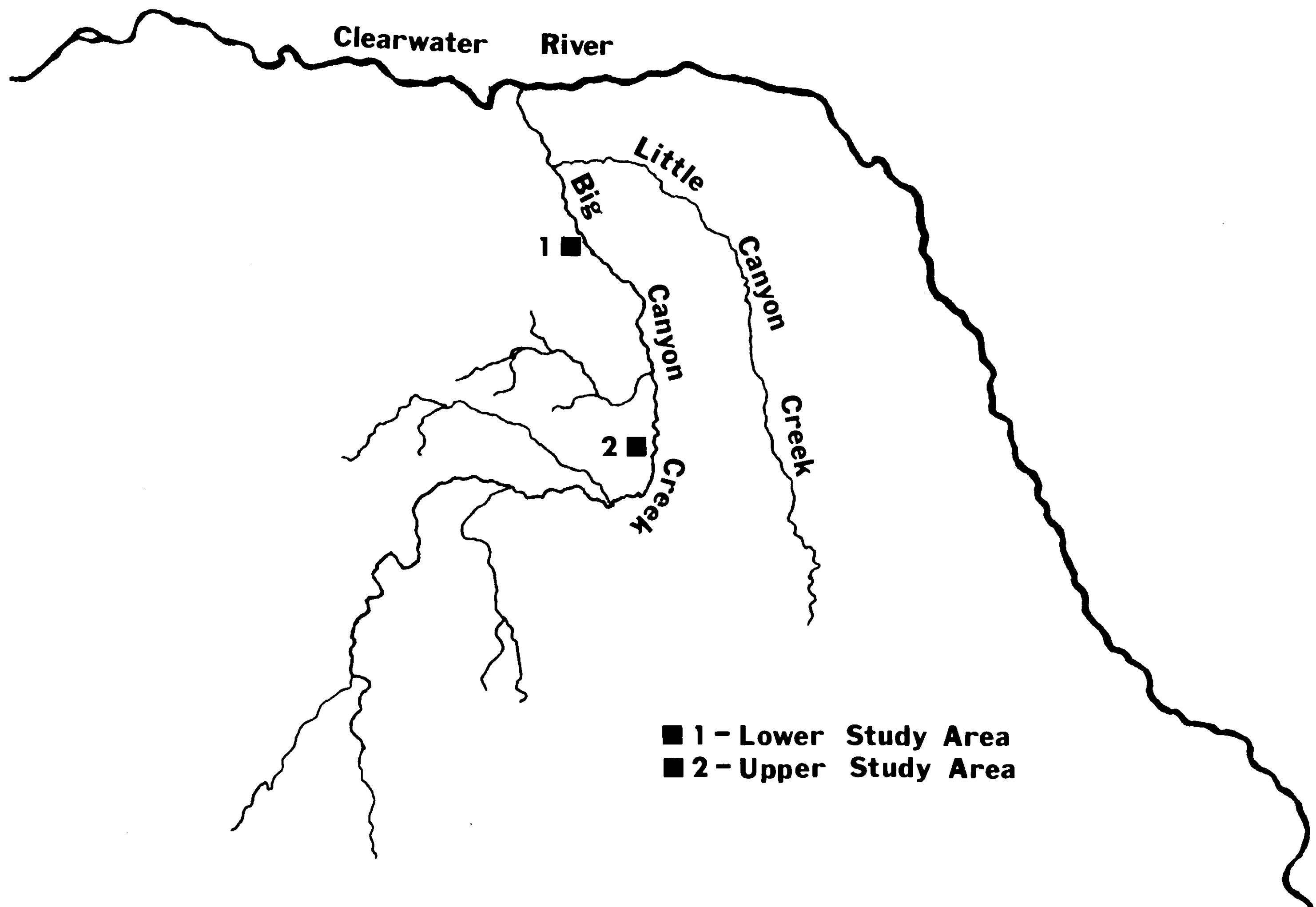


Figure 67. Map of Big Canyon Creek indicating the two study areas sampled in 1983.

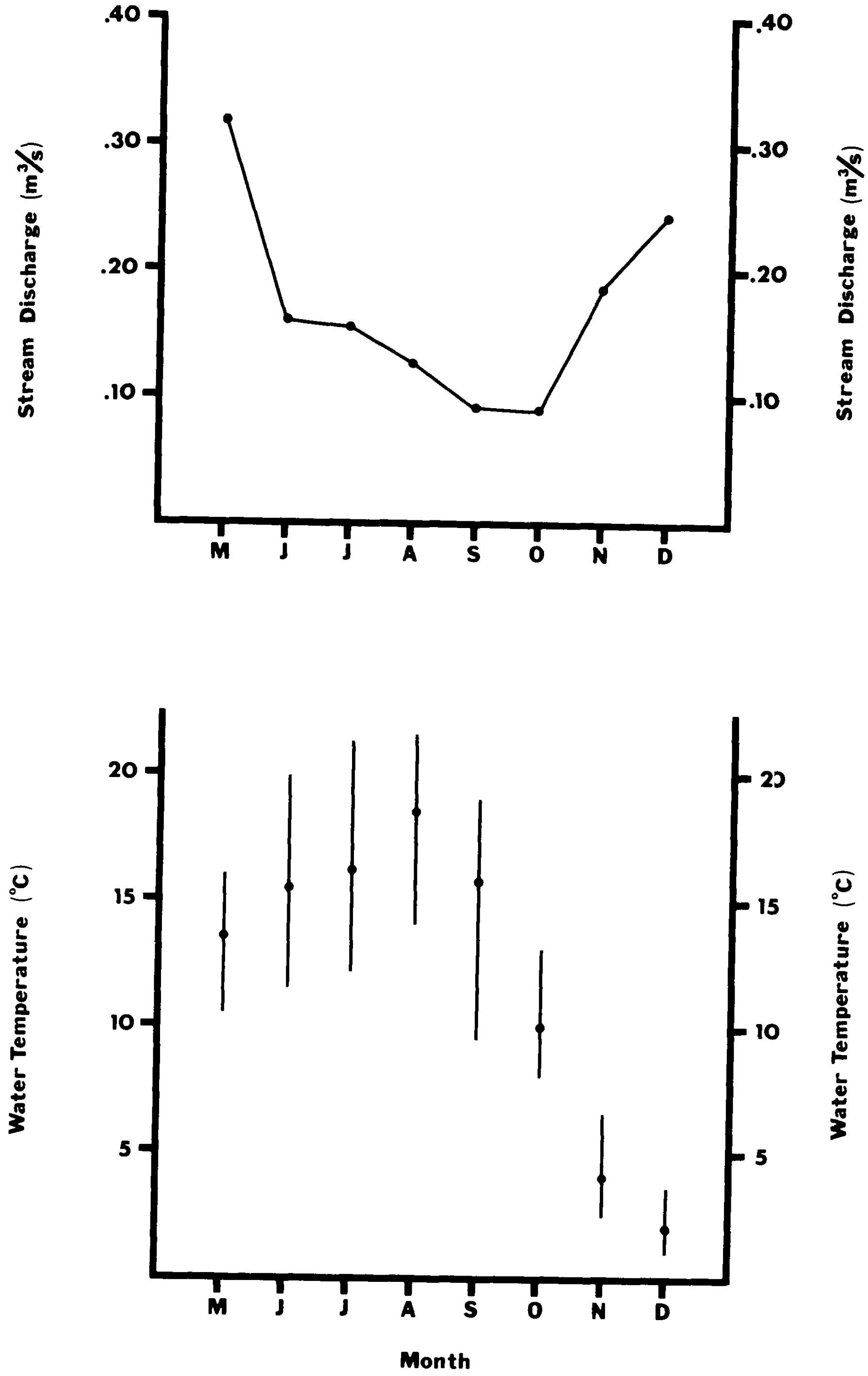


Figure 68 Monthly average and range in water temperature (lower graph) and average stream d.scharge (upper graph) for Big Canyon Creek in 1983.

Table 35. Chemical analysis of water collected from Big Canyon Creek on August 4, 1983.

Constituent	Year 1983
pH	8.47
Calcium, Ca, mg/l	19.58
Magnesium, Mg, mg/l	6.72
Sodium, Na, mg/l	9.67
Potassium, K, mg/l	2.88
Chloride, Cl, mg/l	0.35
Carbonate, CO3, mg/l	9.89
Bicarbonate, HCO3, mg/l	99.40
Sulfate, SO4, mg/l	1.0
Nitrate, NO3, mg/l	0.12
Orthophosphate, PO4, mg/l	0.14
Total Residue, mg/l	132.0
Non-Filtered Residue, mg/l	4.0
Total Dissolved Solids, TDS	128.0

during the study but was believed to be light at the relatively inaccessible upper study area. Pig Canyon Creek is one of the top steelhead producing streams on the Nez Perce Reservation and is ranked as a priority for stream enhancement (Fuller et al. 1986).

Upper Study Area

The upper study area was sampled from May to October, 1983, after which time the area became inaccessible. Rainbow-steelhead trout was the only anadromous salmonid sampled during the study period. Yearling densities during 1983 (Figure 69) fluctuated from .36 fish/m^2 in May down to .28 fish/m^2 in October (Table 36). The lowest point on the graph (Figure 69) reflects only one 50 meter station and not an average density. No major change in density was associated with a concurrent change in habitat variables. Densities were relatively high despite the fact that total measured yearling habitat from June to August was only 2.4 to 6 percent of the total available stream area (Table 37). Estimated monthly densities at the upper study area were about three times higher than densities at the lower study area. The relative inaccesibility to this steep canyon area, through private land holdings, reduces angler access and thus fishing mortality in this section, compared to the lower study area. The habitat quality in the upper study area was believed to be higher than that of the lower study area, thus providing better yearling habitat. Specifically, water temperature reached a high of 18.5 C during August compared to 20.5 C at the lower study area. Cobble embeddedness was estimated to be 25 percent (upper area) versus 33 percent at the lower area. Stream depths averaged less than 11.5 cm during the study period (Table 37) which is at a minimum level in terms of probability-of-use (Rovee 1978). However, yearling densities remained relatively high, declining to .28 fish/m^2 in October. Water velocity, another important factor in probability-of-use data, was more suitable as it was greater than 15 cm/s during all months. Yearling density was significantly negatively correlated with stream velocity (r=-.81). However, the relationship is not a cause-effect one. Lower flows may concentrate a large number of fish but increased flows do not cause lower densities.

Yearling biomass was not significantly correlated with yearling density at the upper study area. Biomass calculations in 1983 ranged from 8.29 g/m^2 in May, 1983, to 4.62 g/m^2 in June when only one 50 meter station was sampled, and up to 10.59 g/m^2 in October (Table 36). Fluctuations in biomass in June and October represent only one 50 meter station being sampled and therefore an average value was not available.

Subyearling densities in 1983 varied from .97 fish/m^2 in June up to 1.51 fish/m^2 in July and decreased to .95 fish/m^2 in October (Figure 70 and Table 38). A marked decrease in density took place from 1.51 fish/m^2 in July to 1.11 fish/m^2

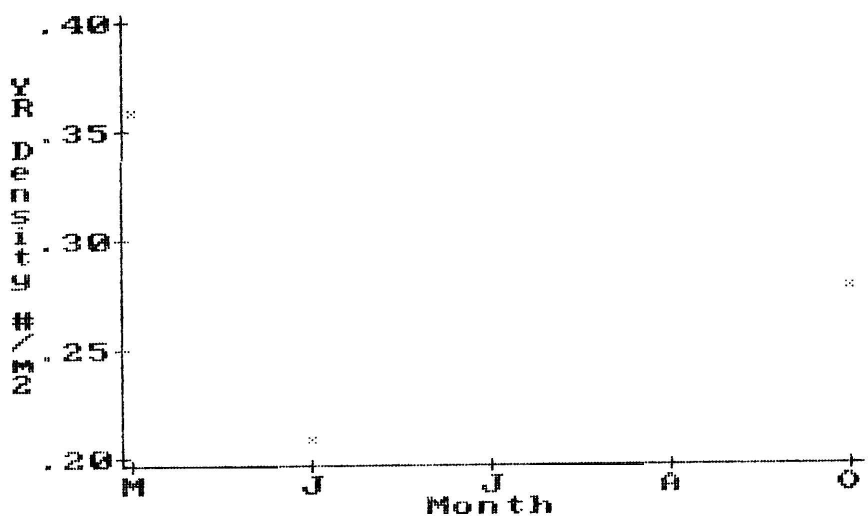


Figure 69. Yearling rainbow-steelhead trout density at the upper study area on Big Canyon Creek from May to October, 1983.

Table 36. Monthly values of stream area and stream volume sampled and average density and biomass (standard deviation in parenthesis) of yearling rainbow-steelhead trout measured in the upper study area on Big Canyon Creek in 1983.

Month	Stream Area Sampled (m2)	Stream Volume Sampted (m3)	Density Number/m2	Density Number/m3	Biomass Grams/m2	Biomass Grams/m3
1983						
May	897.6	100.8	0.360 (.12)	3.12 (.54)	8.29 (.71)	71.40 (12.25)
June a	517.0	43.1	0,210	2.48	4162	55.51
July	791.4	80.4	0,370 (.20)	3.47 (1.24)	9.11 (6.38)	82.74 (42.51)
August	730.4	61.4	0,340 (.22)	3.66 (1.21)	7.33 (5.11)	77.77 (29.50)
September	-					
October a	310.2	25.0	0.280	3.52	10.59	131.42

a Only one 50 meter station sampled

Table 37. Average monthly physical characteristics, standard deviation in parenthesis, of the upper study area on Big Canyon Creek sampled in 1983.

Month	Stream Disch. (m3/s)	Stream Veloc. (cm/s)	Stream Width (cm)	Stream Depth (cm)	Aver. Water Temp. (C)	Depth >30cm (m2)	Undercut Bank (m2)	Overhang. Vegetatn. (m2)	Surface Turb. (m2)	Subm. Rock (m2)	Total Habitat (m2)
1983											
May	0.1838	17.9	897.7	11.5	13.5						
	(.07)	(2)	(222.6)	(1.8)							
June a	0.1124	27.2	1,035.6	8.3	15.5	13.66	0	0	14.58	1.69	29.93
July	0.1195	17.6	791.5	9.8	16.1	8.79	0	0.70	6.90	0.65	17.04
	(.04)	(4.9)	(161.9)	(1.6)		(9.54)		(.98)	(.73)	(.02)	(7.80)
August	0.1109	17.3	730.5	8.8	18.5	4.96	0	0.42	3.02	0.49	8.90
	(.01)	(2.3)	(182.8)	(3.2)		(4.25)		(.60)	(.17)	(.08)	(3.39)
September	-	-	-	-	13.7						
October a	0.1209	16.9	620.4	11.4	10	-	-	-		-	-

a Only one 50 meter station sampled.

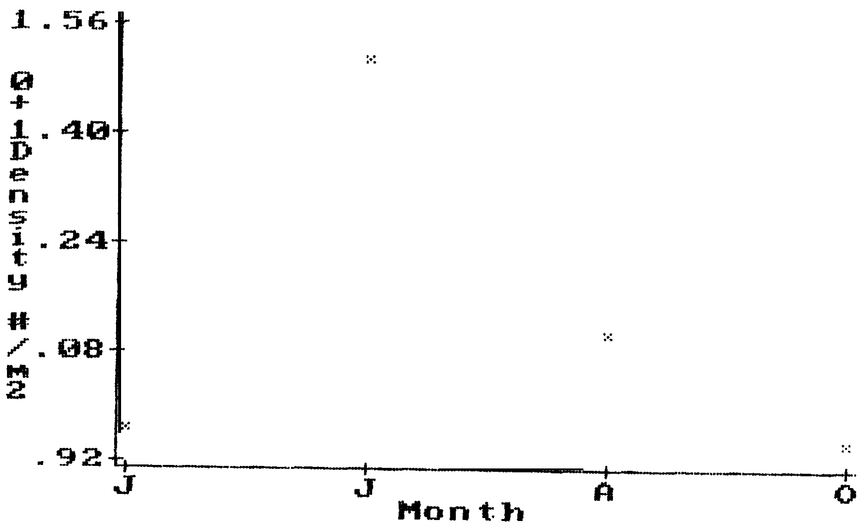


Figure 70. Subyearling rainbow-steelhead trout density at the upper study area on Big Canyon Creek from June to October, 1983.

Table 38. Honthly values of stream area and stream volume sampled and average density and biomass (standard deviation in parentheris) of subyear inq rainbow-steelhead trout measured i n the upper study area on Big Canyon Creek in 1983+

Month	Stream Area Sampled (m2)	Stream Volume Sampled (m3)	Density Number/m2	Density Number/m3	Biomass Grams/m2	Biomass Grams/m3
1983						
May	897.6	100.8				
June a	517.8	43.1	0.970	11.67	1.80	21.60
July	791.4	80.4	1,510 (.49)	14.35 (1.50)	3.63 (1.19)	34.44 (3.60)
August	730.4	61.4	1.110 (.37)	12.73 (.45)	3.34 (1.11)	38.19 (1.38)
September	-					
October a	310.2	25.0	0.950	11.79	6.37	79.03

a Only one 50 meter stat ion sampled

in August as stream discharge remained at .11 m^3/s (Table 37) and average water temperature increased from 16.1 to 18.5 degrees Centigrade. The highest correlation observed between density or biomass and habitat variables was a non-significant association between biomass (g/m^3) and stream depth (r=.72). Subyearling density and maximum water temperature were also correlated (r=.60) but not significantly.

Subyearling rainbow-steelhead trout biomass ranged from 1.80 g/m^2 in June to 3.63 in July and up to 6.37 g/m^2 in October of 1983. As mentioned previously, data from June and October do not reflect an average because only one 50 meter station was sampled (Table 38). Subyearling density and biomass was not significantly associated (r=-.13) at the upper study area.

Substrate sampling indicated that adequate spawning gravels were present for adult steelhead. Available spawning substrate was estimated to be 24.8 percent of the total stream bottom area. Cobble embeddedness was estimated to be about 25 percent. The percentage of each substrate type is presented below: boulder 26.5; large cobble 31.2; small cobble 24.9; very coarse gravel 12.2; coarse gravel .2; medium gravel 4.2; sand .2 and silt .4 percent.

Lower Studv Area

Rainbow-steelhead trout was the only anadromous salmonid sampled at the lower study area in 1983. Yearling abundance varied little from May through October when densities ranged from .10 $fish/m^2$ to .08 $fish/m^2$ (Figure 71 and Table 39). In June an accidental mortality of 41 yearling fish occurred, before they could be placed back into the 50 meter section after shocking operations were completed. However, there was no noticeable difference in density between the June values of .11 $fish/m^2$ and July (.12 $fish/m^2$) as the fish population quickly adjusted to the vacant habitat. A small decline in density occurred from July (.12 $fish/m^2$) to August (.09 $fish/m^2$) as the average water temperature increased to 20.5 C (Table 40). Densities decreased to the lowest level observed in December (.03 $fish/m^2$) during the overwintering period. No notable fluctuations in density were observed in relation to changes in habitat variables. Density of yearling steelhead at the upper study area was three times the observed density at the lower study area (Tables 36 and 39). Yearling density comprised 8 to 13.7 percent of the total salmonid density present with subyearling steelhead making up the remaining percentage. The estimated smolt yield from mainstem Big Canyon Creek, using winter population estimate projections, is between 14,388 to 20,738 fish. This estimate was for 35 of the 48 km of total stream length and assumes no mortality takes place after December.

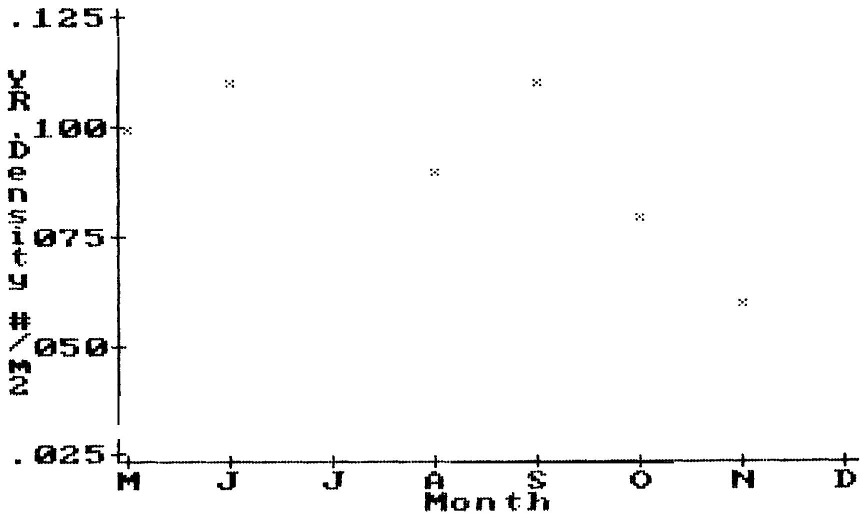


Figure 71. Yearling rainbow-steelhead trout density at the lower study area on Big Canyon Creek from May to December, 1983.

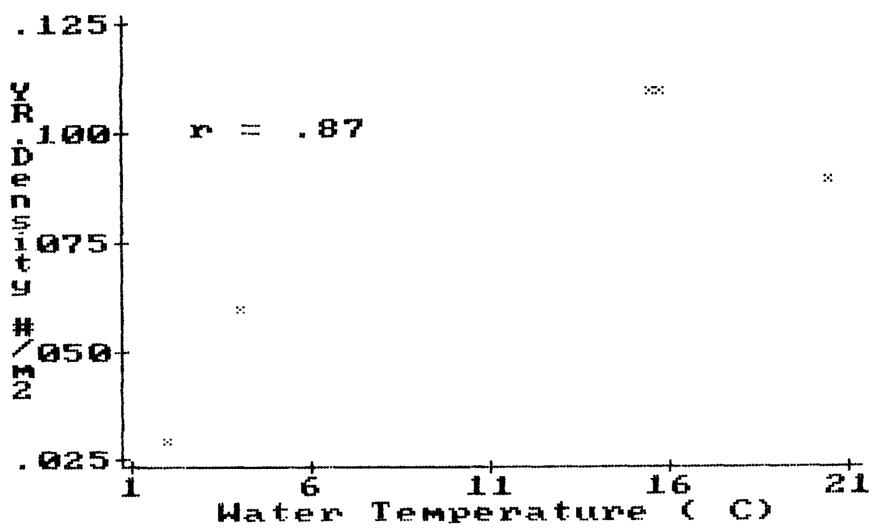


Figure 72. Relation between yearling rainbow-steelhead trout density and average water temperature at the lower study area on Big Canyon Creek from May to December, 1983.

Table 39. Monthly values of stream area and stream volume sampled, and average density and biomass istandard deviation in parenthesis) of yearling rainbow-steelhead trout measured in the Lower study area on Big Canyon Creek in 1983.

Month	Stream Area Sampled (m2)	stream Volume Sampled (m3)	Density		Biomass	
			Number/m2	Number/m3	Grans/M2	Grams/m3 ,
1983						
May	696.8	115.0	0.100 (.06)	0.65 (.37)	3.47 (.74)	22.21 (4.10)
June a	388.5	41.7	0.110	1.01	3.14	29.29
July	613.2	73.3	0.120 (.04)	1.02 (.46)	4.73 (1.96)	40.54 (19.02)
August	557.0	54.4	0.090 (.01)	0.92 (.15)	2.71 (.72)	27.49 (7.28)
September	555.2	62.2	0.110 (.04)	0.98 (.34)	4.82 (1.72)	43.18 (15.72)
October	571.0	69.4	0.080 (.03)	0.71 (.37)	3.79 (2.44)	31.57 (21.12)
November	650.6	99.5	0.060 (.007)	0.43 !.05)	2.45 (.97)	15.74 (5.23)
December	465.4	109.8	0.030 (0)	0.19 !.02)	1.04 (.01)	6.26 (.37)

a Only one 50 meter station sampled.

Table 10. Average monthly physical characteristics, standard deviation in parenthesis, of the lower study area on Big Canyon Creek in 1983,

Month	Stream Disch. (m3/s)	Stream Veloc. (cm/s)	Stream Width (cm)	Stream Depth (cm)	Aver. Water Temp, (C)	Depth >30cm (m2)	Undercut Bank (m2)	Overhang, Vegetatin. (m2)	Surface Turb+ (m2)	Subm. Rock (m2)	Total Habitat (m2)
1983											
May	0.3210 (.09)	21.6 (9.2)	726.6 (89.4)	16.5 (.3)	13.5		-	-			
June a	0.1610	10.7	777.0	10.7	15.5	19.57	0	0	11.62	0.50	38.33
July	0.1534 (.03)	13.8 (5.8)	635.4 (117.1)	11.8 (.7)	18.1	10.30 (5.33)	0	1.39 (.69)	3.90 (.80)	0.75 (.46)	16.34 (7.30)
august	0.1273 (.002)	12.6 (1.1)	574.9 (117.7)	9.7 (.03)	20.5	8.40 (5)	0	1.95 (1.13)	1.20 (.43)	0.51 (.10)	12.07 (6.67)
September	0.0948 (.02)	8.6 (4.5)	574.3 (138.5)	11.2 (.08)	15.7	7.33 (6.06)	0	0.79 (.29)	2.90 (1.01)	0.34 (.18)	11.37 (7.55)
October a	0.0924 i.005)	8.4 (2.8)	593.3 (117.6)	12.1 i.3)	10.0	5.66 (5.29)	0	0.18 (.26)	2.01 (.85)	0.50 (.45)	8.34 (6.33)
November	0.1883 i.004)	13.7 (4)	673.7 (135.8)	15.4 (1)	4.0	14.49 (11.02)	0	0.09 (.13)	4.40 (1.09)	0.29 (.29)	19.28 (12.26)
December	0.2422 (.01)	14.0 (2.9)	689.8 (113.6)	16.6 (1.3)	2.0	27.28 (21.99)	0	0.07 (.10)	6.80 (1.26)	0.25 (.35)	34141 (20.48)

a Only one 50 meter stat ion sampled+

Stream depth at the lower study area averaged 12 cm or less during the summer and early fall months. Water velocity during the same period (Table 40) was less than 14 cm/s. These depths and velocities are at a minimal level in terms of probability-of-use data reported by Bovee (1978) for juvenile steelhead. Wesche (1980) and Everest and Chapman (1972) found that yearling rainbow-trout and steelhead trout utilized depths more often as depth exceeded 15 centimeters. Measured yearling habitat was limited and represented about three to ten percent of the available stream area (Table 40). Depth greater than 30 cm made up the bulk of the measured yearling habitat with surface turbulence comprising most of the rest.

Estimated yearling biomass was significantly associated (r=.87) with yearling density during 1983. Biomass ranged from 3.67 g/m^2 in May to a peak of 4.82 in September and then decreased to 1.04 g/m^2 in December (Table 39). Yearling fish, although composing only 8 to 13.7 percent of the total salmonid density comprised 40 to 72 percent of the total salmonid biomass present.

Correlation matrices between yearling steelhead density and biomass and habitat variables revealed that density was significantly associated with average water temperature (Figure 72). Yearling density would only continue to increase with rising water temperature as the maximum lethal temperature was approached at which point the relationship would truncate. Raleigh et al. (1984) report that the optimum range in water temperature for rainbow trout is 12 to 18 degrees Centigrade. As average water temperature in Rig Canyon Creek reached 20.5 C in August, the far right point on Figure 72, density decreased and then increased slightly in September as stream temperature declined to 15.7 degrees Centigrade (Table 40). The data, however, did not indicate that increased water temperature reduced yearling densities. Yearling density was negatively correlated (r=-, 29) with stream discharge. As stream discharge was significantly positively associated with most components of instream cover, there was also a negative correlation between yearling density and instream cover components. No significant correlations existed that had a biological basis to relate yearling density or biomass information to habitat data. Therefore, regression analysis was not a useful tool in delineating factors that limit steelhead densities or in providing a predictive basis to estimate yearling density from measured habitat variables.

Subyearling rainbow-steelhead trout densities in 1983 ranged from 1.27 fish/m^2 in June (Figure 73 and Table 41) to .60 fish/m^2, under low flow conditions in, October and decreased to .30 fish/m^2 in December. October density (.60 fish/m^2) was about two-thirds that of the abundance observed at the upper study area (.95 fish/m^2) during the same month. Subyearling densities accounted for 86.3 to 92 percent of the total salmonid density present in the study area.

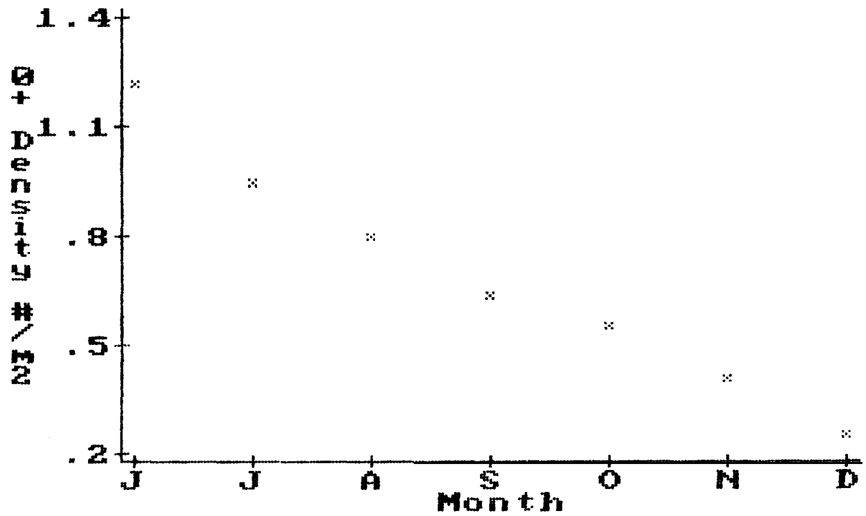


Figure 73. Subyearling rainbow-steelhead trout density at the lower study area on Big Canyon Creek from June to December, 1983.

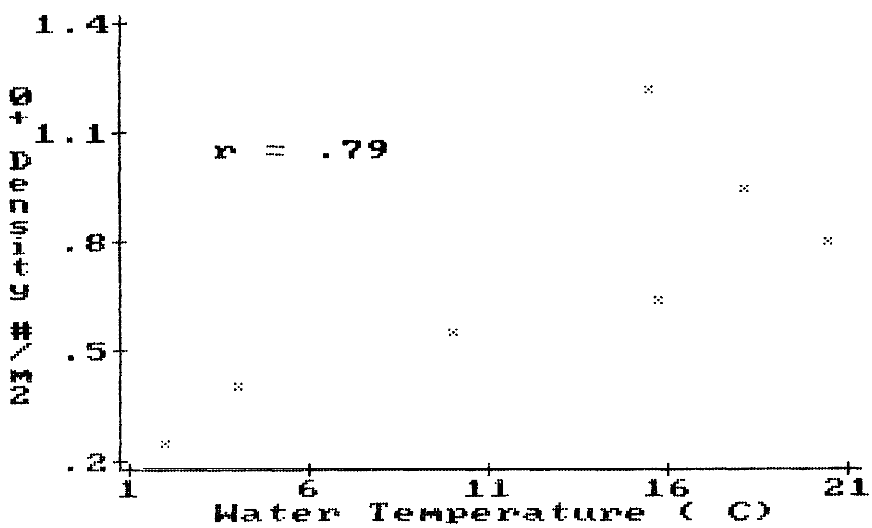


Figure 74. Relation between subyearling rainbow-steelhead trout and average water temperature at the lower study area on Big Canyon Creek from June to December, 1983.

Table 41, Monthly values of stream area and stream volume samp ted and average density and biomass (standard deviation in parenthesis) of subyearl ins rainbow-steelhead trout measured in the lower study area on Big Canyon Creek in 1983.

Month	Stream Area Sampled (m2)	Stream Volume Sampled (m3)	Density Number/m2	Density Number/m3	Biomass Grams/m2	Biomass Grams/m3
1983						
May	696.8	115.0				
June a	388.5	41.7	1,270	11.86	1.78	16.61
July	613.2	73.3	1.00 (.01)	8.45 (.41)	1.85 (.09)	15.62 (.16)
Augst	557.0	54.4	0,850 (.01)	8.76 (.15)	2.14 (.08)	21.91 (.99)
September	555.2	62.2	0,690 (.05)	6.13 (.55)	2.60 i.22)	23.85 (2.10)
October	571.0	69.4	0.600 (.03)	4.97 (.34)	3.81 (.22)	31.49 (2.76)
November	650.6	99.5	0.460 (.06)	3.02 (.20)	3.72 (.49)	24.05 (1.64)
December	665.4	109.8	0.300 (.03)	1.83 (.32)	2.00 (.19)	12.15 (2.08)

a Only one 50 meter stat ion sampled .

Biomass estimates of subyearling fish in 1983 varied from 1.78 g/m^2 in June, increased to a high of 3.81 in October, and declined to 2 g/m^2 in December during the overwintering period. Subyearling density and biomass was negatively correlated (r=-.52). As fish density decreased from June on, subyearling growth continued to increase thus causing the biomass per unit area (g/m^2) to increase through the month of November. Subyearling biomass comprised 28 to 60 percent of the total salmonid biomass present during the sampling period.

Correlation matrices between subyearling steelhead density and habitat variables indicated that density and average water temperature had a significant relationship (Figure 74). As discussed for the yearling fish, water temperature and density could increase only until a maximum lethal temperature was approached and then the association would truncate. Average water temperature in August reached 20.5 C which is above the optimum range of 12 to 18 C for rainbow trout (Raleigh et al. 1984). However, subyearling fish continued to increase in size, both length and weight, through the summer period. Subyearling density was negatively correlated (non-significantly) with both stream discharge and stream velocity. Yearling density and subyearling density was also significantly associated (r=.84). A thorough food habits analysis would need to be conducted to determine if this correlation indicated that intraspecific predation was occurring.

Substrate sampling during the study period indicated that there was sufficient spawning gravel present for adults. Estimated available spawning substrate was 20.4 percent of the total stream bottom area. The percent of each substrate classification present in 1983 is as follows: boulder 34.7; large cobble 28; small cobble 19.6; coarse gravel 10.6; medium gravel 5.7; sand . 2 and silt 1.8 percent. Cobble embeddedness was visually estimated to be 33 percent.

Juvenile Steelhead Age and Growth

A total of 215 juvenile steelhead were aged by the scale method to separate age groups for density and biomass estimates. Two groups of fish are recognized for this report: yearling (age I+ and older) and subyearling (age 0+). During the study period yearling rainbow-steelhead trout ranged in length from 89 to 289 mm and in weight from 6 to 278 grams. The largest fish sampled was an age III+ individual that was 289 millimeters long and weighed 278 grams. Monthly fish collections indicated that a minimum of 87 percent of the fish collected were age I+. These fish ranged in length from 89 to 218 mm and from 6 to 90g in weight. Age II+ rainbow-steelhead varied from 153 to 254 millimeters in total length and in weight from 33 to 148 grams. Subyearling fish ranged up to 124 mm in length and 15.5 g in weight by January of 1984.

Averaqe lenqth of yearlinq rainbow-steelhead trout (Tables 42 and 43) indicated that fish from the lower study area are generally 10 to 15 mm longer and about 10 grams heavier in weight than upper study area fish. Fish from the upper study area grew very little from May thru August, ranging in size from 134 to 143 mm and 20 to 23 grams. There was increasing growth into the month of October when yearling fish averaged 160 mm in length and 38 g in weight. Marking experiments showed that only 17 percent of the fish collected moved into the section in October, so no major influx of fish occurred to account for the larger size. Yearling fish from the lower study area (Table 43) decreased in size from 160 mm and 37.4 g in July to 158 mm and 29 g in August as water temperature reached 20.5 C in August. Yearling steelhead increased in lenqth and weiqht from 158 mm and 29 g in August to about 170 mm and 44 g in-October, but then decreased in November and December (Table 43). Fish sample size was small, (<50) for this size stream, which may have added to the variability in average fish size.

Averaqe fish weiqht and condition factor (Tables 42 and 43) reached their lowest point, at both study areas, in Auqust as the highest average stream temperature was reached (18.5-20.5 C)l Yearling condition factors ranqed from .68 in Auqust to .87 in May at the upper study area. Average fish condition factor at the lower study area varied from .96 in May to a low of .69 in August. Condition factor in December (.71), during the overwintering period, was about the same magnitude as the lowest condition factor observed in August (.69). Yearlinq fish were not in good condition durinq this time. Some fish growth occurred from August to October at both study areas and apparently, fish growth also occurs in the spring period into May and June. This growth was missed as no sampling was conducted in the early sprinq due to higher flows and water turbidity. Outmiqration of the larger smolt-sized fish occurs during the late spring (April to June) and may be causinq some of the observed fluctuation in fish size in this lower study area, thus masking the actual growth increments.

Progression in the averaqe length and weight of subyearlinq fish was generally similar between the two study areas (Tables 42 and 43). Upper study area fish grew somewhat faster initially (from June to July) but the average total lenqth in October was about the same; ranging from 91 to 93 millimeters. Lower study area fish in December were 94 mm long and weithed 6.6 g going into the winter period. Average fish condition factors at the upper study area varied from a low of .76 in July to 1.08 in June (Table 42). Subyearling condition factors at the lower study area were less variable, ranging from .90 in June to a low of . 80 in October (Table 43). The lowest condition factor occurred in October durinq low stream flow conditions of . 0924 m^3/s (Table 40).

Table 42. Average total length, weight and condition factor (standard deviation in parenthesis) of yearling and subyearling rainbow-steelhead trout sampled from the upper study area on Big Canyon Creek in 1983.

Month	Yearling Total Length (mm)	Yearling Weight (g)	Yearling Condition Factor	Subyearling Total Length (mm)	Subyearling Weight (g)	Subyearling Condition Factor
1983						
May	134.5 (20)	22.95 (13.9)	0.87 (.15)			
June a	136.2 (17.9)	22.30 (11.2)	0.83 (.15)	56.8 (7.3)	1.85 (.30)	1.08 (.44)
July	143.7 (25.5)	23.70 (21.6)	0.70 (.15)	69.2 (7.9)	2.40 (.30)	0.76 (.31)
August	140.5 (19.8)	20.2 (11.7)	0.68 (.13)	74.0 (6.9)	3.10 (.67)	0.78 (.22)
September						
October a	160.0 (25.4)	37.90 (22.7)	0.84 (.16)	93.2 (8.9)	7.45 (2.17)	0.89 (.06)

a Only one 50 meter stat ion sampled,

Table 43. Average total length, weight and condition factor (standard deviation in parenthesis) of yearling and subyearling rainbow-steelhead trout sampled in the lower study area on Big Canyon Creek in 1983.

Month	Yearlinq Total Length (mm)	Yearlinq Weight (g)	Yearlinq Condition Factor	Subyearlinq Total Length (mm)	Subyearlinq Weight (g)	Subyearlinq Condition Factor
1983						
May	146.7 (24.2)	34.10 (32.2)	0.96 (.13)	-		
June a	155.1 (22.2)	29.1 (15.9)	0.71 (.09)	55.2 (9.6)	1.40 (.56)	0.90 (.46)
July	160.2 (22.1)	37.4 (17.6)	0.85 (.13)	61.6 (9.8)	1.20 (.56)	0.85 (.33)
August	157.8 (20.6)	29.2 (13.5)	0.69 (.11)	65.9 (10)	2.50 (.90)	0.89 (.26)
September	170.3 (27.8)	43.7 (34.2)	0.77 (.16)	77.2 (9.9)	4.10 (1.62)	0.86 (.05)
October	172.2 (35.2)	45.0 (30.8)	0.77 (.12)	91.4 (13.3)	6.10 (2.76)	0.80 (.17)
November	167.7 (34.3)	38.8 (25.5)	0.72 (.08)	98.1 (12.7)	8.40 (2.80)	0.86 (.07)
December	158.9 (26.4)	31.5 (18)	0.71 (.10)	93.9 (13.8)	6.60 (1.65)	0.84 (.28)

a Only one 50 meter station sample.

The length-weight relationship for juvenile rainbow-steelhead trout (Figure 75) was calculated by a non-linear least squares regression. Juvenile steelhead in Rig Canvon Creek exhibited allometric growth (Tesch 1971) as the exponent exceeded the cubic relationship. In fact, Big Canyon Creek fish had the highest growth rate of all five study stream steelhead populations. The log length-loq weiqht relationship for juvenile rainbow-steelhead trout was log W = -9.2975 + 2.51 log L (R^2=.83).

Enhancement Strateqy

The Big Canyon Creek system, currently, is one of the top steelhead producing streams within the Nez Perce Reservation. Enhancement recommendations for Rig Canyon Creek have previously been made by Kucera et al. (1983) and Fuller et al. (1986). Results from the current study and these reports will be utilized to address anadromous salmonid enhancement potential. Where direct support from the sample data is not available, through regression or correlation, support from the literature is used. Problems that were identified were a lack of perennial flow in 8 to 10 km of stream, lack of yearling habitat, low summer stream flows and elevated water temperatures and extreme variation in annual stream flow.

A lack of perennial stream flow occurs in 8 to 10 km of stream in the middle to upper section of Rig Canyon Creek. Instream flow improvement/augmentation would be required to open up this stream section to steelhead or chinook salmon production (Fuller et al. 1986). The Bureau of Land Management (BLM) is currently investigatin the potential for spring site enhancement to augment flows. Proposed water storage or check dam projects (Fuller et al. 1986) must ensure that water temperatures will not be increased. Current water temperatures reach 20.5 C which is above the optimum range (12-18 C) for rainbow trout (Raleigh et al. 1984). The feasibility of constructing a storage reservoir needs to be examined. The areas discussed below would also need to be addressed if this section of stream-was opened up to steelhead production.

Lack of instream cover for yearling steelhead may be a limiting factor in Rig Canyon Creek. Measured yearling habitat never exceeded about 10 percent of the total stream area with the remainder being riffle or riffle-run habitat. Yearling densities at the upper study area were moderately high, three times higher than the lower study area estimates (Tables 36 and 39). Hiqher densities at the upper studv area occurred even thouqh the percent of yarling habitat was about equal; 2.4 to 6 percent (upper area) versus 3 to 10 percent (lower area). This was believed to be due to factors, other than measured cover alone, that reflect habitat quality such as: a 2 C lower average water temperature, lower cobble embeddedness values, and due to inaccessibility a lower fishing mortality at the upper study area. Yearling steelhead density was not significantly

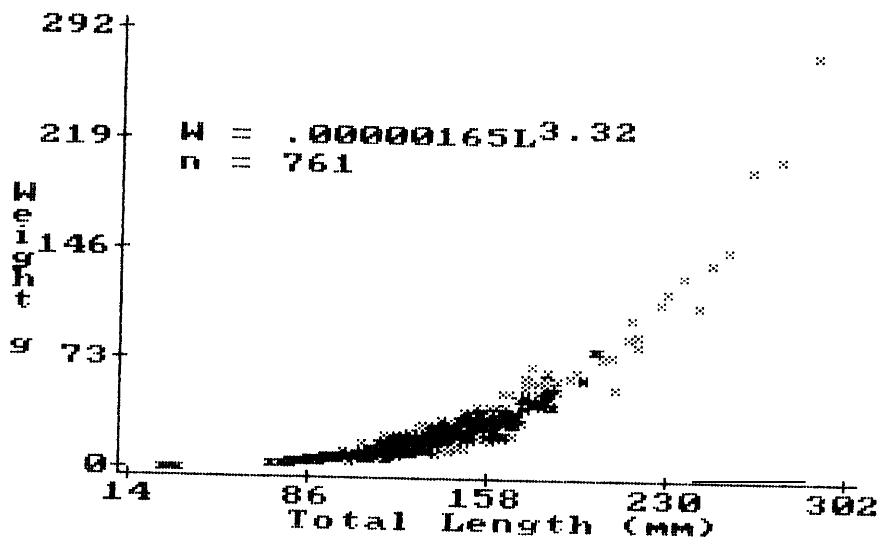


Figure 75. Length-weight relationship for juvenile rainbow-steelhead trout from Big Canyon Creek in 1983.

correlated with total yearling habitat in Big Canvon Creek. Since there was no biological basis to relate yearling density and yearling habitat data, regression analysis was not a useful tool in delineating factors that limit steelhead densities. Other investigators have found significant relationships between yearling steelhead densities and living space variables. Some habitat enhancement measures in the Clearwater Basin have also proceeded on the premise that improving instream habitat will increase steelhead density.

Stream depths during the summer and early fall months averaged 12 cm or less at the lower study area. Water velocities during the same period averaged less than 14 cm/s. Stream depth at the upper study area averaged less than 11.5 cm and water velocity was greater than 17 cm/s. Depths and velocities below 15 cm and 15 cm/s are at a minimum level in terms of probability-of-use curves for juvenile steelhead (Bovee 1978). Yearling rainbow trout (Wesche 1980) and steelhead trout (Everest and Chapman 1972) are reported to utilize depths more often as depth exceeds 15 centimeters. The majority of yearling steelhead habitat is made up of depth greater than 30 cm (pools and runs) and surface turbulence. Placement of instream structures such as woody debris, root wads, boulders, log dams and gabions would help increase the amount of pool habitat. With such limited yearling cover present ((10%) it is estimated that placement of instream habitat structures could substantially increase the smolt yield in Big Canyon Creek. Placement of instream structures should take place as part of an overall enhancement/restoration plan. For example, Jester and McKirdy (1966) reported that water temperature increased 60 percent in 16 stream reaches improved by log dams. Water temperatures in Big Canyon Creek average 20.5 C during the summer months which is above the optimum range of 12 to 18 C for rainbow trout (Raleigh et al. 1984). Riparian revegetation is also required to help reduce water temperatures. Instream habitat enhancement should be directed in the area above the confluence of Little Canyon Creek.

Low summer stream flows and high summer water temperatures are also of concern in the Big Canyon Creek system. Stream discharge reached a low of .092 m^3/s (3.2 cfs) in October. Stream discharge was highly correlated (in most cases) with total. yearling habitat and at low base flows severely limited the available yearling cover. Available yearling cover was lacking (<10%) under low flow conditions as the majority of habitat present (90%) was riffle or riffle-run habitat. Average water temperatures in Big Canyon Creek reached 20.5 C during the summer period. Yearling steelhead growth in weight is negative from July to August as water temperatures are elevated. Big Canyon Creek is situated in a wide U-shaped canyon with very limited overhead canopy due to grazing and peak spring runoff. Platts and Rinne (1985) state that summer solar radiation accounts for 95 percent of the heat input in streams during midday. A moderate overhead canopy is essential to shade the stream and keep water temperatures at acceptable levels for salmonid production. Raleigh et al. (1984) report that the optimum range in water temperature for rainbow trout is between 12 to 18 degrees Centigrade. Water temperature and yearling density are positively significantly correlated in Big Canyon Creek. The data did not indicate that increased water temperature reduced yearling densities. Increase in fish density along with water temperature could only occur up to the point that lethal temperatures were approached and then the relationship would truncate. The upper limit in optimum water temperature (Raleigh et al. 1984) has been exceeded and yearling growth is negative and low condition factors result during the summer (August). Riparian revegetation is necessary to help shade the stream thus reducing water temperature. It would also help stabilize stream banks which would reduce the rate of water runoff in the spring and sediment input. Channel stability and increased stream flow may also result from good riparian development. Exclusion of cattle will be required to establish both stream bank vegetation and overhead canopy.

Aerial and ground observation has indicated that severe flooding has occurred in the Big Canyon Creek system in the past. Stream discharge during the sampling period ranged from .0763 to .383 m^3/s, from May to December, but spring flows of 56.6 m^3/s at the mouth are considered normal (Morrison and Maierle 1977). Little Canyon Creek contributes perhaps 30 to 40 percent of the 56.6 m^3/s spring discharge. Assuming that Little Canyon Creek contributes 30 percent of the discharge, the Big Canyon Creek annual flow variation is estimated to he 519 fold. Since the stream was studied for only a one year period it is not positively known how stable the stream channel is in this [J-shaped canyon area. Spring runoff and grazing currently inhibits riparian vegetation establishment on the stream banks. Placement of instram structures such as woody debris may be done to help control channel stability (Heede 1981) while also creating high quality pools (Platts and Rinne 1985). Stream braiding exists in several stretches of Big Canyon Creek and a definite channel needs to be reconstructed and stabilized.

An enhancement/restoration plan of riparian revegetation, placement of instream structures and channel stabilization would substantially increase smolt yield in Big Canvon Creek. Riparian revegetation is necessary to help shade the stream thus reducing water temperatures and to stabilize stream banks to reduce water runoff and sediment input. Development of stream bank vegetation and overhead canopy may also help stabilize the channel and increase stream flow. Placement of instream structures would improve the amount of habitat for yearling steelhead and may be placed to improve channel stability. The feasibility of flow augmentation through spring enhancement and/or reservoir storage needs to be evaluated further.

Some channel reconstruction also needs to be conducted in areas of stream braiding. If flow augmentation was determined to be practical an additional 10 to 12 km of stream would be opened up to steelhead production. The current steelhead smolt yield from mainstem Big Canyon Creek ranged between 14,388 to 50,738 fish. It is estimated (indirectly) that the smolt yield would be doubled if all the above measures were implemented.

JACKS CREEK

Jacks Creek flows for about 12.9 km in length (Figure 76) and is joined by several small tributaries in the mid to upper sections. The stream courses through a rather steep canyon area and riparian vegetation is well developed. Cattle grazing in the canyon bottom is light to moderate. Logging activity has taken place in the recent past and old logging roads remain.

Jacks Creek was the smallest of the five study streams that were investigated. Stream discharge in Jacks Creek ranged from .005 to .2743 m^3/s during the one year study period (Figure 77). Monthly average water temperatures (Figure 77) varied from 1 to 16.3 C, with maximum temperature up to 20.5 C during August. Stream gradient at the study area ranged between 2 to 10 percent and averaged about four percent. Water quality analysis (Table 44) indicated that constituents measured did not appear limiting to fish production althouqh nitrate level (.92 mg/l) was the highest observed among the five study streams. Small volumes of water, such as the low discharge in Jacks Creek, mav reflect more concentrated nutrient levels due to a lack of dilution (Hem 1975). Fish species inhabiting Jacks Creek are: rainbow-steelhead trout, chinook salmon, speckled dace, Paiute sculpin and bridgelip sucker. Presence of adult steelhead was not documented in Jacks Creek during the study period. Fishing mortality was not quantified during this studv, but was believed to be light at the upper study area.

Upper Studv Area

Rainbow-steelhead trout was the sole anadromous salmonid sampled in Jacks Creek with an occasional chinook salmon being collected. Yearling densisy during 1983 (Figure 78) decreased from a high of .325 $fish/m^2$ in May to .265 in August and declined to .06 $fish/m^2$ in January of 1984 (Table 45). Fish density decreased from .32 $fish/m^2$ in June to .24 $fish/m^2$ in July as measured yearling habitat decreased from 9.92 to 2.6 square meters (Table 46). The largest decrease in yearling numbers, not densities, also occurred from June to July. Estimated population abundance was about the same from October to January but rising discharge increased the available stream area, thus decreasing the density of fish per unit area. Yearling density comprised from 28 to 37 percent of the total salmonid density present from June to November, with subyearlinq fish representing the remainder. Difficulty in sampling subyearling rainbow-steelhead trout from December on precludes a density comparison during that time. Based on January density estimates the projected smolt yield for Jacks Creek is 1,750 fish. This estimate assumed no mortality occurred after the January sample date.

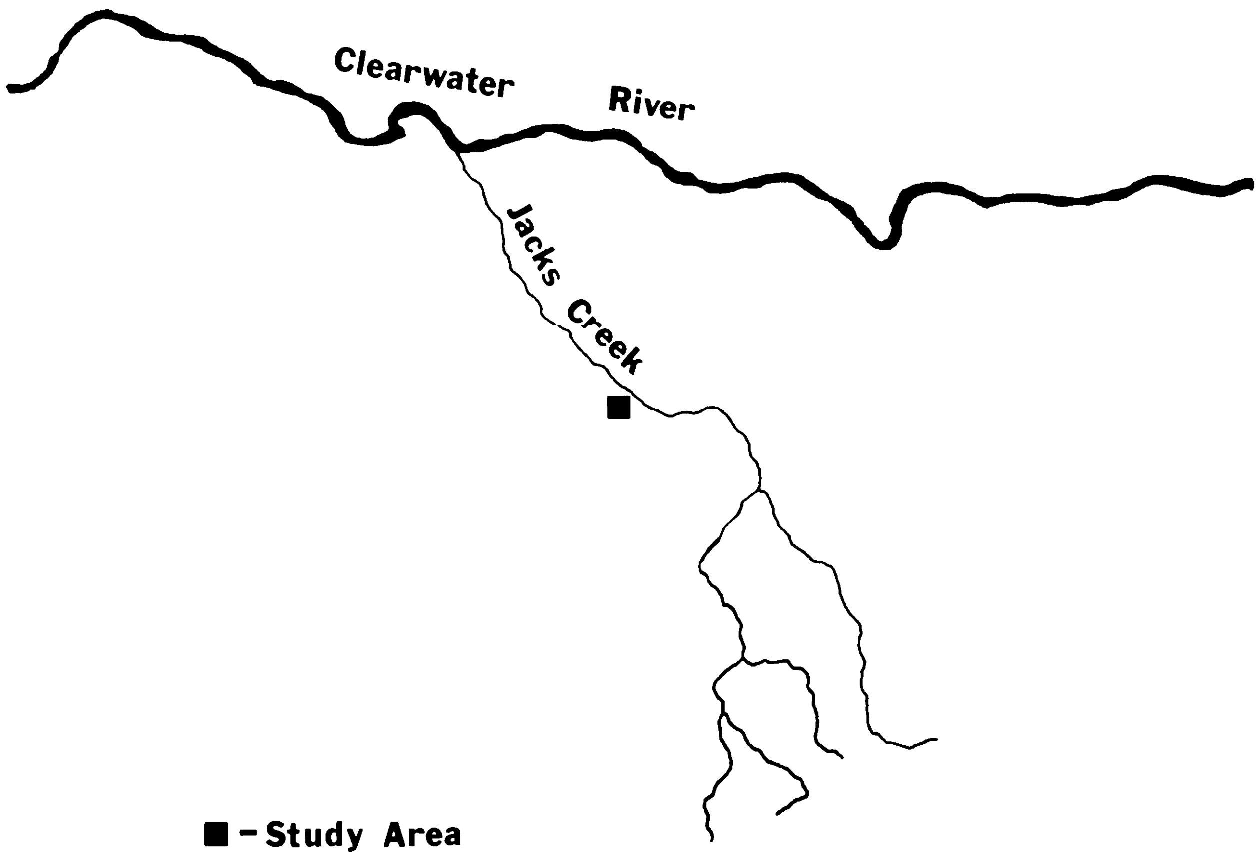


Figure 76. Map of Jacks Creek indicating the study area sampled in 1983.

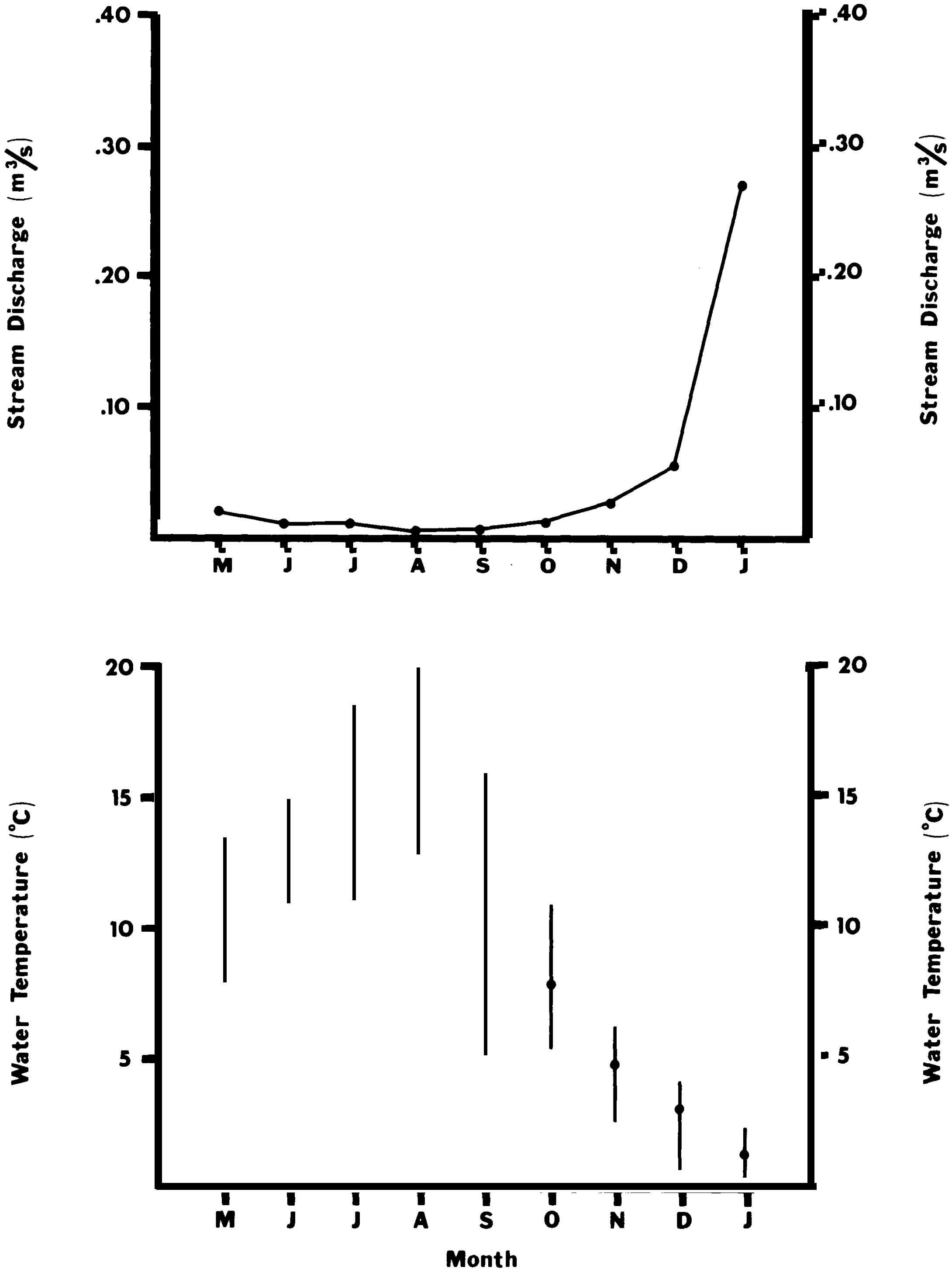
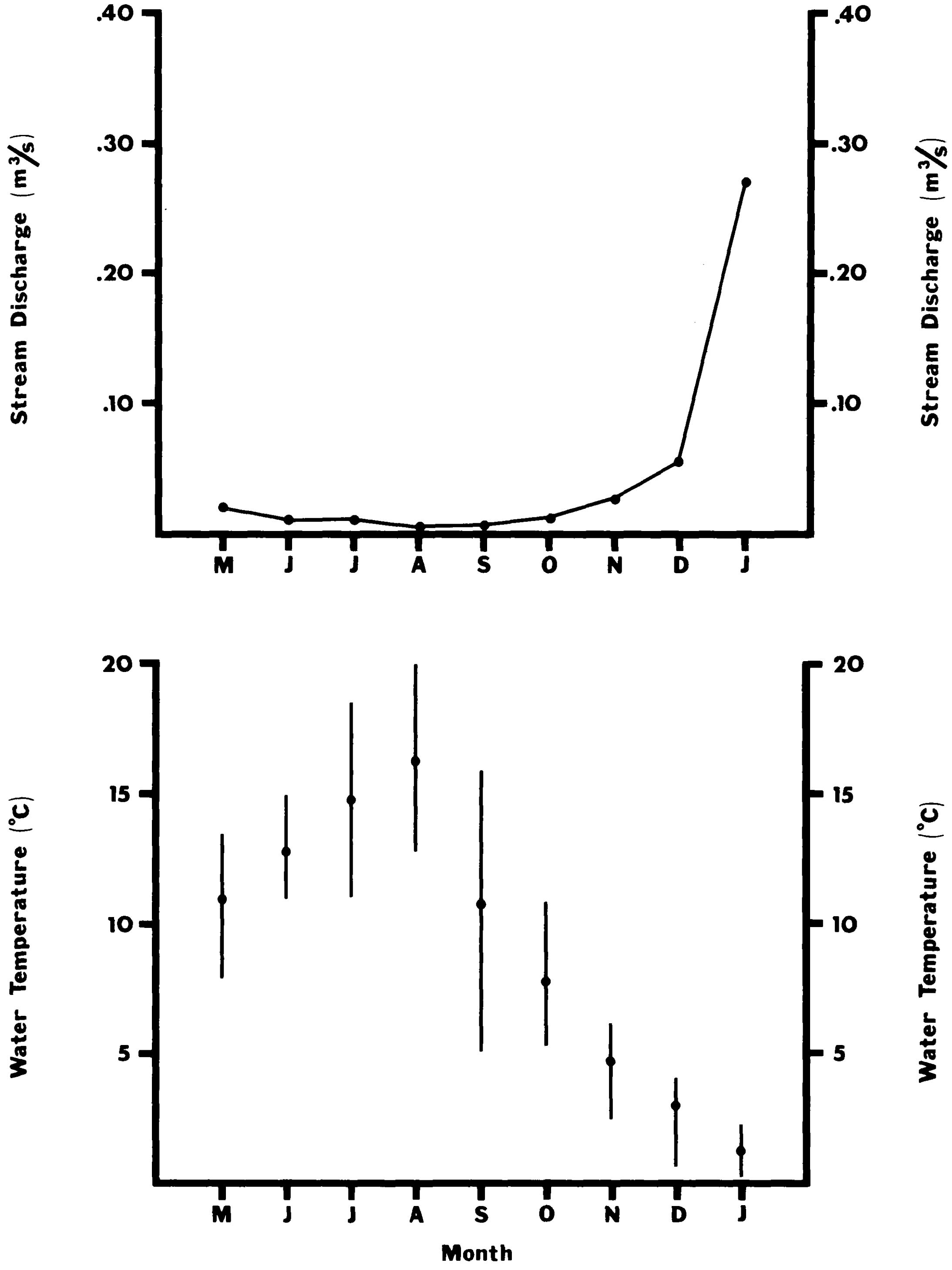


Figure 77. Monthly average and range in water temperature (lower graph) and average stream discharge (upper graph) for Jacks Creek in 1983.

Table 44. Chemical analysis of water collected from Jacks Creek on August 4, 1983.

Constituent	Year 1983
pH	8.22
Calcium, Ca, mg/l	13.48
Magnesium, Mg, mg/l	4.74
Sodium, Na, mg/l	5.40
Potassium, K, mg/l	1.26
Chloride, Cl, mg/l	0.35
Carbonate, CO3, mg/l	Nil
Bicarbonate, HCO3, mg/l	79.27
Sulfate, SO4, mg/l	2.0
Nitrate, NO3, mg/l	0.92
Orthophosphate, PO4, mg/l	0.10
Total Residue, mg/l	112.0
Non-Filtered Residue, mg/l	6.0
Total Dissolved Solids, TDS	116.0



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Magnesium, Mg, mg/l	4.74
Sodium, Na, mg/l	5.40
Potassium, K, mg/l	1.26
Chloride, Cl, mg/l	0.35
Carbonate, CO3, mg/l	Nil
Bicarbonate, HCO3, mg/l	79.27
Sulfate, SO4, mg/l	2.0
Nitrate, NO3, mg/l	0.92
Orthophosphate, PO4, mg/l	0.10
Total Residue, mg/l	112.0
Non-Filtered Residue, mg/l	6.0
Total Dissolved Solids, TDS	116.0

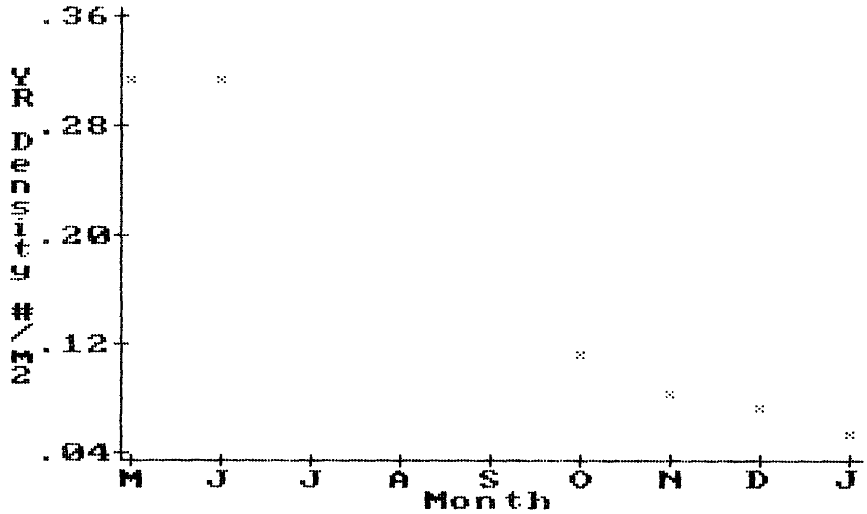

Figure 78. Yearling rainbow-steelhead trout density at the upper study area on Jacks Creek from May, 1983 to January, 1984.

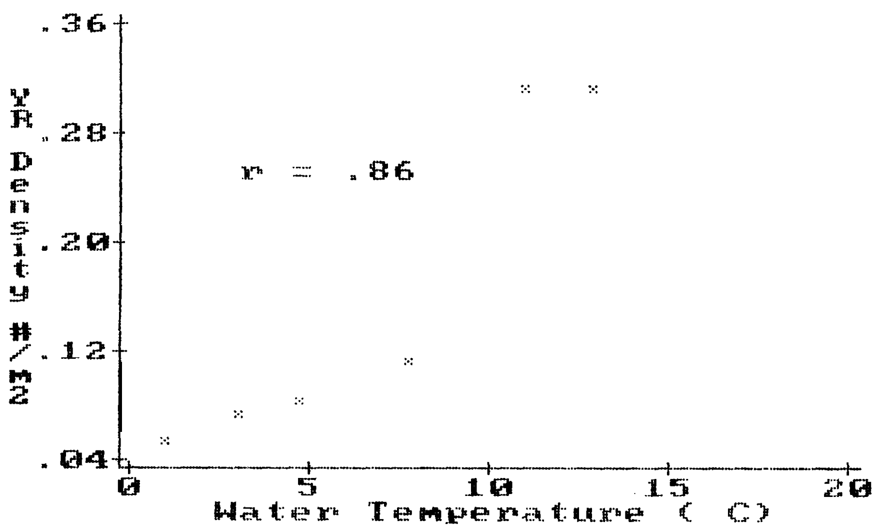

Figure 79. Relation between yearling rainbow-steelhead trout density and average water temperature at the upper study area on Jacks Creek from May, 1983 to January, 1984.

Table 45. Monthly values of stream area and stream volume sampled and average density and biomass (standard deviation in parenthesis) of yearling rainbow-steelhead trout measured at the upper study area on Jacks Creek in 1983,

Month	Stream Area Sampled (m2)	Stream Volume Sampled (m3)	Density Number/m2	Density Number/m3	Biomass Grams/m2	Biomass Grams/m3
1983						
Mar	347.6	24.8	0.325	4.83	4.55	67.12
			(.02)	(.66)	(.44)	(.60)
June	308.0	19.7	0.320	6.35	3.94	75.90
			(.05)	(4.02)	(.41)	(43.56)
July	292.0	15.0	0.240	4.84	3.14	63.40
			(.05)	(.48)	(.75)	(6.37)
August	249.6	12.4	0.265	6.03	3.25	73.59
			(.007)	(2.22)	(.17)	(21.64)
September	267.4	15.6	0.200	3.67	3.09	57.34
			(0)	(.74)	(.07)	(12.81)
October	309.4	22.4	0.120	1.92	2.23	32.51
			(.02)	(.39)	(.73)	(1.82)
November	320.2	21.2	0.090	1.51	1.49	23.79
			(.01)	(.16)	(.37)	(5.22)
December a	192.4	24.4	0.080	0.61	1.55	12.21
January	471.8	88.4	0.060	0.34	0.82	4.65
			(0)	(.08)	(.06)	(.92)

a Only one 50 meter station sampled.

Table 46. Average monthly physical characteristics, standard deviation in parenthesis, of the upper study area on Jacks Creek in 1983.

Month	Stream Disch. (m3/s)	Stream Veloc. (cm/s)	Stream Width (cm)	Stream Depth (cm)	Aver. Water Temp. (C)	Depth >30cm (m2)	Undercut Bank (m2)	Overhang. Vegetatn. (m2)	Surface Turb. (m2)	Subm. Rock (m2)	Total Habitat (m2)
1983											
May	0.0190 (.01)	6.9 (2.8)	366.7 (13.8)	7.1 (.09)	11	-		-	-	-	
June	0.0132 (.003)	5.5 (1.6)	324.0 (9.4)	8.1 a	12.9 a	6.22 a	0 a	0 a	3.60 a	0.10 a	9.92 a
July	0.0102 (.002)	4.2 (1.6)	309.8 (54.3)	5.2 (.3)	14.8	1.67 (.64)	0	0.27 (.38)	0.50 (.28)	0.16 (.17)	2.60 (.71)
August	0.0068 (.009)	3.2 (1.1)	261.8 (22.7)	4.8 (1.3)	16.3	1.78 (.92)	0	0	0.29 (.30)	0.06 (.09)	2.14 (1.31)
September	0.0052 (.003)	2.7 (1.5)	280.9 (15.3)	5.8 (.7)	10.8	0.91 (.41)	0	0.08 (.12)	1.69 (.56)	0.06 (.08)	2.74 (.94)
October	0.0101 (.002)	3.1 (.6)	326.1 (10)	7.2 (2.2)	7.8	1.39 (.42)	0	0	1.15 (.39)	0	2.54 (.81)
November	0.0268 (.005)	7.7 (.4)	338.8 (44.5)	6.6 (.3)	4.7	1.11 (.09)	0	0	2.35 (.007)	0	3.47 (.08)
December a	0.0542	13.3	384.9	12.7	3.0		-	-		-	
January	0.2743 (.003)	30.0 (8.3)	498.5 (49.8)	18.7 (.9)	1.0			-	-	-	

a Only one 50 meter station sampled.

Average stream depths in Jacks Creek are low, averaging less than 8 cm from May to November. Stream velocities are similarly low (<8 cm/s), during the same time frame, in this small lowland valley stream. Stream depths and velocities below 15 cm and 15 cm/s are at a minimal level in terms of probability-of-use data presented by Bovee (1978) for juvenile steelhead. Everest and Chapman (1972) reported a higher density of age I+ steelhead in depths greater than 15 centimeters. Stream discharge was also low from May to November and reached a base flow of .005 m^3/s (.18 cfs) in September. As stream discharge was positively significantly correlated (P<0.05) with most of the habitat variables measured, the low flows reduced stream depth, velocity and amount of yearling habitat available. The majority of measured yearling habitat present was depth greater than 30 cm (pools) and surface turbulence. Excellent riparian vegetation shaded the stream, keeping water temperature lowered in this small stream.

Estimated yearling biomass and density was highlv correlated (r= 97) during 1983 with both variables following similar trends in relation to measured habitat variables. Biomass declined from a peak of 4.55 g/m^2 in May (Table 45) to 3.25 in August and down to .82 g/m" in January of 1984. Yearling rainbow-steelhead, although comprising only 28 to 37 percent of the total salmonid density, represented 64 to 87 percent of the total salmonid biomass present from June to November.

Average water temperture and yearling steelhead density had a significant association as indicated through calculation of correlation matrices (Figure 79). Average water temperature in Jacks Creek (Table 46) reached a high of 16.3 C in August, which is below the upper boundary in optimum temperatures (18 C) for rainbow trout (Raleigh et al. 1984). The maximum water temperature was 20.5 C during August. The lowest water temperature observed was 1 C during Januarv, 1984. Theoretically, density could only increase until an upper lethal temperature was approached and the relationship would truncate. Good overhead canopy development shades the stream for most of its length thus reducing water temperature. The highest correlation observed between yearling density and yearling habitat was a nonsignificant one with depth greater than 30 centimeters (r=.71). Total yearling habitat and density were not significantly related (r=.55) despite the low percentage of measured cover (generally (3%). This suggests that yearling rainbow-steelhead trout have adapted to utilizing cover other than that which we measured, or other mechanisms act or interact to affect densities. Yearling numbers, not densities, decreased most Sharply from June to July as stream discharge remained at .01 m /s. Yearling numbers declined from 53 to 37 fish as they either undergo mortality or emigrate to other areas. Stream discharge and yearling density and biomass were nonsignificantly negatively correlated.

Subyearling rainbow-steelhead trout density varied from .595 fish/m^2 in June, with a marked decrease from .53 fish in August to .34 fish/m^2 in September. Densities declined to .105 fish/m^2 in January (Figure 80 and Table 47). The reduction in density from August to September occurred as stream discharge dropped from .0068 m^3/s to the lowest discharge observed of .0052 m^3/s in September. Density in November was estimated to be .225 fish/m^2 prior to subyearling movement into the substrate. Estimates from December on reflect inefficient sampling of age 0+ fish from the substrate. Subyearling fish accounted for 63 to 72 percent of the total salmonid density present with yearling fish comprising the remainder.

Biomass estimates of subyearling fish (Table 47) ranged from .57 g/m^2 in June to a high of 1.07 in August, which declined to .39 g/m^2 in December. This decline in biomass and density from November to December, occurred as fish became more heavily associated with the substrate, and partially reflects inefficient sampling. Subyearling biomass and density was not significantly associated (r=.52) in Jacks Creek. However, a distinct decline in biomass and density occurred from Auqust to September as stream discharge dropped to the lowest point (.0052 m^3/s) in September (Table 46). Subyearling biomass composed 12.7 to 35.5 percent of the total salmonid biomass present during the study period.

Average water temperature and subyearlig rainbow-steelhead trout density (Figure 81) had the highest observed relation among the variables examined. Subyearling density increased with water temperature within the ranqe of 1 to 16.3 degrees Centigrade. Density would not continue to increase as the upper lethal temperature was approximated; the relation would eventually truncate. Correlation matrices also showed that subyearling density and stream discharqe were nonsiqnificantly correlated (r=-.57) indicating an inverse relationship between the variables. Low stream discharqe may concentrate fish into a smaller available area, but higher flows do not reduce densities. Age 0+ density was hiqhly associated (r=.98) with yearling rainbow-steelhead density durinq the study period. Whether this is indicative of intraspecific predation could only be determined by a thorough food habits investigation.

Substrate sampling indicated that spawning gravels were probably adequate for adult steel-head. Estimated available spawning substrate in 1983 was 20 percent of the total stream bottom area. Spawning substrate was not availanle in large continuous expanses but, was present in patches of suitable

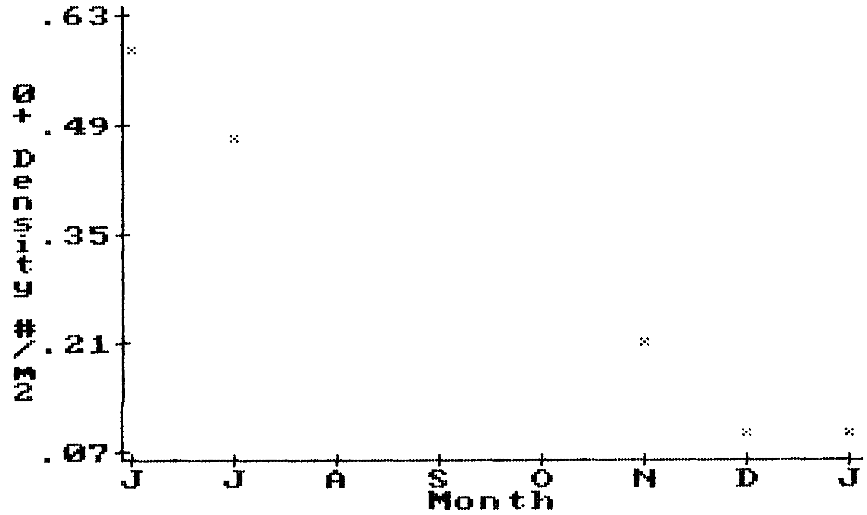

Figure 80. Subyearling rainbow-steelhead trout density at the upper study area on Jacks Creek from June, 1983 to January, 1984.

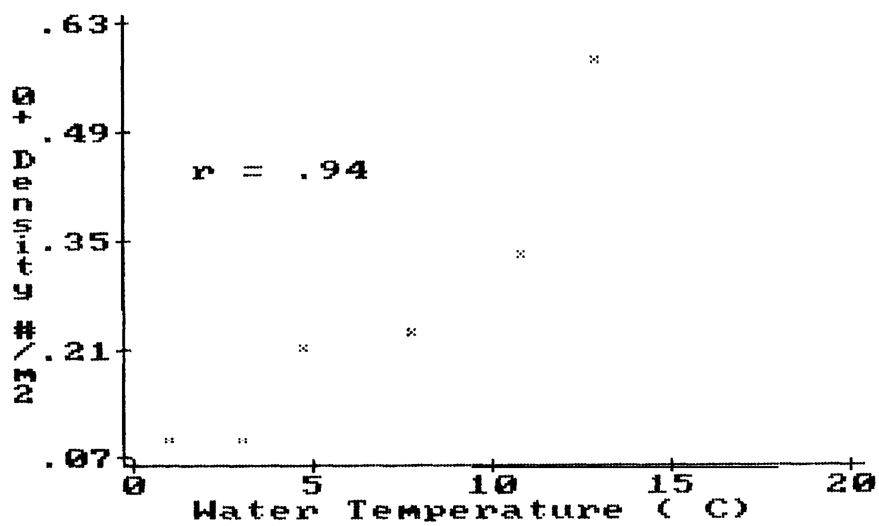

Figure 81. Relation between subyearling rainbow-steelhead trout density and average water temperature at upper study area on Jacks Creek from June, 1983 to January, 1984.

Table 47. Monthly values of stream area and stream volume sampled and average density and biomass (standard deviation in parenthesis) of subyearling rainbow-steelhead trout measured at the upper study area on Jacks Creek in 1983.

Month	Stream Area Sampled (m2)	Stream Volume Sampled (m3)	Density		Biomass	
			Number/m2	Number/m3	Grams/m2	Grams/m3
<u>1983</u>						
May	347.6	24.8	-	-	-	-
June	308.0	19.7	0.595 (.03)	11.44 (6.16)	0.57 (.11)	11.26 (7.40)
July	292.0	15.0	0.480 (.05)	9.84 (.23)	0.72 (.06)	14.99 (3.40)
August	249.6	12.4	0.530 (.10)	12.07 (5.84)	1.07 (.38)	25.94 (17.05)
September	267.4	15.6	0.340 (.07)	6.43 (2.64)	0.86 (.29)	16.55 (8.55)
October	309.4	22.4	0.245 (.007)	3.80 (1.55)	0.77 (.08)	12.26 (5.85)
November	320.2	21.2	0.225 (.007)	3.52 (.03)	0.82 (.02)	13.16 (.76)
December [a]	192.4	24.4	0.100	0.78	0.39	3.11
January	471.8	88.4	0.105 (.03)	0.61 (.27)	0.41 (.10)	2.37 (.88)

[a] Only one 50 meter station sampled.

sized gravel. The percent of each substrate classification present is given below: boulder 42.7; large cobble 23.7; small cobble 16.9; very coarse gravel 11.6; medium gravel 2.9; fine gravel .9 and silt 1.2 percent. Cobble embeddedness was visually estimated to be 25 percent.

Juvenile Steelhead Age and Growth

A total of 103 juvenile rainbow-steelhead trout were aged via the scale method to separate age groups for density and biomass estimates. Two groups of fish are recognized for this report: yearlings (age I+ and age II+) and subyearlings (age 0+). Yearling rainbow-steelhead trout ranged from 78 to 21.7 mm in total length and 4 to 89 g in weight. Ninety percent of all yearling fish examined were age I+ fish. These fish ranged in size from 78 to 169 mm in lenqth and 4 to 41 grams in weight. The remaiming fish were age II+ individuals which were 149 to 217 mm long and varied from 19 to 89 grams in weith No age III+ fish were collected in Jacks Creek. Subyearlinq rainbow-steelhead ranged up to 99 mm and 5.8 g in weight by January.

Average length and weiqht of yearling fish (Table 48) was fairly constant from May to August ranging from 111 to 116 mm and 12 to 14 grams. Some growth occurred in September and October as fish increased in size to 135 mm and about 19 g in weight in October, as water temperatures began to decline during the fall period. Fish size decreased from 125.5 mm and 19 q in October to January when yearlings averaged 119 mm and 12.45 g during the overwintering period. The growth that occurred during the early spring period was missed as no sampling was conducted. Yearling condition factors (Table 48) ranged from a high of .84 in May to a low of .54 in December. A condition factor of .65 was reached in September, during low stream flow, which was about the same magnitude as that reached in January (.69). The lowest value recorded in December (.54) may have been partially due to a small fish sample size n=15), as only one 50 meter station was completed.

Subyearling rainbow-steelhead trout steadily progressed in size (Table 48) from 48 mm and .95 g in June, up to 79 mm and 3.9 grams in January of 1984. Compared to the other study streams, these subyearlins fish are in the lower ranqe of fish size observed during the overwintering period. Hunt (1969) found that larger size was important in the overwintering survival of wild subyearling brook trout. Condition factors for age 0+ fish ranged from a low of .73 in August to .96 in January. Although subyearling fish were not very large going into the winter period their condition factor was the highest observed during the study period on Jacks Creek.

Table 78. Average total length, weight and condition factor (standard deviation in parenthesis) of yearling and subyearling rainbow-steelhead trout sampled from the upper study area on Jacks Creek in 1983.

Month	Yearling Total Length (mm)	Yearling Weight (g)	Yearling Condition Factor	Subyearling Total Length (mm)	Subyearling Weight (g)	Subyearling Condition Factor
1433						
May	111.4 (26.1)	14.0 (14.95)	0.84 (.16)	-	-	
June	111.4 (22.9)	12.15 (11.06)	0.75 (.10)	48.2 (6.5)	0.95 (.22)	0.92 (.54)
July	116.8 (25.8)	12.95 (10.8)	0.71 (.13)	58.7 (8.2)	1.50 (.48)	0.75 (.30)
August	115.7 (25.1)	12.35 (10.28)	0.71 (.16)	66.3 (7.7)	2.05 (.44)	0.73 (.27)
September	121.8 (28.5)	14.70 (15.66)	0.65 (.18)	69.8 (7.0)	3.10 (.90)	0.88 (.10)
October	125.5 (30.7)	18.95 (18.32)	0.77 (.11)	72.6 (7.6)	3.15 (.43)	0.85 (.27)
November	122.7 (26.6)	16.50 (11.38)	0.82 (.13)	75.3 (6.4)	3.75 (.43)	0.90 (.21)
December	136.8 (31.8)	17.25 (16.15)	0.54 (.12)	77.4 (8.3)	3.40 (.68)	0.75 (.19)
January	119.4 (16.3)	12.45 (5.47)	0.69 (.12)	78.6 (11.9)	3.90 (1.10)	0.96 (.98)

The length-weight relationship for juvenile rainbow-steelhead from Jacks Creek (Figure 82) was calculated by a non-linear least squares regression. Growth slightly exceeded the cubic relationship resulting in allometric growth (Tesch 1971) during natal stream residence. The log length-log weight relationship was log W = -10.9334 + 2.8312 log L (R^2 =.97).

Enhancement. Strategy

Kucera et al. (1.983) and Fuller et al. (1986) have previously made enhancement recommendations for the Jacks Creek system. Results from these studies and the current survey will be used to address anadromous salmonid enhancement potential. Where direct support was not available from the sample data, throuqh regression or correlation, support from the literature was used. Problem areas that may limit production were a lack of yearling habitat, low summer stream flow and elevated water temperatures.

Lack of instream cover for yearling fish is a limiting factor to anadromous salmonid production in Jacks Creek, as in other stream systems (Everest and Sedell 1984). Total measured yearling habitat never exceeded seven percent of the available stream area and was usually about two percent. The majority of yearlinq habitat present was surface turbulence and small plunge pool-like cover with water depth greater than 30 cm as cover. Yearlinq density was correlated with depth greater than 30 cm (r=. 71) but not siqnificantlv (P>0.05). No siqnificant correlations existed that provided a bioloqical basis to relate yearling density data to habitat information. Regression analysis, therefore, was not a useful tool in defining factors that limit densities or in providing a redictive basis to estimate densities from measurement of habitat variables. Other investigators (Burns 1971; Gordon and MacCrimmon 1982) have found signifcant relationships between yearling steelhead densities and habitat variables that would more directly support enhancement through use of instream structures.

Stream depths in Jacks Creek are low averaging less than 8 cm and water velocities averaged less than 8 cm/s during most of the year. These reduced depths and water velocities are below the minimum level in terms of probability-of-use for juvenile steelhead (Bovee 1978). Wesche (1980) and Everest and Chapman (1972) have reported that yearling rainbow trout and steelhead utilize depths more often as depth exceeds 15 centimeters. Total yearling habitat comprised less than two percent of the available stream area and is believed to be limiting. Placement of instream structures such as woody debris, boulders, root wads, gabions and check dams would help increase the amount of pool habitat. The placement of instram habitat structures culd significantly increase the smolt yield.

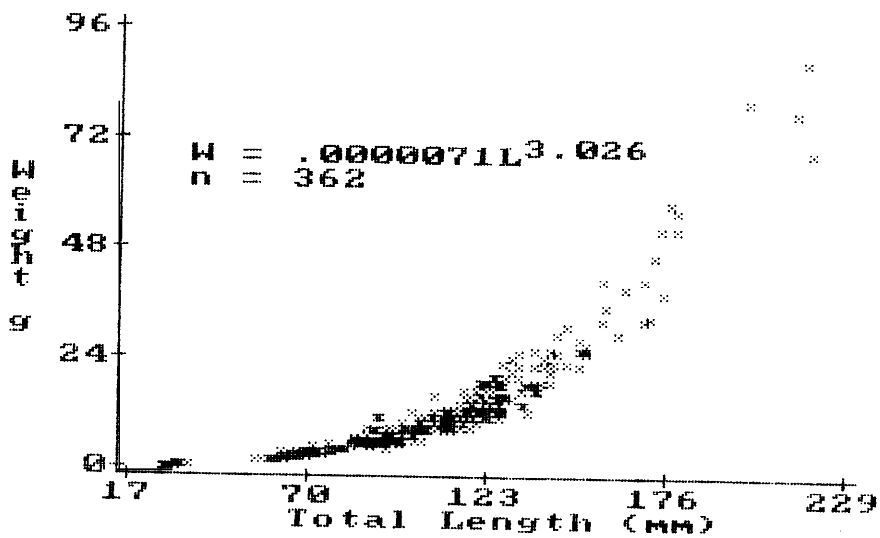

Figure 82. Length-weight relationship for juvenile rainbow-steelhead trout from Jacks Creek in 1983.

Low summer stream flow and high summer water temperatures are of concern in the Jacks Creek system. Stream discharge was as low as .005 m^3/s (.18 cfs) during September of 1983. Stream discharge was significantly positively correlated with yearling habitat (in most cases) and at base flows severely restricted the available vearling cover. Yearling habitat comprised only two percent of the available habitat during base flows as the majority was riffle habitat. Yearling numbers decreased most sharply from June to July as stream discharge remained at .014 m^3/s. Average water temperature in Jacks Creek reaches 16.3 C in August with maximum temperatures up to 20.5 degrees Centigrade. The observed average water temperatures were below the 18 C upper range in optimum temperature for rainbow trout (Raleigh et al. 1984). Good overhead canopy development shades the stream for most of its length thus reducing water temperature. However, elevated water temperatures are of concern in such a small stream system, which can be greatly affected by land management practices. Development of spring areas may be a method to supplement low flow periods which would also increase available yearling habitat.

Placement of instream structures and flow augmentation through spring enhancement would improve the smolt yield in Jacks Creek. The current estimated yield of smolts from the system is 1,750 fish. Implementation of these enhancement measures could conceivably increase smolt numbers by two fold. The feasibility of spring enhancement requires further evaluation.

MISSION CREEK

Mission Creek courses for approximately 34.3 km and discharges into Lapwai Creek (Figure 83), which in turn flows into the Clearwater River. The upper 7.2 kilometers of stream flows through meadow/pasture environs (Kucera et al. 1983) that accommodate agricultural activity and moderate to heavy grazing by cattle. Below this area Mission Creek breaks into a steep canyon, for about 17.7 km and then flows through the lower stream section where various agricultural activity occurs down to the confluence with Lapwai Creek. The lower section of stream courses through a broadened valley that has sparse riparian development to shade the stream. The lower stream section has been channelized (Cates 1981) and irrigation withdrawals also occur in this stream reach. Logging, grazing, roadinq and agricultural practices occur in the drainage which initiate heavy siltation loads (Fuller et al. 1986).

Stream discharge ranged from .0302 m^3/s to .2769 m^3/s during the fish population sampling period (Figure 84). Monthlv average water temperatures (Figure 84) varied from 1.5 to 16.7 C with maximum stream temperatures up to 22.3 degrees Centigrade. Stream gradient was estimated to average about four to five percent at the study area. Water quality analysis showed that the constituents measured did not appear limiting to fish production (Table 49). Fish species inhabiting Mission Creek are rainbow-steelhead trout, speckled dace, northern squawfish, redside shiner, chiselmouth and Paiute sculpin. Adult steelhead have also been collected in the Mission Creek system. Due to the presence of adult steelhead and less than 10 percent of the yearlings being age II+ or older, we believe the fish to be steelhead and not a resident population of rainbow trout. Steelhead from Mission Creek, electrophoretically, were indistinguishable from the Bedrock Creek population; which was the only population studied that was not significantly different from Dworshak Hatchery fish. Fishing mortality was not quantified during the study period but fishing pressure was believed to be moderate.

<u>Upper Study Area</u>

Rainbow-steelhead trout was the only anadromous salmonid sampled during the study period.2 Density of yearling fish was very low ranging from .03 fish/m in May to .08 in June and declining to .004 fish/m^2 in January of 1984 (Figure 85 and Table 50). With such a small range in density between months, no major changes in vearling abundance was observed in relation to physical habitat variables. Depth greater than 30 cm and surface turbulence made up the majority of yearling habitat present (Table 51). Yearling fish comprised 3.6 to 11.2 percent of the total salmonid density present during June to October,

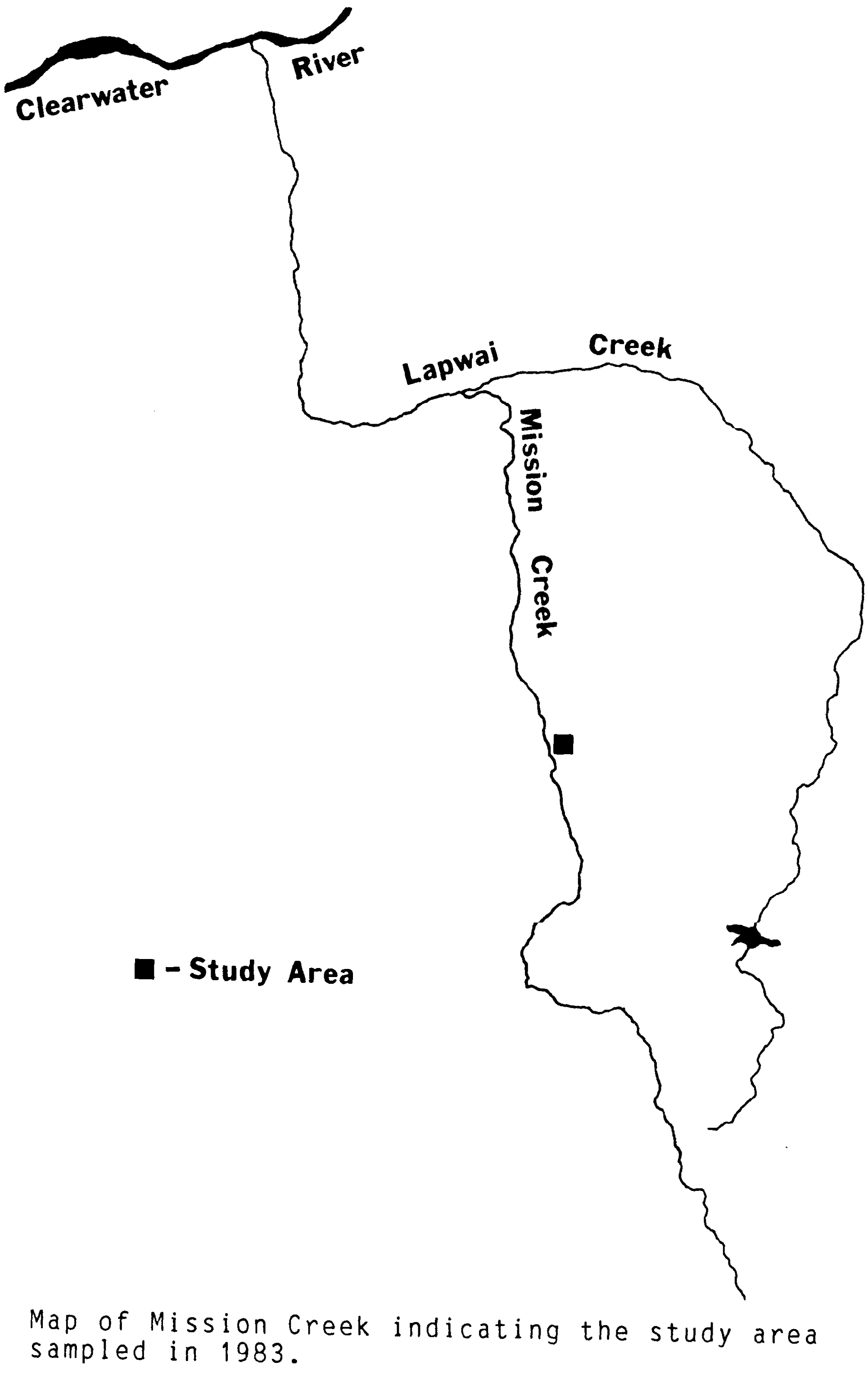

Figure 83. Map of Mission Creek indicating the study area sampled in 1983.

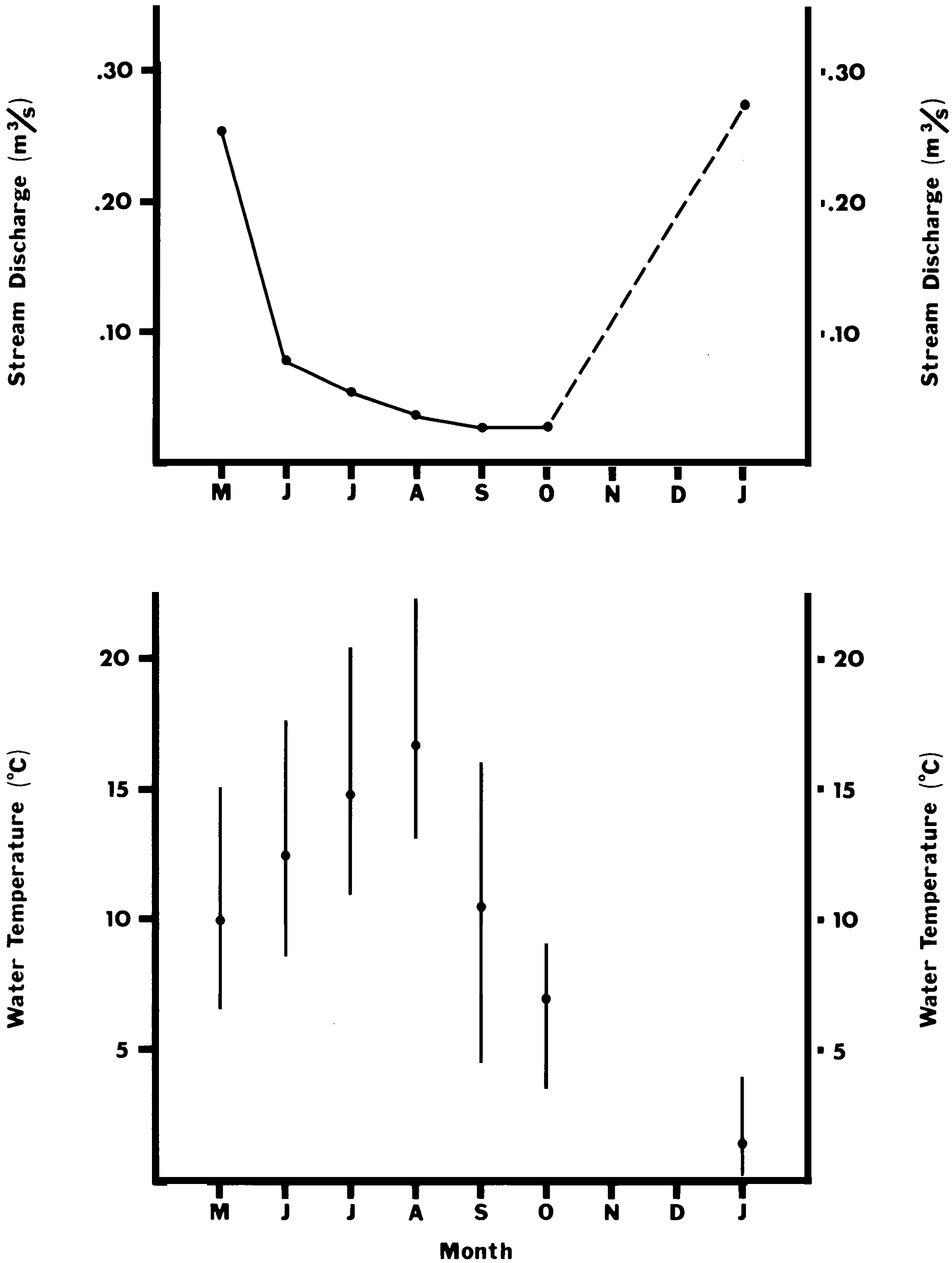

Figure 84. Monthly average and range in water temperature (lower graph) and average stream discharge (upper graph) for Mission Creek in 1983.

Table 49. Chemical analysis of water collected from Mission Creek on August 4, 1983.

Constituent	Year 1983
pH	8.13
Calcium, Ca, mg/l	14.76
Magnesium, Mg, mg/l	4.90
Sodium, Na, mg/l	6.17
Potassium, K, mg/l	1.16
Chloride, Cl, mg/l	0.35
Carbonate, CO3, mg/l	Nil
Bicarbonate, HCO3, mg/l	81.71
Sulfate, SO4, mg/l	1.0
Nitrate, NO3, mg/l	0.01
Orthophosphate, PO4, mg/l	0.06
Total Residue, mg/l	94.0
Non-Filtered Residue, mg/l	<1
Total Dissolved Solids, TDS	93.0

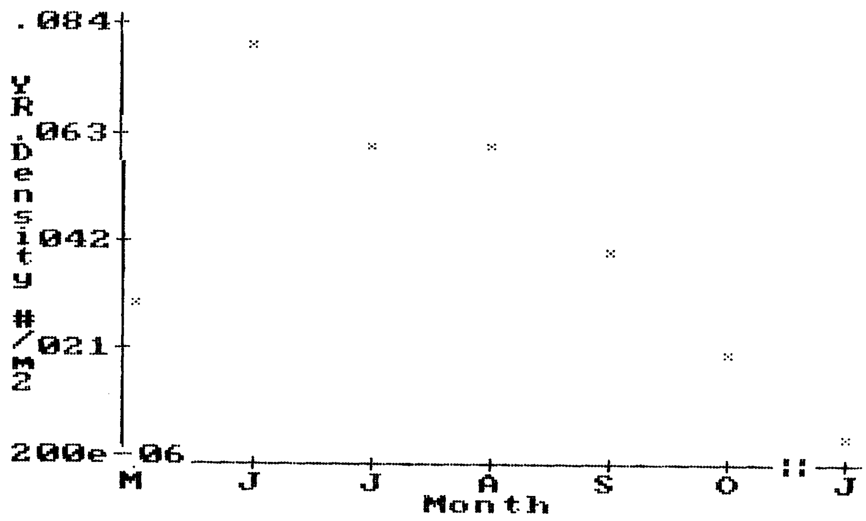

Figure 85. Yearling rainbow-steelhead trout density at the upper study area on Mission Creek from May, 1983 to January, 1984.

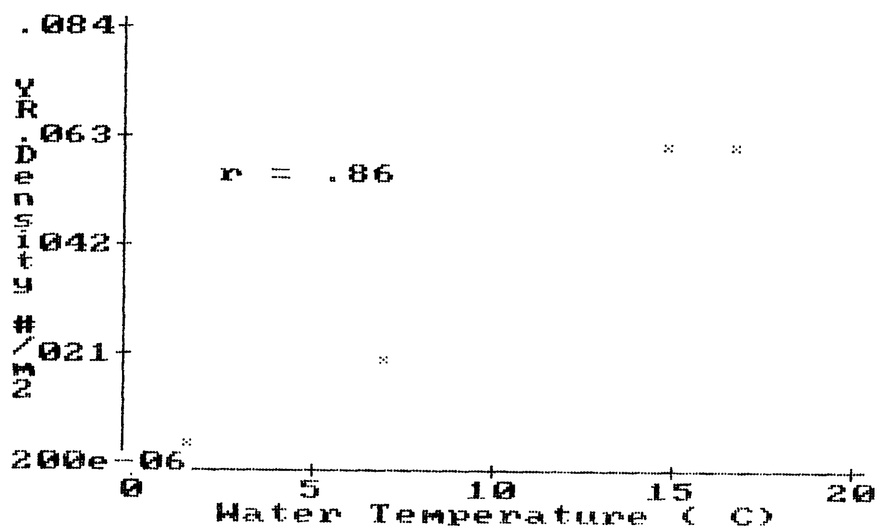

Figure 86. Relation between yearling rainbow-steelhead trout density and average water temperature at the upper study area on Mission Creek from May, 1983 to January, 1984.

Table 50. Monthly values of stream area and stream volume sampled and average density and biomass (standard deviation in parenthesis) of yearling rainbow.-steelhead trout measured in the upper study area on Mission Creek in 1983.

Month	Stream Area Sampled (m2)	Stream Volume Sampled (m3)	Density		Biomass	
			Number/m2	Number/m3	Grams/m2	Grams/m3
1983						
May	65640	90.4	0.030 (.02)	0.29 (.24)	0.88 (.68)	7.01 (6.21)
June	568.2	51.0	0.080 (0)	0.93 (.19)	2.64 (.30)	29.59 (3.25)
July	541.0	45.7	04060 (.007)	0.79 (.03)	1.85 (.16)	21.87 (.45)
August	455.8	27.2	04060 (.01)	1.04 (.18)	1.71 (.35)	28.77 (3.14)
September	50240	32.4	0.040 (0)	0.61 (.01)	1.15 (.18)	17.83 (1.94)
October	464.2	36.1	0.020 (.003)	0.34 (.13)	0.89 (.04)	11.66 (2.97)
November	-	-	-	-	-	-
December	-	-	-	-	-	-
January	677.2	104.0	0.004 (.002)	0.02 (.01)	0.18 (.03)	1.20 (.19)

Table 51, Average monthly physical characteristics, standard deviation in parenthesis, of the upper study area on Mission Creek in 1983.

Month	Stream Disch. (m3/s)	Stream Veloc. (cm/s)	Stream Width (cm)	Stream Depth (cm)	Aver. Water Temp. (C)	Depth >30cm (m2)	Undercut Bank (m2)	Overhang. Vegetatn. (m2)	Surface Turb. (m2)	Subm. Rock (m2)	Total Habitat (m2)
1983											
Mar	0.2556 (.23)	25.8 (8.8)	655.9 (108.1)	1346 (2.4)	10.0	–	–	–			
June	0.0843 (.004)	20.0 (1.4)	568.1 (27.4)	9.0 (2)	12.5	6.35 (2.19)	0	0	5.05 (.54)	0.36 (.19)	11.76 (1.46)
July	0.0583 (.002)	14.1 (1.5)	541.0 (58.7)	8.5 (.6)	14.8	5.74 (2.88)	0	0.12 (.17)	4.0 (1.02)	0.32 (.19)	10.19 (2.23)
August	0.0399 (.001)	10.8 (1.9)	455.8 (80.8)	5.9 (.6)	16.7	2.15 (2.14	0	0	2.13 (1.58)	0.13 (.07)	4.41 (3.65)
September	0.0302 (.001)	10.2 (.8)	501.9 (52.2)	6.4 (.3)	10.5	2.92 (2.25)	0	0	2.18 (1.50)	0.29 (.41)	5.40 (4.16)
October	0.0303 (.004)	8.2 (2.3)	464.2 (75.2)	8.0 (2.4)	7.0	2.89 (2.10)	0	0	ii+93 (.39)	0	3.83 (1.70)
November	–	–	–	–	–						
December	–	–	–	–	–	–	–	–			–
January	0.2769 (.04)	31.3 (2.8)	677.2 (13.6)	15.4 (.5)	1.5	–	–	–	–		

with subyearling fish making up the remainder. January data are not included due to less efficient sampling. Densities in Mission Creek were the lowest observed among the five study streams. Cobble embeddedness at this study area was about 44 percent which may be limiting available yearling habitat. Embeddedness was also the highest noted among the five study streams. The estimated current smolt yield in Mission Creek, based on October density estimates, is 1,700 fish. This estimate assumed no mortality occurred after the October sample date, and was calculated for 19.1 km of stream where steelhead and habitat currently exist. Smolt yield from the entire 34.3 km of stream would be considerably more, if the entire stream area was in production.

Stream depth and water velocity averaged less than 9 cm and 14 cm/s, respectively, from July to October (Table 51). Depths and velocities that range below 15 cm and 15 cm/s are at a minimum level in terms of probability-of-use for juvenile steelhead (Bovee 1978). Stream discharge was also low from July to October and reached a base flow of .03 m^3/s in September and October. Stream discharge was significantly positively related ($P<0.05$) to measured yearling habitat and at base flows limited the amount of available yearling cover. The majority of yearling habitat was depth greater than 30 cm (small plunge pools and pocket habitat) and surface turbulence.

Estimated yearling biomass ranged from .88 g/m^2 in May to a high of 2.64 in June and then decreased to .18 g/m^2 in January of 1984 (Table 50). Although yearling densities comprised only 3.6 to 11.2 percent of the total, yearling biomass accounted for 33 to 76.1 percent of the total salmonid weight. Biomass and density were highly correlated ($r=$ 97) during 1983 and generally exhibited similar relationships with respect to measured habitat variables.

Correlation matrices showed a significant relationship between yearling density and average water temperature (Figure 86). Average water temperature in Mission Creek peaked at 16.7 C in August which is within the optimum range, of 12 to 18 C, for rainbow trout (Raleigh et al. 1984). Maximum water temperature reached 22.3 C in August. Density could only continue to increase with water temperature until an upper lethal temperature was approached and the association would decline or truncate. Elevated water temperatures are currently of concern in the lower section of stream. At base flows (.03 m^3/s) higher water temperatures could affect -juvenile steelhead production if a hotter summer period occurred. Surface turbulence had a significant positive relationship with densitv (Figure 87) as yearling biomass had with total habitat (Figure 88). Limited ranges in yearling density(.02-.08 $fish/m^2$) and biomass (.89-2.64 g/m^2) existed as fish population estimates were low. Relationships between yearling density and/or

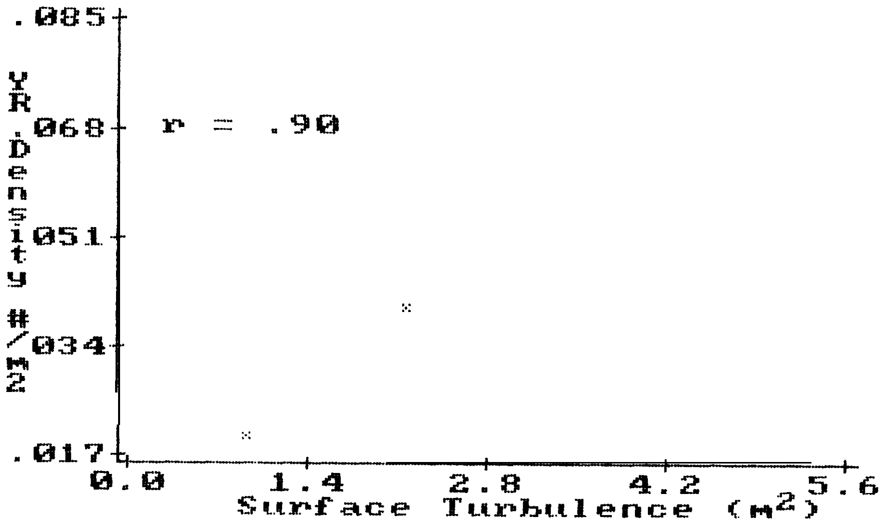

Figure 87. Relation between yearling rainbow-steelhead trout density and surface turbulence at the upper study area on Mission Creek from June to October, 1983.

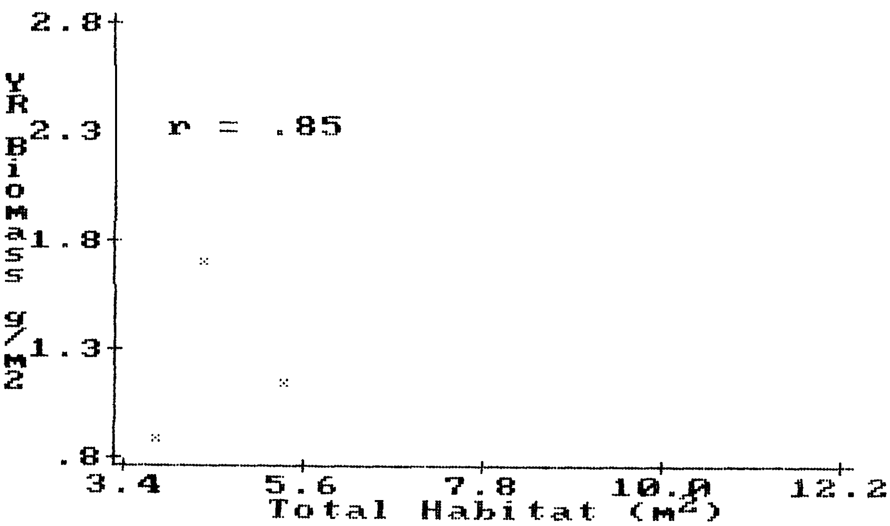

Figure 88. Relation between yearling rainbow-steelhead trout biomass and total habitat at the upper study area on Mission Creek from June to October, 1983.

biomass and yearling habitat changed between years at the other study streams. A second years data collection on Mission Creek would allow further examination of the relationships. An intensive long term study would be required to more fullv establish and model cause-effect relationships. Stream discharge was nonsignificantly negatively correlated with density and biomass, but was highly associated ($P<0.05$) with most of the yearling habitat components.

Subyearling rainbow-steelhead trout density in 1983 (Figure 89) fluctuated from .63 fish/m^2 in June to a high of .74 in August and declined to an estimated .16 fish/m^2 in January, 1984 (Table 52). Densities dropped off from .74 fish/m^2 in August to .55 fish/m^2 in September as stream discharge reached its lowest level of .0302 m^3/s (Table 51). Fish density and stream discharge both remained at similar levels in September and October as base flows existed. Subyearling abundance comprised 89 to 96.4 percent of the total salmonid density from June to October; when fish were sampled more effectively than in January.

Subyearlinq biomass in 1983 ranged from .83 g/m^2 in June to about 1.8 g/m^2 from August to October and then decreased to .74 g/m^2 in January, 1984. Biomass remained relatively constant as stream discharge remained low from August to October. As age 0+ density decreased from August (.74 fish/m^2) to September (.55 fish/m^2), increased growth compensated for the decrease in density (see juvenile steelhead acre and growth section) and kept the estimated biomass at the same level. subyearling densitv and biomass was not significantly associated ($r=.42$). Subyearling rainbow-steelhead trout biomass made up 23.9 to 67 percent of the total salmonid biomass present during the study period.

Analysis of subvearling density and habitat variables indicated that average water temperature was siqnificantlv correlated with density (Figure 90) over the study period. Age 0+ density increased with water temperature within the range of 1.5 to 16.7 degrees Centigrade. Density would not continue to increase as the upper lethal temperature was approached as the relationship would truncate. Correlation matrices also showed that age 0+ density and stream discharge were significantly negatively related (Figure 91). Low stream discharge acts to concentrate fish into a smaller available area but higher flows do not reduce subyearling densities.

Substrate sampling indicated that 17.3 percent of the bottom substrate was estimated to be of suitable size for spawning steelhead. Spawning substrate, generally, was available in small pockets or patches of suitable sized gravel as opposed to large, continuous areas of gravel. The percentage of each substrate classification present is given below: boulder

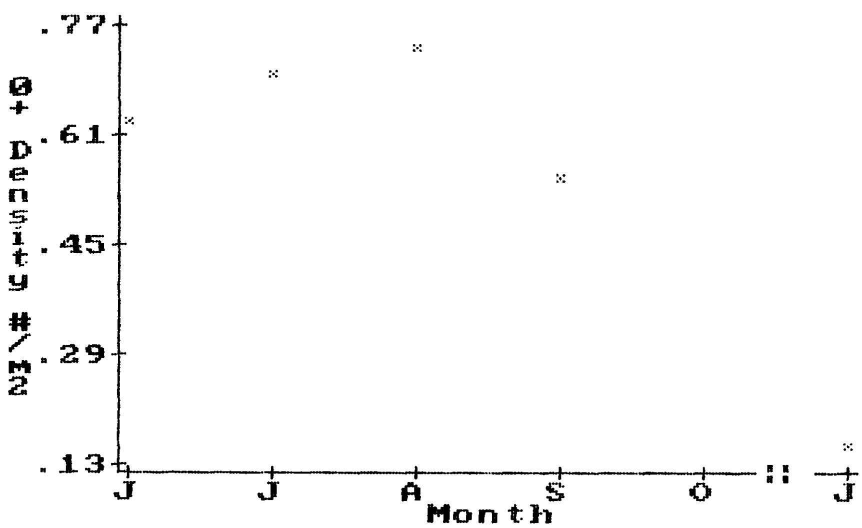

Figure 89. Subyearling rainbow-steelhead trout density at the upper study area on Mission Creek from June, 1983 to January, 1984.

Table 52. Monthly values of stream area and stream volume sampled and average density and biomass (standard deviation in parenthesis) of subyearling rainbow--steelhead trout measured at the upper study area on Mission Creek in 1983.

Month	Stream Area Sampled (m2)	Stream Volume Sampled (m3)	Density		Biomass	
			Number/m2	Number/m3	Grams/m2	Grams/m3
1983						
May	656.0	90.4		-	-	-
June	568.2	51.0	0.630 (.05)	7.25 (2.20)	0.83 (.39)	9.97 (6.46)
July	541.0	45.7	0.700 (.03)	8.25 (.92)	1.04 (.05)	12.38 (1.38)
August	455.8	27.2	0.740 (.01)	12.63 (1.50)	1.78 (.03)	30.31 (3.58)
September	502.0	32.4	0.550 (.05)	8.57 (.34)	1.80 (.17)	27.84 (1.11)
October	464.2	36.1	0.540 (.007)	7.09 (2.05)	1.80 (.07)	23.46 (6.08)
November	-	-	-	-	-	-
December	-	-	-	-	-	-
January	677.2	104.0	0.160 (.02)	1.06 (.12)	0.74 (.08)	4.83 (.41)

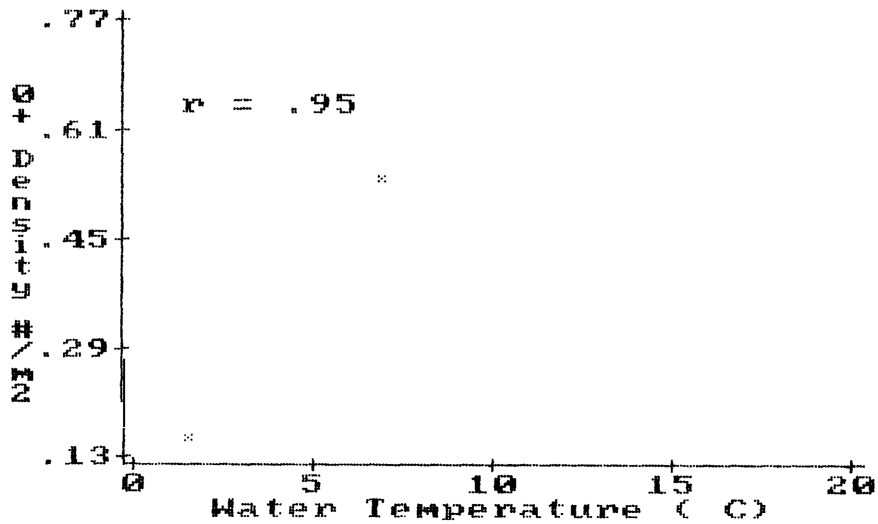

Figure 90. Relation between subyearling rainbow-steelhead trout density and average water temperature at the upper study area on Mission Creek from June, 1983 to January, 1984.

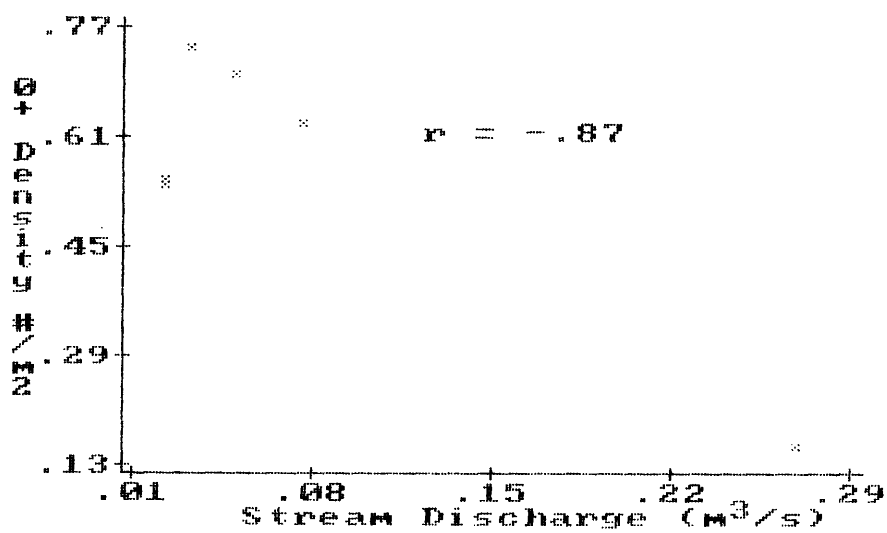

Figure 91. Relation between subyearling rainbow-steelhead trout density and stream discharge at the upper study area on Mission Creek from June, 1983 to January, 1984.

29.6; large cobble 23; small cobble 18.4; very coarse gravel 8.1; medium gravel . 7; sand 7.2 and silt 12.8 percent. With sand and silt, combined, comprising 20 percent of the available bottom substrate, and a cobble embeddedness value of 44.4 percent, Mission Creek had the highest sedimentation rate of the five study streams.

Juvenile Steelhead Age and Growth

A total of 51 juvenile rainbow-steelhead trout were aged to separate age groups for density and biomass estimates. Two groups of fish were recognized in this report: yearlings (age I+ and age II+) and subyearlings (age 0+). Yearling fish ranged in total length from 113 mm to 227 mm and in weight from 12 to 99 grams. Over 90 percent of the yearling fish examined were age I+ and these fish ranged in size from 113 to 191 millimeters in length and 12 to 53 grams in weight. The few age II+ fish sampled, ranged in length from 196 to 227 mm and in weight from 62 to 99 grams. No age III+ individuals were collected in Mission Creek. Subyearling rainbow-steelhead trout ranged up to 116 mm in total length and 13 g in weight by January of 1984.

Yearling fish increased in length and weight from 139 mm and 27.7 g in May to 153 mm and 31.8 g in June (Table 53). Fish growth declined in the summer period as yearling weight decreased from 32 g in June down to 23 g in August. Stream discharge decreased to approximately base flow level of .0399 m^3/s in August as maximum water temperature increased to 22.3 degrees Centigrade. Fish size increased from September on as water temperatures decreased in the fall and as yearling density also decreased. The sample size of yearling fish was small (<20) from October on which may affect a more precise estimate of fish growth. For example, fish increase in weight from 33 to over 36 grams in weight from December to January (Table 53) which would not be expected at average water temperatures of 1.5 to 4 degrees Centigrade. Fish growth that occurred during the early spring was missed as no sampling was conducted due to higher flows and water turbidity. Average yearling condition factors ranged from .97 in May to a low of .69 in August when maximum summer stream temperatures ocured. Condition factors increased during the fall period and averaged .81 during overwintering conditions.

Subyearling rainbow-steelhead trout grew in length and weight from 50 mm and 1.2 g in June up to 81 mm and 4.5 g in January (Table 53). These subyearling fish are in the lower range of fish size, compared to the other study streams, during the overwintering period. larger size may be important in terms of the overwintering survival of subyearling fish. More information needs to be collected on the overwintering survival of juvenile steelhead. Fish condition factors varied from 1.09 in June to a low of .75 in July. Average condition factor in January, during the overwintering period, was .87. Although

Table 53. Average total length, weight and condition factor (standard deviation in parenthesis) of yearling and ing rainbow-steelhead trout sampled at the upper study area on Mission Creek in 1983.

Month	Yearling Total Length (mm)	Yearling Weight (g)	Yearling Condition Factor	Subyearling Total Length (mm)	Subyearling Weight (g)	Subyearling Condition Factor
1983						
May	139.4	27.70	0.97	-	-	-
	(16.5)	(11.30)	(.11)			
June	153.3	31.80	0.80	49.8	1.20	1.09
	(22.9)	(19.33)	(.10)	(9.6)	(.49)	(.55)
July	147.5	26.95	0.81	59.5	1.50	0.75
	(15)	(8.93)	(.12)	(9.8)	(.49)	(.39)
August	147.8	22.95	0.69	65.1	2.40	0.89
	(14.1)	(7.17)	(.10)	(10)	(.82)	(.33)
September	150.3	25.65	0.74	70.7	3.10	0.83
	(12.8)	(8.81)	(.16)	(10)	(1.37)	(.10)
October	156.1	31.05 [a]	0.82	73.6	3.20	0.81
	(14.1)			(8.8)	(1.01)	(.21)
November	-	-	-	-	-	-
December	159.2	32.90 [a]	0.81			
	(12.5)					
January	164.5	36.25 [a]	0.81			
	(37.5)					

a Weight derived from the log length - log weight regression equation.

subyearling fish were not very large in January they were in good condition as reflected by the condition factor.

The length-weight relationship for juvenile rainbow-steelhead from Mission Creek is presented in Figure 92. The length-weight equation showed that growth was just about a cubic relationship indicating isometric growth (Tesch 1971) during natal stream habitation. The log length-log weight regression equation was log W = -11.4375 + 2.945 Log L (R^2=.99).

Enhancement Strategy

Recommendations that address enhancement/restoration of the Mission Creek system have been proposed by Kucera et al. (1983) and Fuller et al. (1986). Results from these studies and the current survey will be used to address anadromous salmonid enhancement potential. Where direct support was not available from the sample data, through regression or correlation, support from the literature is used. Problem areas that may limit production were a lack of yearling habitat, low summer stream flow and potential elevated stream temperatures and heavy sedimentation.

Lack of instream yearling habitat appears to be a limiting factor to anadromous salmonid production in Mission Creek as has been found in other studies (Everest and Sedell 1984). Measured yearling cover did not exceed four percent of the total available area and usually comprised about two percent. The majority of yearling habitat present were small stair-step plunge pools with water depth greater than 30 cm and surface turbulence providing cover. Yearling rainbow-steelhead trout density was significantly positively related to surface turbulence (Figure 87) and total yearlinq habitat (Figure 88) with a high (r=.66) but nonsignificant correlation with depth greater than 30 centimeters. This supports the idea that increased yearling habitat will support a larger number of yearling fish. However, where two years of data were available from other streams the relationships changed between years. In any event, instream enhancement is based on the premise that increased habitat will support a larger number of fish. The amount of sediment in Mission Creek reduces the amount of available habitat, especially during the winter period. A cobble embeddedness value of 44.4 percent indicated that sediment was filling in many of the interstices that fish may potentially utilize as cover, and may affect aquatic insect production.

Stream depths in Mission Creek are low, averaging less than 9 cm and water velocities averaged less than 14 cm/s durinq most of the year. Depths and velocities that range below 15 cm and 15 cm/s are at a minimum level in terms of probability-of-use information for juvenile steelhead (Rovee 1978). Wesche (1980)

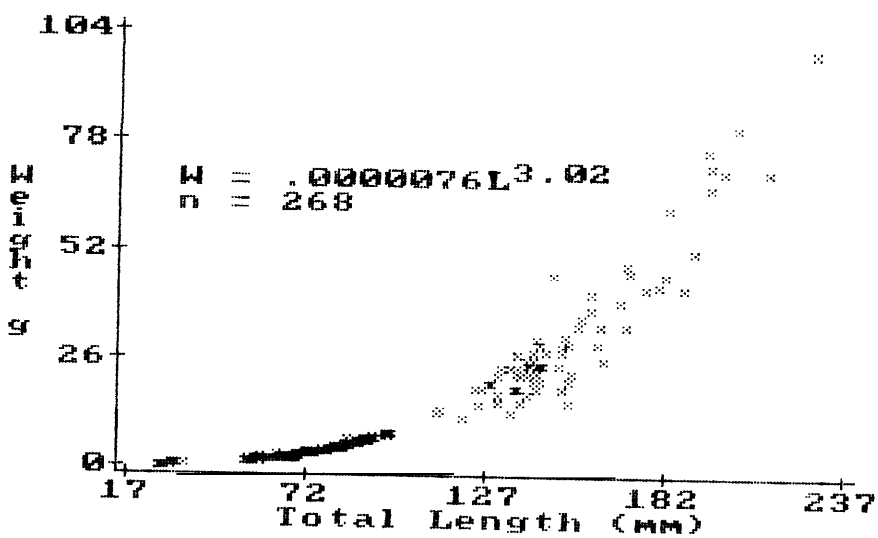

Figure 92. Length-weight relationship for juvenile rainbow-steelhead trout from Mission Creek in 1983.

and Everest and Chapman (1972) have reported that yearling rainbow and steelhead trout utilize depths more as depth exceeds 15 centimeters. Total yearling habitat was less than four percent of the available stream area and is believed to be limiting. Placement of instream structures such as woody debris, root wads, gabions, check dams and boulders would help increase the amount of pool habitat.

Low summer stream flow and potentially high summer water temperatures are of concern in the Mission Creek system. Stream discharge durinq the late summer (September) dropped to .03 m^3/s (1 cfs). As stream discharge was siqnificantly positively correlated ($P<0.05$) with yearling habitat, it limited the amount of yearling cover (<4%) present at base flows. The majority of the habitat present was riffle habitat. Averaqe water temperature in Mission Creek reached 16.7 C in August with maximum temperatures up to 22.3 degrees Centigrade. The average temperatures were below the 18 C upper range in optimum temperature for rainbow trout (Raleiqh et al. 1984). Yearlinq density and averaqe water temperature were significantly positively correlated durinq 1983. Increased water temperature was not shown to reduce yearling density. However, elevated water temperatures are of concern in lower Mission Creek and in subsequent years could affect steelhead production in other sections of stream during the summer period. Riparian revegetation is crucial in the grazed upper watershed to stabilize banks and thus reduce the rate of water runoff and sediment input. It will also help shade the stream and reduce water temperatures. Thomas et al. (1985) estimated that adequate riparian vegetation remained on only 28 percent of Mission Creek. Good riparian development may also enhance channel stability and increase stream flow. Riparian enhancement is also necessary in the lower stream reaches below the Slickpoo Mission.

Sedimentation, although not directly studied durinq this project, may be a limiting factor to rainbow-steelhead trout production in Mission Creek. Cobble embeddedness was estimated to be 44.4 percent and sand and silt, combined, comprised 20 percent of the bottom substrate types. These were the hiqhest values observed among the five study streams. Rainstorm events in the drainage would cause heavy sediment loads in the stream for several days which indicated the erosive potential i thedrainage. Bjornn et al. (1977) report that fine sediment is a limiting factor to salmonid production. Fine sediment may fill in or cover adult spawning substrate, reduce aquatic insect production on which fish feed (Cordone and Kelly 1961, Crouse et al. 3981), fill in interstices in the substrate which fish utilize as cover and may cause gill irritation. Riparian revegetation is particularly necessary in the grazed headwater section to stabilize banks,- shade the stream and decrease runoff in the sprign and thus incoming sediment. Exclusion of livestock will be necessary to ensure riparian development. Once the upper stream section is addressed the existing sediment in the bottom substrate could be trapped or removed in conjunction with the instream options or by mechanical means.

An enhancement plan of riparian revegetation and placement of instream structures would substantially increase the smolt yield in Mission Creek. Establishment of multi-layered riparian vegetation is important to help stabilize banks thus reducing the rate of water runoff and sediment input into the stream. It will also shade the stream and reduce water temperatures. Good riparian development may also aide in stabilizing the channel and increasing stream flow. Placement of instream structures will improve the amount of yearling habitat present. Structures may be placed to aid in sediment trapping and to help in channel stability if desired. It is estimated from this studv and Kucera et al. (1983) that about 55 percent of the Mission Creek system is currently producing steelhead. The projected smolt yield from this area (19.1 km) is 1,700 fish. If the enhancement measures are implemented it is estimated that the current low smolt yield could conservatively be tripled or quadrupled. Thomas et al. (1985) estimate the potential smolt production in the Mission Creek system to be as high as 11,366 fish.