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EFFECTS OF LOGGING ON RESIDENT AND SEARUN POPULATIONS OF CUTTHROAT TROUT (*SALMO CLARKI*) IN SMALL TRIBUTARIES OF THE CLEARWATER RIVER, JEFFERSON COUNTY, WASHINGTON, 1978-1979.

by

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Submitted by

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FINAL REPORT

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ABSTRACT

Five streams were chosen for a study of the effects of logging on resident and sea-run cutthroat trout. The two resident cutthroat trout streams, one logged and the other in its natural state, were studied intensively with a short-term perspective (2-yr period), and the three logged sea-run and resident cutthroat trout streams were studied extensively with a long term perspective (recovery of up to 18 yrs). The populations of trout in the logged resident cutthroat streams were determined to have maintained their abundance and age distribution over the course of the study, in spite of logging operations in and across the stream channels. Stream morphology and organic debris studies determined that the sources of organic debris providing in-stream fish habitat had been considerably reduced due to logging. This may have long-term deleterious effects on the trout population.

The extensive study showed that with proper logging techniques, streams can support abundant numbers of trout after being logged. The substrate and organic debris sources were not significantly disrupted during yarding operations and, therefore, provided stable habitat which is conducive to good fish production.

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INTRODUCTION

Numerous small streams and rivers drain the forested mountain regions of the Pacific Northwest. Many of the streams are utilized by resident and anadromous salmonids. The prosperity of the salmonids inhabiting these streams is closely related to the amount of desirable habitat available to them.

Much of the stream habitat required by the salmonids is associated with forest debris, such as boles, limbs, branches, and root wads. This material is required for cover and shelter (Giger 1973), over-winter protection (Bustard 1973; Chapman and Bjornn 1969; Bjornn 1971) and primarily, a stable stream environment (Swanson and Lienkaemper 1976a; Sedell and Triska 1976; Froehlich 1973; Hall and Baker 1975). A stable stream environment is critical to resident trout as they have a home territory, which might be a small pool, in which they may spend their entire lives (Miller 1957). Any alteration in the amount or type of forest debris which reaches streams could have deleterious effects on the fish population and stream morphometry. On the Olympic Peninsula coast, the most common cause of debris alteration is the felling and yarding of trees associated with logging operations.

Logging contributes considerably to the amount of forest debris contained in small headwater streams (Froehlich 1973). Increased volume of debris can be caused directly by logging and road construction operations, or by mass movement of material after such operations are completed. For convenience of discussion, I have divided forest debris into two general catagories: large and small debris.

Large debris consists of boles and large branches, and small debris of twigs, small branches, needles, leaves, and other fine material (Hall and Baker 1975). Some large, coarse debris can have a relatively long residence time (greater than 200 years) in or near the stream channel. The decaying and weathering processes are sometimes interrupted by extreme floods and sluice-outs. Finer material moves more readily through the system and either decays rapidly or is flushed out during high flows (Froehlich 1973).

The study of large debris has been limited in the past, but there is some direct evidence that debris has both positive and negative biological and physical roles in the stream system. Positive effects of large debris occur when it creates rearing and resting habitat for fish; and in its acting as a sediment trap, which creates habitat for invertebrates and enables microorganisms to process fine particulate matter and detritus (Hall and Baker 1975; Swanson and Lienkaemper 1976a; Martin 1976). Large debris can act to benefit stream morphometry by: 1) reducing stream velocity, which reduces the stream's erosive force (Meehan et al. 1969; Heede 1975); 2) protecting against freshet damage (Larkin and graduate students 1969); 3) trapping spawning gravel, and 4) creating pools and habitat for fish and other aquatic organisms (Anderson 1975).

Large debris in excessive amounts, however, creates the potential of deleterious effects with regard to channel morphology and streambed stabilization. A change in size, quantity, or position of large debris could produce extensive and prolonged erosion of the stream bank, bed, and channel (Hall and Baker 1975). Large accumulations of debris can divert flows which cut new channels or undercut banks, causing accelerated hillside failure and increased sediment input (Swanson and Lienkaemper 1976a). Bank cutting, gravel shifting, and related sedimentation attributed to excessive large debris jams can cause entrapment and scouring of eggs and fry, as well as hindering the oxygen exchange between surface and intragravel water (Bishop and Shapley 1963; McNeil 1966; Tagart 1976; Hall and Baker 1975; Hall and Lantz 1969).

The removal of large organic debris from streams could have serious adverse, long-term effects on small streams by inducing channel degradation and channelization. After excessive debris removal, streams which previously flowed in a series of steps assume a more uniform, steep profile and experience other changes in channel morphology. These factors decrease the diversity of the stream habitat by eliminating pools, which are primary areas of productivity. Fine organic matter is transported more rapidly through the system because of increased water velocity, and the opportunity for use by aquatic organisms is decreased. The removal of large debris reduces the long-term biological productivity and increases the rate of sediment transfer from headwater areas to downstream areas (Swanson et al. 1976b).

Small debris also has the potential for both beneficial and adverse effects. Small debris is an important food source for many aquatic invertebrates (Cummins 1974) which are very important in the food chain of trout, especially in small headwater streams.

Adverse effects of small debris are evidenced in changes of the stream channels. The stream may push small debris, such as branches, into piles resembling beaver dams. These piles may deflect the water out of the existing channel into a bank, causing heavy erosion. Piles which stack up in midstream sometimes form sediment traps, therefore preventing the stream from flushing itself (Anderson 1975).

Removal of streamside vegetation can significantly increase temperatures in small headwater streams (Brown and Krygier 1967; Chapman 1962; Narver 1972; Hall and Lantz 1969). Both summer maxima and diurnal fluctuations can be greatly increased. In a clearcut study stream on the Alsea watershed in Oregon the summer maximum temperature recorded immediately after clear-cutting operations was 24°C, 8° higher than the previous maximum. The maximum diurnal fluctuation was 8°C, while previous values ranged from 0.5° to 1.5°. The following summer the maximum temperature was recorded at 30°C with a maximum diurnal fluctuation of 16°C (Hall and Lantz 1969). These maximum temperatures are probably above the lethal temperature for trout juveniles and adults, and are well above lethal temperatures for eggs and alevins (Dr. Ernest Brannon, personal communication). A more subtle effect of increased temperature is increased parasitism and disease (Chapman 1962; Narver 1972; Davis 1953).

Removal of streamside vegetation can also lower winter minima (Green 1950) which is harmful to incubating embryos (Chapman 1962). Decreased temperatures create a longer incubation time which subjects the eggs to greater probability of scour due to flooding. Chapman (1962) found that increased incubation time decreased growth for the first year, which increased losses due to predation.

In some instances, increased temperature in spring and summer may be beneficial (Chapman 1962; Narver 1972). Increased temperature may increase primary productivity, which would create more available energy along the aquatic food chain. An increase in fish metabolism, due to warmer water, coupled with a more abundant food source could result in more rapid fish growth. Increased growth can remove fish from the predator-vulnerable range sooner (Chapman 1962) and increase size at ocean entrance for anadromous fish (Shapovalov and Taft 1954), thus reducing mortality in both instances. However, the likelihood of increased secondary infections in juvenile fish, lethal temperature, and other adverse effects are very real (Narver 1972).

Water-soluble extractions from western red cedar, heartwood, bark, and foliage have been found toxic to fish to certain degrees (Peters et al. 1976; Hall and Baker 1975). Heartwood, lignins, and bark extractions were found to be moderately toxic, but foliage terpenes and heartwood tropolones were much more toxic. Tropolones were more toxic to coho salmon than to invertebrates, and more toxic to fry than to eyed eggs. The effect of tropolones on coho fry was moderated by a previous sublethal exposure or the presence of a chelatable cation. Substances toxic to fish have been documented from Sitka spruce and western hemlock (Buchanan and Tate 1975).

The primary reason that large debris, and to some extent small debris, is so important is that cutthroat trout utilize log jams, upturned roots, and small accumulations of debris as winter habitat (Bustard 1973). Bustard indicated that at low temperatures cutthroat juveniles preferred overhanging banks with root wads and branches as opposed to barren areas, and clean rubble as opposed to silted rubble. Similarly, steelhead fry preferred rubble substrate as over-winter habitat. They burrowed under the rubble and remained in the interstices between rocks. Larger steelhead juveniles, however, preferred root wads and logs as over-winter habitat (Bustard 1973). Chapman and Bjornn (1969) and Bjornn (1971) have shown that steelhead trout migrate out of small tributaries into larger streams when winter habitat in small streams is poor. Removal of too much large debris, causing debris torrents or sluice-outs, may drastically reduce the amount of over-winter habitat in small headwater streams.

This study was initiated to investigate the effects of clearcut logging on resident and anadromous cutthroat trout (*Salmo clarki*). The objectives were to determine any changes in cutthroat population, biomass and densities, and to compare survival, growth, and condition factor of the trout. Stream morphometrics were monitored throughout the study.

Two streams which had been previously investigated were chosen for intensive study. Lestelle (1978) conducted a debris removal study in 1972 and 1973 on one of the streams, and used the other one for a control. During Lestelle's study, most all old growth boles were cut up and removed from the experimental stream to determine the reliance of cutthroat trout on this material. Standing timber adjacent to the stream was not disturbed. The control stream was left in its natural state. Lestelle concluded that after one year the trout biomass and densities had returned to pre-treatment levels. In 1978 Lestelle's unlogged control stream was logged, and our study was initiated. Thus, the roles of Lestelle's streams were reversed; his control stream became our logged experimental stream and Lestelle's recovered experimental stream became our control. The sampling procedures used by Lestelle were followed in this study. Both streams contained only resident nonanadromous cutthroat trout and two species of cottids.

Three other streams were chosen for an extensive study which would be comparable to the streams used for intensive study. These three extensive streams contained populations of resident and sea-run cutthroat trout. The watersheds for these streams had been logged and were in various stages of recovery. The purpose of the extensive part of the study was to determine the long-term effects of logging assuming that these streams would exhibit results, after various periods of post-logging, similar to those which would be observed by continually monitoring a single stream after logging (Hall et al. 1978).

DESCRIPTION OF STUDY AREAS

Intensive Study Areas

The intensive study area is located in the remote headwater area of the Clearwater River in Jefferson County, Washington (Fig. 1). Two small feeder streams of 'C' Tributary were used as experimental streams. 'C' Tributary is a main branch of Stequaleho Creek, which enters the Clearwater River 38.6 km upstream from its mouth.

The area is characterized by deep, V-shaped drainages with very steep hillside slopes. The hillsides consist mainly of sandstones and siltstones with a thin soil covering. This highly erosive combination of rock and soil contributes to accumulations of debris in the basin bottoms.

The old growth areas adjacent to the experimental streams are comprised mainly of Sitka spruce, *Picea sitchensis*; western hemlock, *Tsuga heterophylla*; Douglas fir, *Pseudotsuga menziesii*; and western red cedar, *Thuja plicata*.

Weather conditions are normally wet, with the area averaging 350-460 cm of rainfall per year. The majority of the precipitation occurs during the extremely wet winters, as the summers are usually fairly dry. Frequent storms have the capacity of producing large quantities of rainfall over a short period of time; over 13 cm in 24 hr for example. Examples of large storms are 77.5 cm in 12 days, with 24.6 cm in one 24-hr period, which occurred in December 1972, and 79.5 cm in 8 days in December 1979.

The two experimental streams were called East Fork (Plate 1) and West Fork (Plate 2) of 'C' Tributary (Fig. 2). East Fork was used as the experimental stream and West Fork as the control stream. The watershed areas were:

East Fork	81 ha
West Fork	108 ha
'C' Tributary	469 ha

The average gradient of each study section in East and West Fork was 6.2 percent and 5.1 percent, respectively.

Discharges were taken for East and West Forks in July 1978 and 1979, and were approximately 7 liters/sec. These values would be close to summer low flow. Discharges were not taken during winter storms, but an estimate of the low flow:high flow ratio is 1:400-500.

East Fork and West Fork are inhabitated by natural resident (non-anadromous) populations of cutthroat trout, *Salmo clarki*, and three

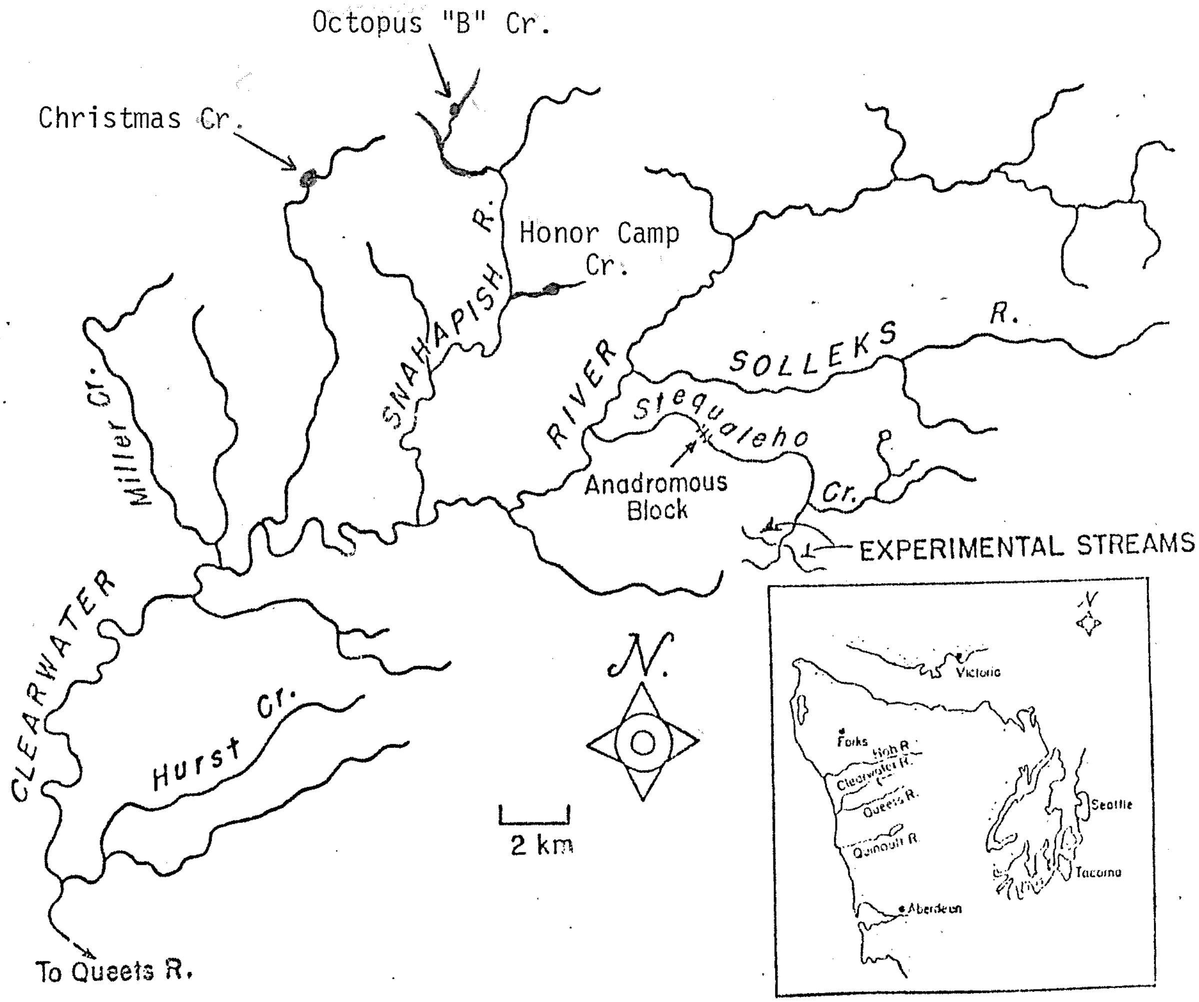

Fig. 1. The Clearwater River and the location of effects of logging on cutthroat trout study.

Plate 1. East Fork Stequaleho Creek (experimental stream).

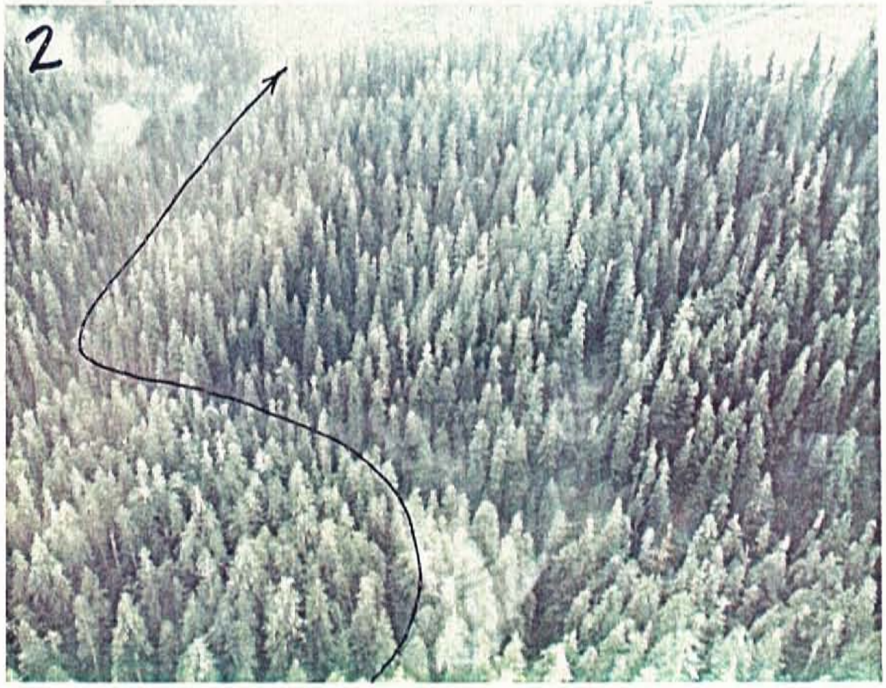

Plate 2. West Fork Stequaleho Creek (experimental stream).

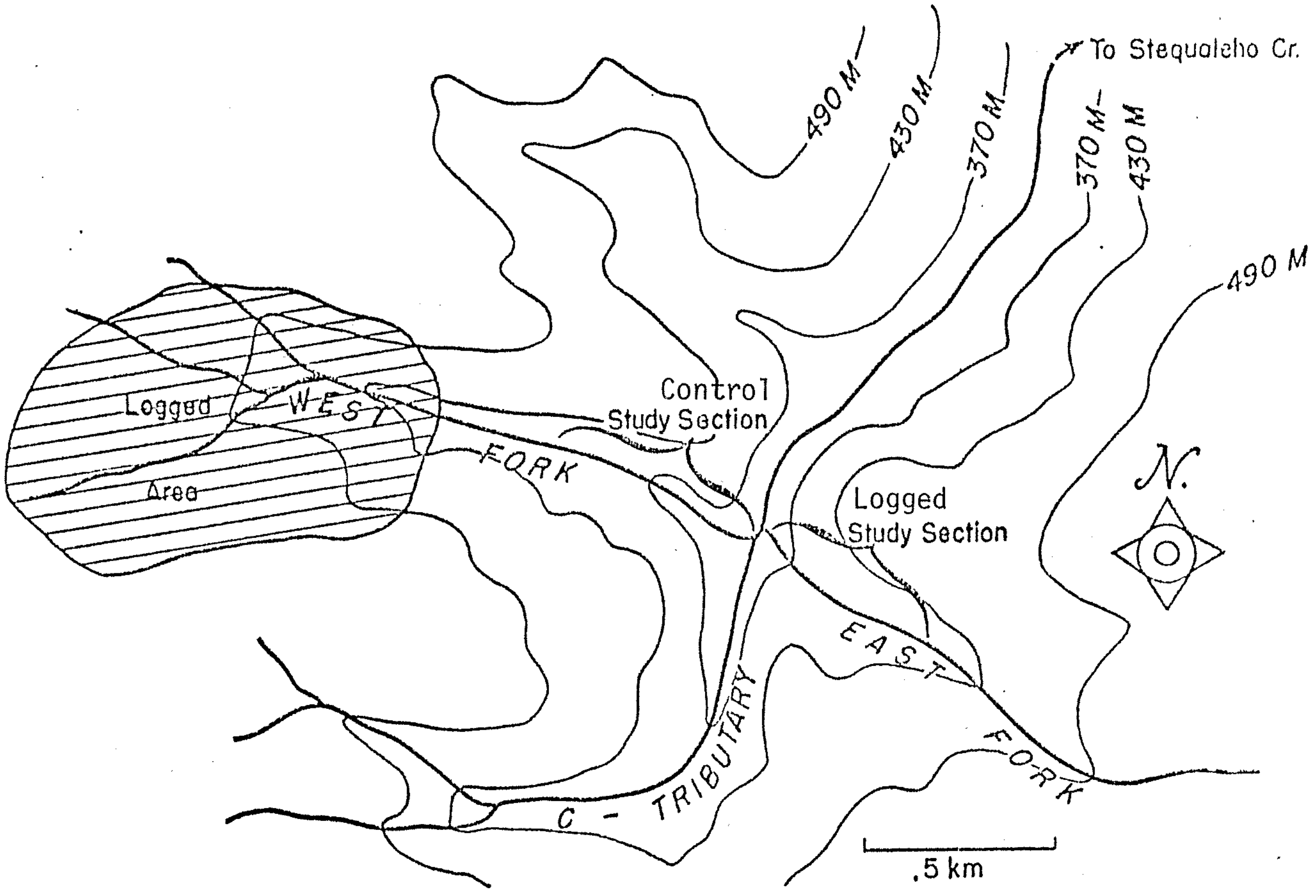

Fig. 2. Locations of the study sections within West Fork and East Fork of "C" Tributary, Stequaleho Creek.

species of cottids: the torrent sculpin, *Cottus rhotheus*; the prickly sculpin, *Cottus asper*; and the mottled sculpin, *Cottus bairdi*. A large falls permits penetration by anadromous fishes to only the lower 3.4 km of Stequaleho Creek.

The upper 48.6 ha of the control stream had been logged prior to this study (Fig. 1), but the study section was sufficiently downstream to not be significantly affected by siltation, bedload movement, or forest debris accumulations.

East Fork was logged from its mouth to 323 m upstream in May and June 1978. It was mistakenly classified as type 5 water,[1] which offers no protection for the stream. Logs were yarded across the stream bed. Stream clean-out was performed after completion of the yarding operations.

Extensive Study Areas

The extensive study areas were also located in the Clearwater River drainage. Three streams were chosen with similar physical characteristics to East and West Forks, which were in various stages of recovery from logging. The three streams chosen were Octopus 'B' Tributary (Plate 3), Christmas Creek (Plate 4), and Honor Camp Creek (Plate 5).

Octopus 'B' Tributary is a tributary of Octopus Creek. Octopus Creek feeds into the Snahapish River, which is the largest tributary of the Clearwater River.

Octopus 'B' was completely clearcut as a type 3 water[2] in 1977. The yarding was done across the stream, but logs were suspended above the streambed to minimize damage. Stream clean-out was performed after completion of the yarding operations.

The average gradient of the study section was 9.6 percent. Discharge taken in July 1978 and 1979 was approximately 11 liters/sec.

Christmas Creek flows directly into the Clearwater River. The watershed was logged in September-October 1973. The stream bed was yarded across, and stream clean-out was performed.

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[1] Appendix I from *Washington Forest Practices, Rules and Regulations*. *See* Literature Cited.

[2] *See* footnote 1.

Plate 3. Octopus "B" Creek.

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Plate 4. Christmas Creek.

Plate 5. Honor Camp Creek.

The average gradient of the study section was 4.1 percent. Discharge taken in July 1978 and 1979 was approximately 34 liters/sec.

The watershed of Honor Camp Creek, a tributary of the Snahapish River, which feeds the main Clearwater River, was logged in 1960 or 1961. The trees were yarded across the stream and the stream was not "cleaned-out."

The average gradient of the study section was 6.3 percent. Discharge taken in July 1978 and 1979 and was approximately 17 liters/sec.

The post-logging recovery periods for the extensive study streams were:

Octopus 'B' - 1 yr
Christmas Creek - 5 yr
Honor Camp Creek - 18 yr

The watershed areas for the extensive study streams are:

Octopus 'B' - 107 ha
Christmas Creek - 324 ha
Honor Camp Creek - 135 ha

All three extensive study streams are inhabited by natural populations of resident and searun cutthroat trout (*Salmo clarki*)and two species of cottids: the torrent sculpin (*Cottus rotheus*); and the prickly sculpin (*Cottus asper*). Octopus 'B' also contained a third cottid, the coastrange sculpin (*Cottus aleuticus*).

METHODS AND MATERIALS

The intensive study part of the project consisted of monitoring changes in East Fork and West Fork of Stequaleho Creek. To complete the extensive study part of the project several streams in various stages of recovery needed to be selected. Some of the criteria used for selection were basin size, gradient, fish habitat, stream discharge, and date and type of logging. The aim was to find streams similar in these characteristics to East and West Fork.

Once the streams used for extensive study were selected, a study section was established in all five streams. Each section ranged in length from 154 m in Octopus 'B', Honor Camp, and Christmas Creeks, to 253 m in West Fork and 323 m in East Fork. The sections were further subdivided into 15 m intervals.

Fish population surveys were conducted in each stream five times during the course of the study: July and October 1978, and April, July, and October 1979. A Smith-Root Type V battery-powered electrofisher was used for all surveys. Before shocking, stop nets were installed at the downstream and upstream ends of the sections to prevent immigration or emigration.

Electroshocking procedures were conducted from the bottom of the study section upstream until the entire section was covered. Trout and cottids received the same treatment throughout the study. Captured fish were placed in buckets along the stream bank in the general proximity of where they had been caught. Individual fish were then anesthetized with MS-222, measured and weighed, marked, and placed in freshwater for recovery. Lengths (fork length) were measured to the nearest mm and weights to the nearest 0.1 g. An Ohaus dial balance was used for measuring weight. The mark, which was used for population estimation, consisted of a clip of the dorsal lobe of the caudal fin. All fish were marked on the first electrofishing pass through the section. After recovery from the anesthetic the fish were replaced in the stream as close as possible to the site of original capture. The fish population was allowed to recover for a 24-hr period to assure resumption of normal activity and random distribution of marked fish.

After a 24-hr period, the electroshocking procedures were repeated in the same manner. The numbers of marked and unmarked fish were recorded. Marked fish were measured for length only. Unmarked fish were measured for length and weight. No fish were marked on the second pass.

The formula used for computing population estimates is the modified Peterson estimate (Chapman 1951):

$$\frac{(M+1)\ (C+1)}{R+1} - 1 = \hat{N}$$

where:

M = # marked fish
C = # fish captured on second pass (marked and unmarked)
R = # marked fish recaptured on second pass
$\hat{N}$ = estimated population

Ricker (1975) has shown this to be an accurate estimator.

Population estimates were computed for all year-classes on each sampling date. The total population was obtained by summing the estimates of the individual year-classes. Year-classes were divided into three groups: 0+, I+, and $\geq$ II+. Age 0+ fish were the young of the year. Age I+ fish were those which had experienced one winter, and had formed one annulus. Age $\geq$ II+ were those fish which had experienced two or more winters and formed two or more annuli. The numbers of III+ and IV+ fish were so small that individual population estimates could not be calculated, so they were lumped with the II+ age fish. The only exception to the age group designations was in April 1979, where the age groups were designated as I, II, and $\geq$III, because the fish were forming an annulus at this time of year.

Year-classes were differentiated by the use of length-frequency histograms and by scale analysis. For further verification, scales were analyzed from fish taken from the study streams as well as from several streams in the adjacent area (Fuss, in preparation).

Confidence limits of 95 percent were calculated for each population estimate with the following formulae from Seber (1967):

1) $\frac{R}{C} = \hat{P}$

2) $\hat{P} \pm 1.96 \sqrt{\frac{\hat{P}(1-\hat{P})}{C} \ (1 - \frac{C}{\hat{N}})}$

Formula 2 generates $\hat{P}$ upper and $\hat{P}$ lower. Since $R = C\hat{P}$, from equation 1, $C\hat{P}$ can be substituted back into the Peterson estimate formula to give the 95 percent confidence limit. This is accomplished as follows:

$$\frac{(M+1)(C+1)}{C\hat{P}_u + 1} - 1 \leq M \leq \frac{(M+1)(C+1)}{C\hat{P}_L + 1}$$

where $\hat{P}_u = \hat{P}$ upper
$\hat{P}_L = \hat{P}$ lower

When C is less than 50, binomial tables should be used to obtain an accurate value for $\hat{P}_u$ and $\hat{P}_L$. This being the case, the computer subroutine Belbin, from the International Mathematical and Statistical Libraries, was used to obtain exact values for $\hat{P}_u$ and $\hat{P}_L$. The computer then generated the confidence limits with the values obtained from Belbin. Confidence limits calculated by the Belbin method were used because of their higher precision than the Seber equation.

Pool, riffle, and depth measurements were taken to document any morphometric changes which might have occurred over the course of the study. Stream widths were measured every 5-6 m starting at the bottom of the section and working upstream to the end. Depths were taken along the thalweg of the stream, one on each width transect and one half-way between each transect. Pool data were recorded, starting at the upper end of the section, and lengths, widths, and depths of all pools in the section were measured in a downstream direction.

Measurements of accumulated logging debris within and just above the highwater mark were conducted twice (October 1978 and October 1979) in East and West Forks. Two sections were established in each stream; one from 92 to 154 m and one from 215 to 277 m. Measurements of twigs, small branches, and larger branches, as well as large coarse debris such as logs, were recorded. Coarse debris was divided into three categories: actual, potential, and bank potential. "Actual" coarse debris was in, or less than 1 m above, the stream, and was directly providing habitat for the fish. "Potential" coarse debris was contained within the high water mark, was not directly providing habitat for fish, but might be claimed by the stream at higher water levels. "Bank potential" coarse debris was contained outside the highwater mark and might be claimed by the stream only during severe flood conditions. From these data an estimate of the volume and weight of debris could be calculated (Van Wagner 1968; Froehlich et al. 1972).

Stream discharge and maximum-minimum water temperature for the months of June through September 1979 (Appendix II) were measured continuously.

Average stream gradients were measured in all five study streams using a hand clinometer.

Seasonal and annual mortality rates were computed for the various trout year-classes and for the total populations of trout and cottids in the study streams. In 1972 and 1973 Lestelle was not able to document the 0+ year class trout in July because fry emergence from the gravel was not complete and the fry were too small to capture when the population was assessed. Since emigration from the study sections cannot be distinguished from actual mortality, these rates are the relative rates of change between population or year-class size. The disappearance of fish, regardless of cause, will be referred to as mortality. Seasonal and annual mortality rates (A) were computed for each period between sampling dates. The formula is (Ricker 1975):

$$A = 1 - S$$

where

$$S = \frac{\hat{N}_2}{\hat{N}_1}$$

$\hat{N}_2$, $\hat{N}_1$ = estimates of population size or year-class size at times t_1 and t_2, respectively.

RESULTS

Intensive Study

Population Surveys

Differences in population size estimates did occur between 1972-73 and 1978-79 in East Fork (experimental stream) (Table 1). Comparison of 0+ age fish was not possible in July of either year because estimates were not computed in 1972 or 1973. It was determined that 0+ age fish were not susceptible enough to capture by electrofishing to perform population estimation methods (Lestelle 1978). The number of fish in East Fork increased, overall, from 1972-73, prior to logging, to 1978-79, after logging. These significant increases in population estimates were found in October 1978, July 1979, and October 1979 (Fig. 3).

Differences in population size estimates between 1972-73 and 1978-79 in West Fork (control stream) were not nearly as evident as in East Fork (Table 2). Comparison of 0+ age fish in July was not possible. The only significant difference was in April, and that difference was small (Fig. 4). Very good over-winter survival of 0+ age fish appeared to be the cause. No other significant difference existed in the control stream over the course of the study.

The comparison of East and West Forks over the course of the 1978-79 study shows no significant differences between the experimental stream and the control stream (Fig. 5). Population estimates were nearly identical in the two streams except in July 1978 and 1979.

Biomass (g/m^2) and density ($\#/m^2$) for East Fork revealed few differences between 1972-73 and 1978-79 (Table 3). The biomass estimates in 1978-79 were slightly higher than in 1972-73 in several instances, alluding to the increased population estimates, but no consistent trend was indicated. The same held true for density estimates. Densities were very similar in all cases.

Biomass (g/m^2) and density ($\#/m^2$) estimates for West Fork were similar to those of East Fork (Table 4). However, biomass estimates showed there to be an increase in I+ age fish in 1978-79 over that in 1972-73. For I+ age fish the low biomass estimate in 1978-79 was .73 and the high in 1972-73 was .49. Density estimates for West Fork in 1972-73 and 1978-79 were similar, and did not reflect the increased biomass of the I+ age fish.

Debris Measurement

The volume of coarse debris changed considerably in two of three categories in East Fork from 1978 to 1979 (Table 5). Coarse material that fell into the "Actual" category remained virtually unchanged in both sections; the 91-152-m section decreasing from 2.45 m^3 to 2.17 m^3,

Table 1 - Trout population estimates and 95% confidence intervals for East Fork "C" Tributary.

JULY 1972	JULY 1978
0+ - --------	0+ - 137 (91-230)
I+ - 39 (25-60) N = 82 (67-106)	I+ - 76 (59-111) N=256(214-318)
II+ - 43 (34-58)	II+ - 43 (31-71) [N=119(102-140)][1]
OCTOBER 1972	OCTOBER 1978
0+ - 94 (74-132)	0+ - 110 (71-192)
I+ - 18 (13-28) N=160 (143-181)	I+ - 75 (61-100) N=226 (190-280)
II+ - 48 (42-58)	II+ - 41 (28-71)
APRIL 1973	APRIL 1979
I+ - 29 (20-45)	I+ - 42 (26-32)
II+ - 24 (17-39) N=102 (80-141)	II+ - 69 (45-127) N=128 (104-168)
III+ - 49 (33-70)	III+ - 17 (9-42)
JULY 1973	JULY 1979
0+ - --------	0+ - 151 (113-215)
I+ - 48 (41-60) N=78 (73-84)	I+ - 72 (51-114) N=297 (255-356)
II+ - 30 (27-38)	II+ - 74 (50-130) N=146 (122-189)[1]
OCTOBER 1973	OCTOBER 1979
0+ - 59 (50-73)	0+ - 205 (181-240)
I+ - 45 (39-59) N=130 (119-144)	I+ - 45 (39-58) N=301 (277-330)
II+ - 26 (22-35)	II+ - 51 (43-71)

[1] Population estimates and confidence intervals for year-class I+ and ≤ II+ only.

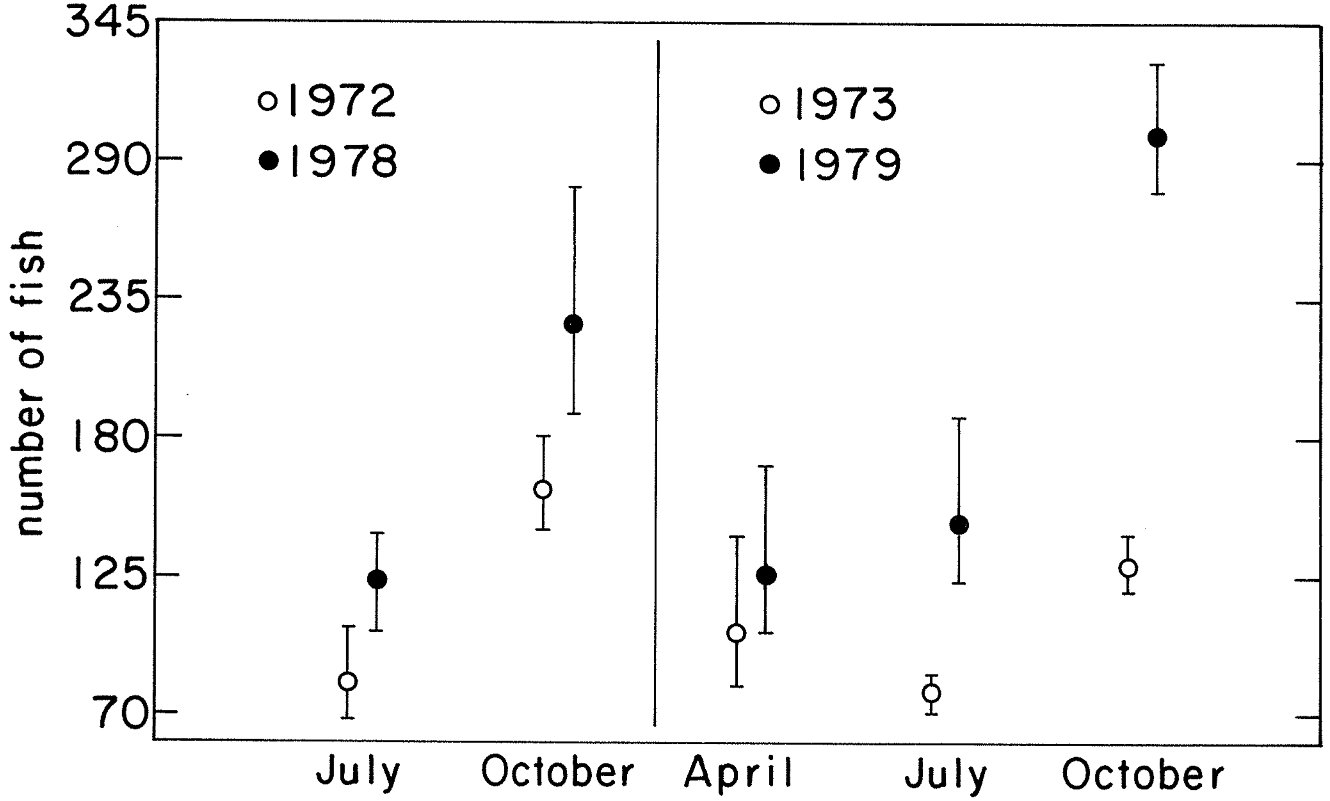

Fig. 3. Trout population estimates and 95% confidence intervals for East Fork "C" Tributary.

Table 2 - Trout population estimates and 95% confidence intervals for West Fork "C" Tributary.

JULY 1972	JULY 1978
0+ - --------	0+ - 224 (164-330)
I+ - 89 (65-133) N=172 (127-266)	I+ - 91 (73-125) N=352 (298-430)
II+ - 83 (57-125)	II+ - 37 (28-58) [N=128 (114-149)][1]
OCTOBER 1972	OCTOBER 1978
0+ - 62 (53-76)	0+ - 94 (47-221)
I+ - 96 (75-132) N=251 (220-292)	I+ - 73 (54-110) N=199 (158-269)
II+ - 93 (71-132)	II+ - 32 (24-50)
APRIL 1973	APRIL 1979
I+ - 33 (22-56)	I+ - 71 (40-156)
II+ - 40 (29-59) N=97 (83-116)	II+ - 68 (45-119) N=160 (128-212)
III+ - 24 (18-38)	III+ - 21 (13-48)
JULY 1973	JULY 1979
0+ - --------	0+ - 75 (41-172)
I+ - 42 (31-61) N=120 (101-148)	I+ - 88 (71-120) N=220 (185-271)
II+ - 78 (58-94)	II+ - 57 (40-92) [N=145 (133-180)][1]
OCTOBER 1973	OCTOBER 1979
0+ - 162 (126-223)	0+ - 139 (107-193)
I+ - 56 (46-81) N=263 (232-304)	I+ - 79 (68-99) N=255 (225-295)
II+ - 45 (38-58)	II+ - 37 (31-51)

[1] Population estimate and confidence interval for year-class I+ and II+ only.

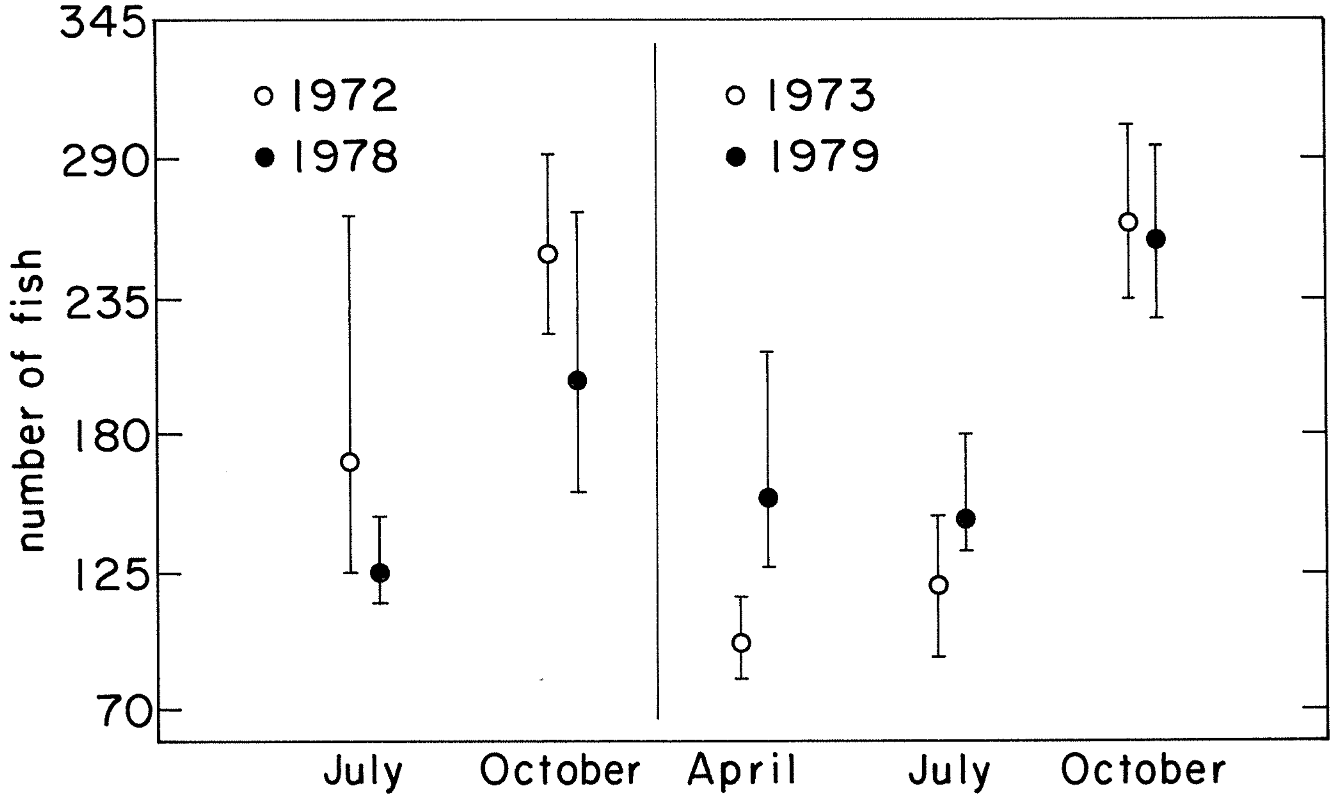

Fig. 4. Trout population estimates and 95% confidence intervals for West Fork "C" Tributary.

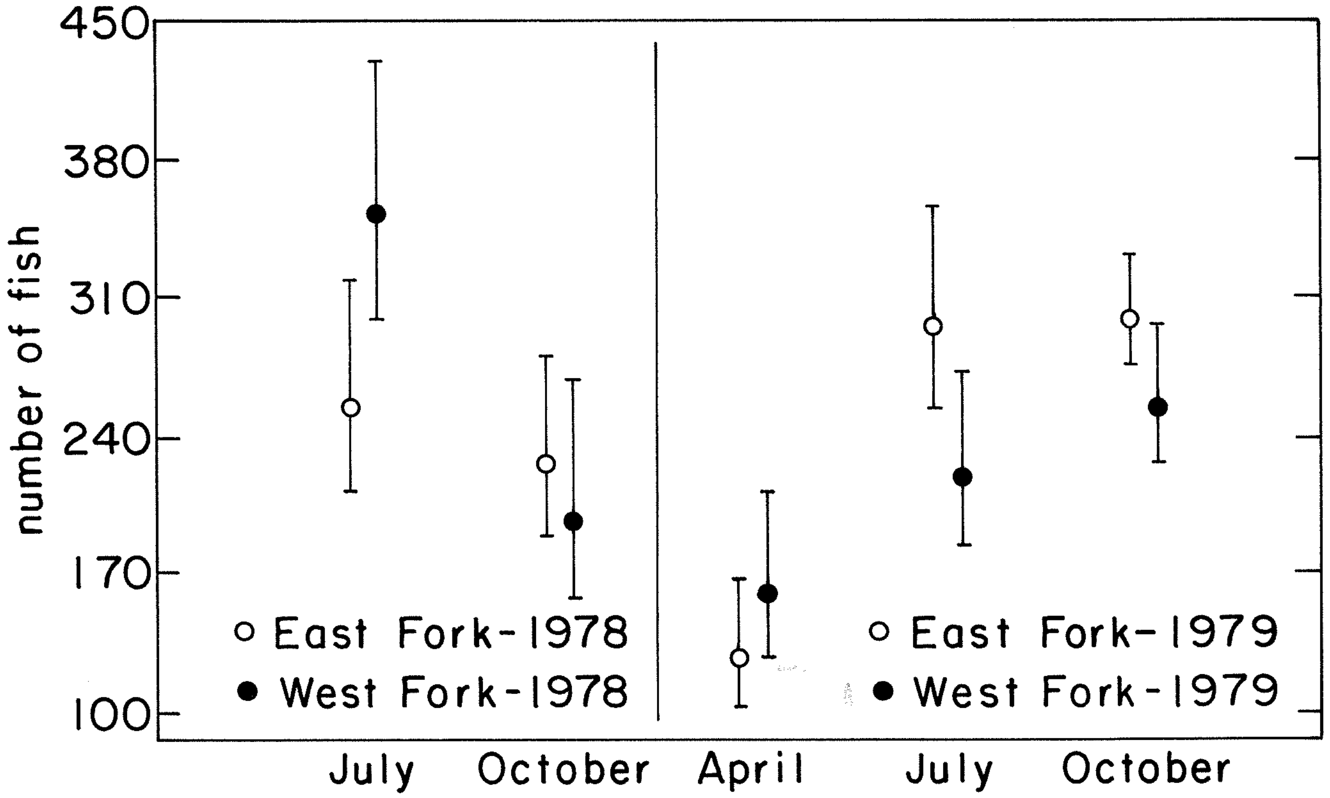

Fig. 5. Trout population estimates and 95% confidence intervals for East and West Fork "C" tributaries.

Table 3 - Trout biomass and densities for East Fork "C" Tributary.

Date	Biomass		(g/m^2)
Age-class[1]	0+	I+	≥ II+
July 1972	-	.30	1.13
October 1972	.17	.26	1.54
April 1973	.11	.18	1.08
July 1973	-	.39	1.13
October 1973	.16	.66	1.31

Date	Biomass		(g/m^2)
Age-class[1]	0+	I+	≥ II+
July 1978	.11	1.2	1.9
October 1978	.38	1.03	1.3
April 1979	.14	.81	.56
July 1979	.03	.76	1.98
October 1979	.59	.61	1.3

Date	Density		(#/m^2)
Age-class[1]	0+	I+	≥ II+
July 1972	-	.08	.10
October 1972	.19	.07	.13
April 1973	.09	.04	.08
July 1973	-	.09	.07
October 1973	.17	.10	.08

Date	Density		(#/m^2)
Age-class[1]	0+	I+	≥ II+
July 1978	.30	.17	.09
October 1978	.16	.11	.06
April 1979	.05	.08	.02
July 1979	.22	.10	.11
October 1979	.30	.07	.07

[1] Year-classes for April are I, II, and ≥ III.

Table 4 - Trout biomass and densities for West Fork "C" Tributary.

Age-class[1]	0+	I+	≥ II+	Age-class[1]	0+	I+	≥ II+
July 1972	-	.38	1.22	July 1978	.12	.96	1.1
October 1972	.20	.49	1.31	October 1978	.18	.76	.93
April 1973	.06	.24	.44	April 1979	.17	.73	.69
July 1973	-	.39	1.8	July 1979	.01	.87	1.98
October 1973	.32	.48	1.42	October 1979	.24	.82	1.14

Date	Density		(#/m^2)	Date	Density		(#/m^2)
Age-class[1]	0+	I+	≥ II+	Age-class[1]	0+	I+	≥ II+
July 1972	-	.09	.09	July 1978	.34	.14	.06
October 1972	.22	.09	.09	October 1978	.12	.09	.04
April 1973	.05	.05	.03	April 1979	.09	.09	.03
July 1973	-	.07	.11	July 1979	.13	.15	.10
October 1973	.29	.07	.08	October 1979	.20	.11	.05

[1] Year-classes for April are I, II, and ≥ III.

Table 5 - Volume of coarse debris in East and West Fork "C" Tributaries (values are in m^3).

	Potential	Actual	Bank Potential
East Fork			
October 1978			
91 m - 152 m	5.70	2.45	4.83
213 m - 274 m	6.96	8.10	11.12
October 1979			
91 m - 152 m	.53	2.17	3.41
213 m - 274 m	1.01	8.98	3.53
West Fork			
October 1978			
91 m - 152 m	4.26	5.91	13.87
213 m - 274 m	5.38	8.65	18.13
October 1979			
91 m - 152 m	5.1	5.32	13.18
213 m - 274 m	5.37	7.34	16.78

and the 213-274-m section increasing from 8.10 m^3 to 8.98 m^3. However, the categories of "Bank Potential" and "Potential" decreased markedly. "Bank Potential" decreased in both sections, with the greatest decrease coming in the 213-274-m section, a decrease from 11.42 m^3 to 3.53 m^3.

The most significant decrease occurred in the volume of "Potential" debris. The stream was left with almost no bank material after the 1978-79 winter. The 91-152 m section decreased from 5.70 m^3 to .53 m^3, a reduction of 5.17 m^3 of material. The 213-274-m section decreased from 6.96 m^3 to 1.01 m^3, an even greater reduction of 5.95 m^3.

West Fork, the control stream, experienced little or no reduction in the volume of forest debris over the 1978-79 winter. The post- and pre-winter volume estimates in both sections are virtually the same. Debris reduction in both East and West Forks was due to winter and spring high water conditions.

Seasonal Mortality

Seasonal mortality rates for East and West Forks differed on several occasions between sampling dates (Table 6). Mortality rates were higher in West Fork than in East Fork for all year-classes for the period of July 1978 to October 1978. This was the period immediately following the logging of East Fork. The mortality rates for all year-classes were higher in East Fork for the period of October 1978 to April 1979, which is the over-winter period. The total mortality rate was higher in East Fork than in West Fork, .43 compared to .20, and markedly higher for the 0+ and $\geq$ II+ age-classes; .62 to .24 and .59 to .34, respectively. Mortality rates in 1979, between July and October, were more consistent in both streams.

Growth

Growth between sampling periods was very consistent throughout the course of the study in both East Fork (Figs. 6 and 7) and West Fork (Figs. 8 and 9). East Fork exhibited slightly larger fish than West Fork in each year-class in all months except July 1978. The largest differential in size between year-classes occurred in July and October 1979 when East Fork fish were approximately 10 mm larger. Differences were most pronounced in 0+ year-class fish, but were still detectable in older year-classes. Growth in length was comparable for the same months in 1978 and 1979 for both streams.

Extensive Study

Population Surveys

Population size estimates remained very consistent for Honor Camp and Christmas Creek (Table 7) and Octopus 'B' Tributary (Table 8)

Table 6 - Seasonal mortality rates of trout in East Fork and West Fork "C" Tributaries.

	July 78-Oct 78	Oct 78-Apr 79	Apr 79-July 79	July 79-Oct 79
East Fork				
0+	.20	.62	--[1]	--
I+	.01	.08	--	.38
≥ II+	.05	.59	--	.31
Total	.12	.43	--	--
West Fork				
0+	.58	.24	--	--
I+	.21	.07	--	.10
≥ II+	.14	.34	--	.35
Total	.43	.20	--	--

[1] Indicates increase in population size.

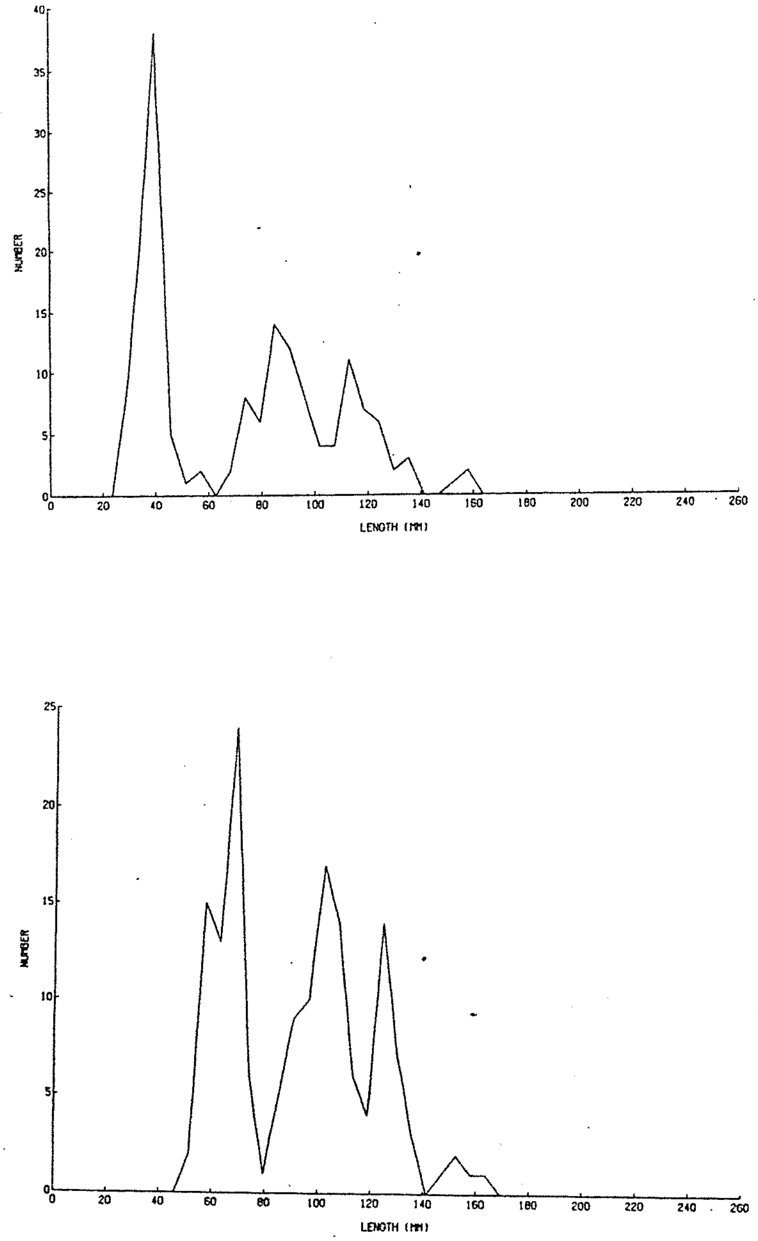

Fig. 6. Length-frequency distribution of trout in East Fork "C" Tributary, July and October 1978.

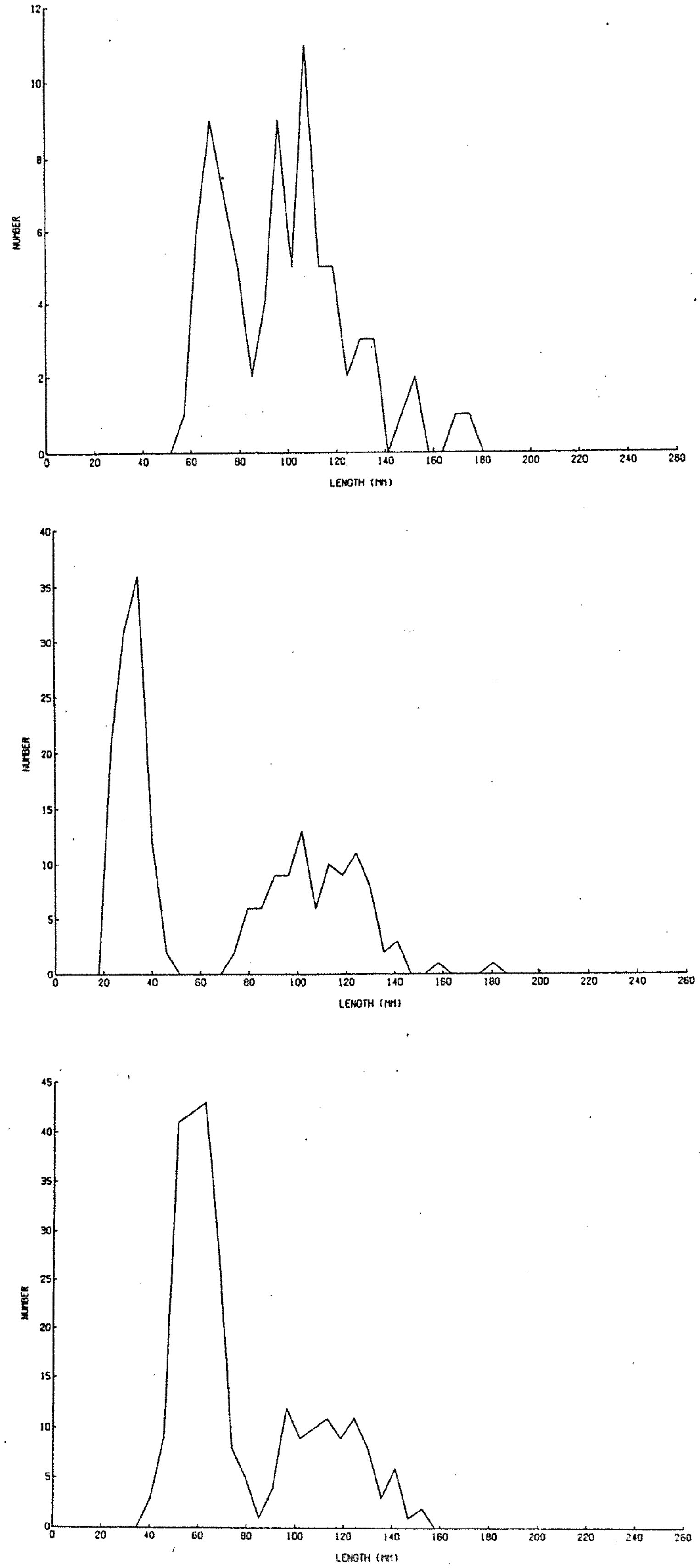

Fig. 7. Length-frequency distribution of trout in East Fork "C" Tributary, April, July, and October 1979.

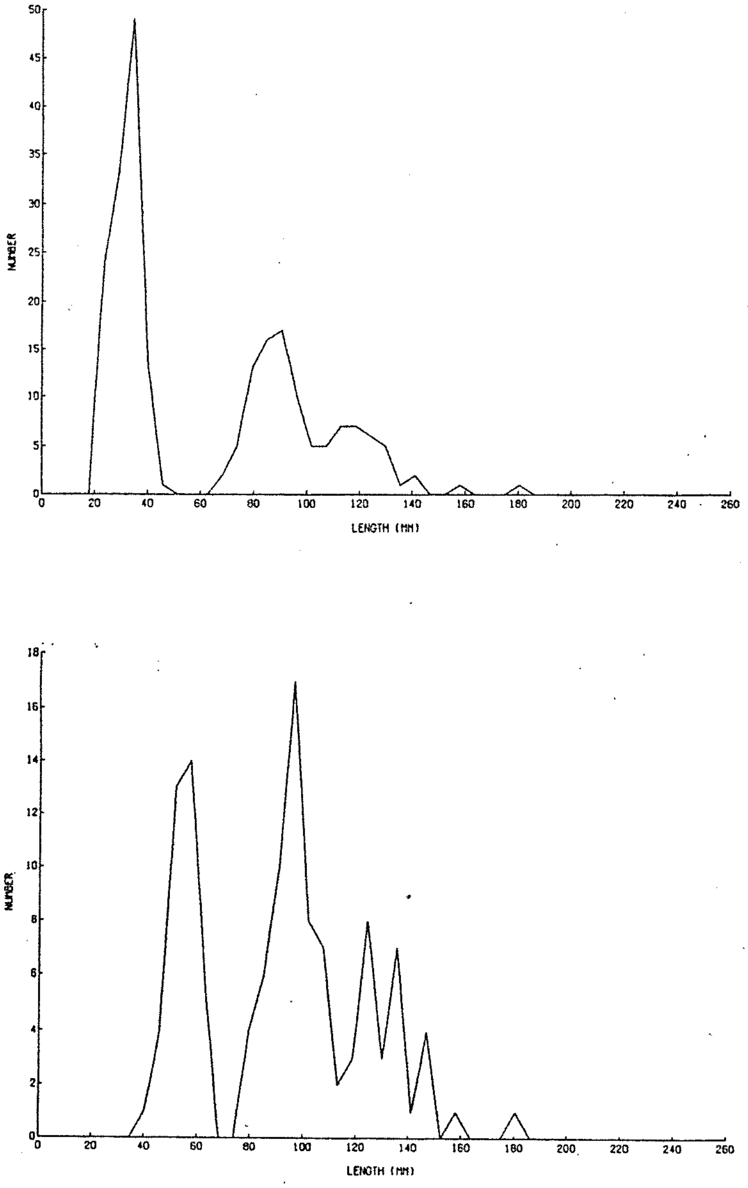

Fig. 8. Length-frequency distribution of trout in West Fork "C" Tributary, July and October 1978.

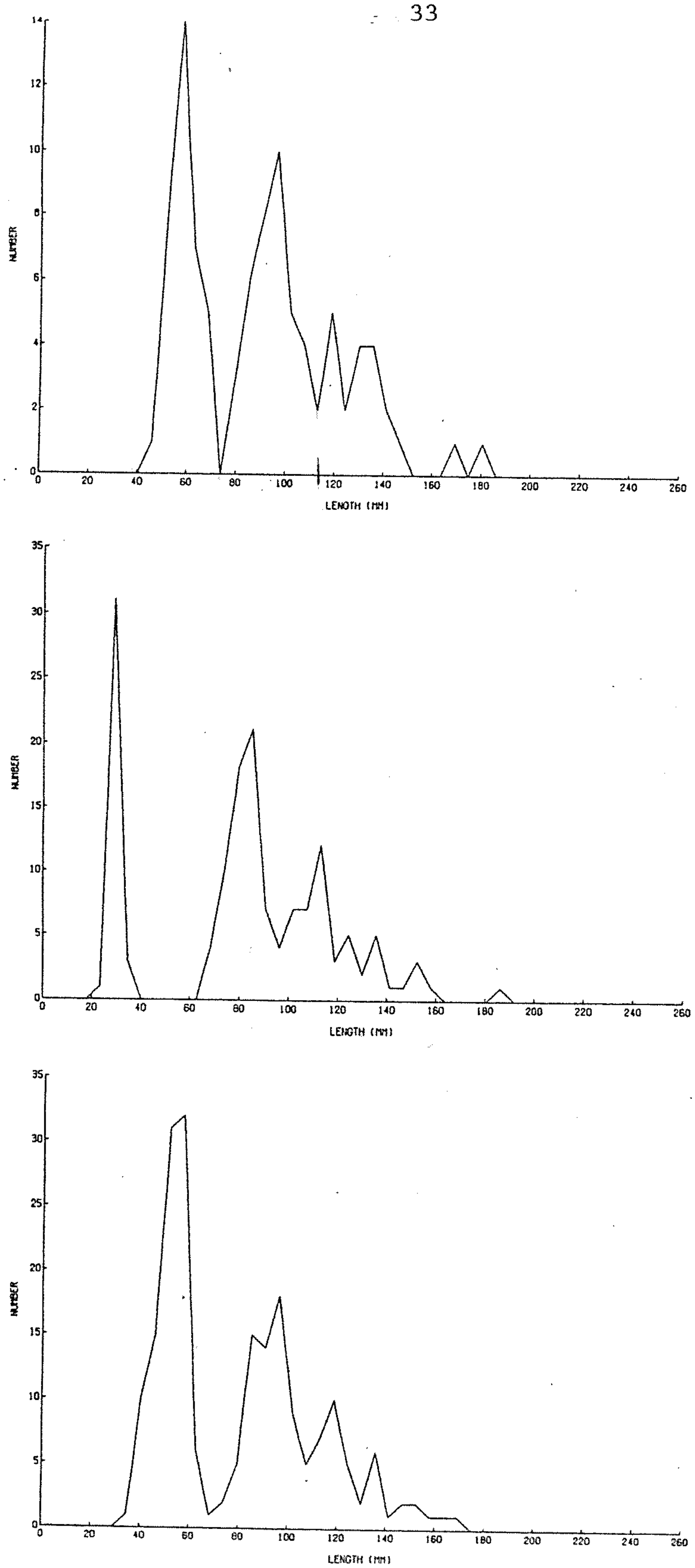

Fig. 9. Length-frequency distribution of trout in West Fork "C" Tributary, April, July, and October 1979.

Table 7 - Trout population estimates and 95% confidence intervals for Honor Camp Creek and Christmas Creek.

	Honor Camp		Christmas
	July 1978		July 1978
0+	427 (391-473)	0+	189 (157-237)
I+	44 (38-57) N=479 (445-519)	I+	103 (77-151) N=303 (266-351)
≥ II+	8 (8-8)	≥ II+	11 (6-26)
	October 1978		October 1978
0+	203 (168-256)	0+	100 (67-168)
I+	24 (18-39) N=232 (201-274)	I+	53 (40-82) N=168 (139-213)
≥ II+	5 (5-5)	≥ II+	15 (10-35)
	April 1979		April 1979
I	72 (52-113)	I	76 (57-116)
II	10 (9-19) N=87 (71-113)	II	39 (28-66) N=123 (104-150)
≥ III	5 (2-11)	≥ III	8 (6-21)
	July 1979		July 1979
0+	220 (160-327)	0+	180 (119-299)
I+	41 (28-69) N=275 (224-355)	I+	93 (54-187) N=307 (248-404)
≥ II+	14 (10-34)	≥ II+	34 (20-78)
	October 1979		October 1979
0+	190 (172-215)	0+	107 (97-123)
I+	25 (22-34) N=224 (208-243)	I+	46 (35-70) N=177 (163-194)
≥ II+	9 (8-17)	≥ II+	24 (19-38)

Table 8 - Trout population estimates and 95% confidence intervals for Octopus "B" Tributary.

	July 1978	
0+	645 (564-749)	
I+	87 (71-114)	N=749 (675-842)
≥ II+	17 (13-29)	
	October 1978	
0+	359 (322-406)	
I+	67 (51-98)	N=441 (404-465)
≥ II+	15 (11-29)	
	April 1979	
I+	173 (153-203)	
II+	20 (17-29)	N=201 (182-224)
≥ III+	8 (6-16)	
	July 1979	
0+	431 (376-504)	
I+	162 (144-188)	N=610 (557-674)
≥ II+	17 (14-28)	
	October 1979	
0+	349 (325-380)	
I+	97 (91-109)	N=458 (434-485)
≥ II+	12 (8-23)	

throughout the course of the study. Differences did occur in the July 1978 and 1979 estimates in Honor Camp Creek and Octopus 'B' Tributary. These differences were attributable to the success of recruitment, as the discrepancy in numbers was due solely to the 0+ year-class. Honor Camp Creek had a 0+ year-class estimate of 427 in July 1978 and 220 in July 1979. Octopus 'B' Tributary estimates were 645 and 431, respectively, for the same months and year-class. Recruitment for Christmas Creek in July 1979 was more successful since the 0+ year-class estimate was virtually identical to the July 1978 estimate. Population estimates for the other year-classes, I+ and II+ were very comparable between 1978 and 1979 for the same respective months.

Even though differences did occur in July estimates in 1978 and 1979, the October estimates in both years were nearly identical. These October estimates could be a good indicator of stream carrying capacity.

Seasonal Mortality

No definite trends could be determined from mortality rates between any of the extensive study streams (Table 9). However, during October 1978 to April 1979, or over-winter, estimates for all year-classes tended to be higher in Octopus 'B' Tributary and Honor Camp Creek than in Christmas Creek. These higher over-winter mortality rates were comparable to those in East Fork, which was experiencing its first winter after logging (Table 6). The lower Christmas Creek estimates were similar to those found in West Fork, the control stream.

Growth

Growth rates in the extensive study streams were very similar to those found in the intensive study streams between all sampling dates except October 1978 to April 1979 (Figs. 10-15). Trout in the extensive study streams averaged approximately 10 mm of growth over this time period, whereas those in the intensive study streams averaged 5 mm. The average size of individuals for all year-classes in the extensive study streams was 20-25 mm larger than in the intensive study streams. This size difference occurred on all sampling dates.

Table 9 - Seasonal mortality rates of trout in Octopus "B" Tributary, Honor Camp, and Christmas creeks.

	July 78-Oct 78	Oct 78-Apr 79	Apr 79-July 79	July 79-Oct 79
Octopus 'B'				
0+	.44	.52	—[1]	.19
I+	.23	.70	—	.40
≥ II+	.12	.47	—	.29
Total	.41	.54	—	.25
Christmas				
0+	.47	.24	—	.41
I+	.49	.26	—	.51
≥ II+	—	.47	—	.29
Total	.45	.27	—	.62
Honor Camp				
0+	.52	.65	—	.14
I+	.45	.58	—	.39
≥ II+	.38	0.00	—	.36
Total	.52	.63	—	.19

[1] Indicates increase in population size.

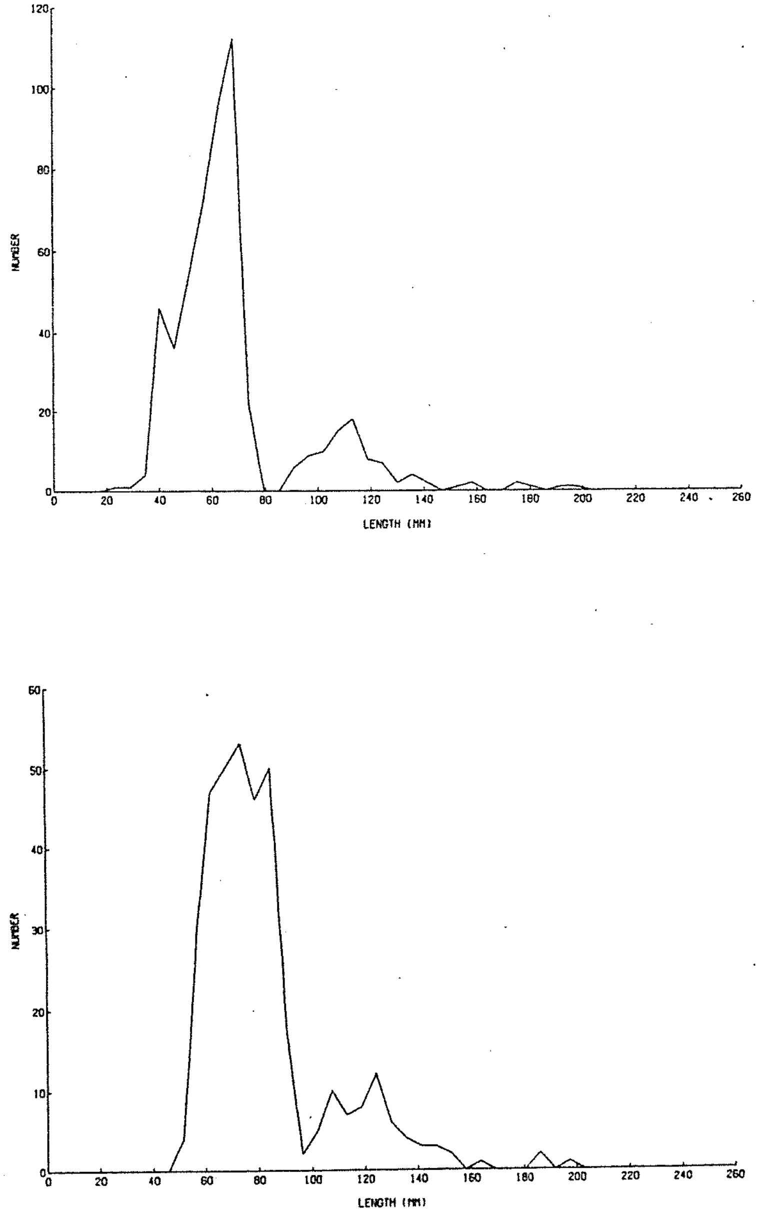

Fig. 10. Length-frequency distribution of trout in Octopus "B" Tributary, July and October 1978.

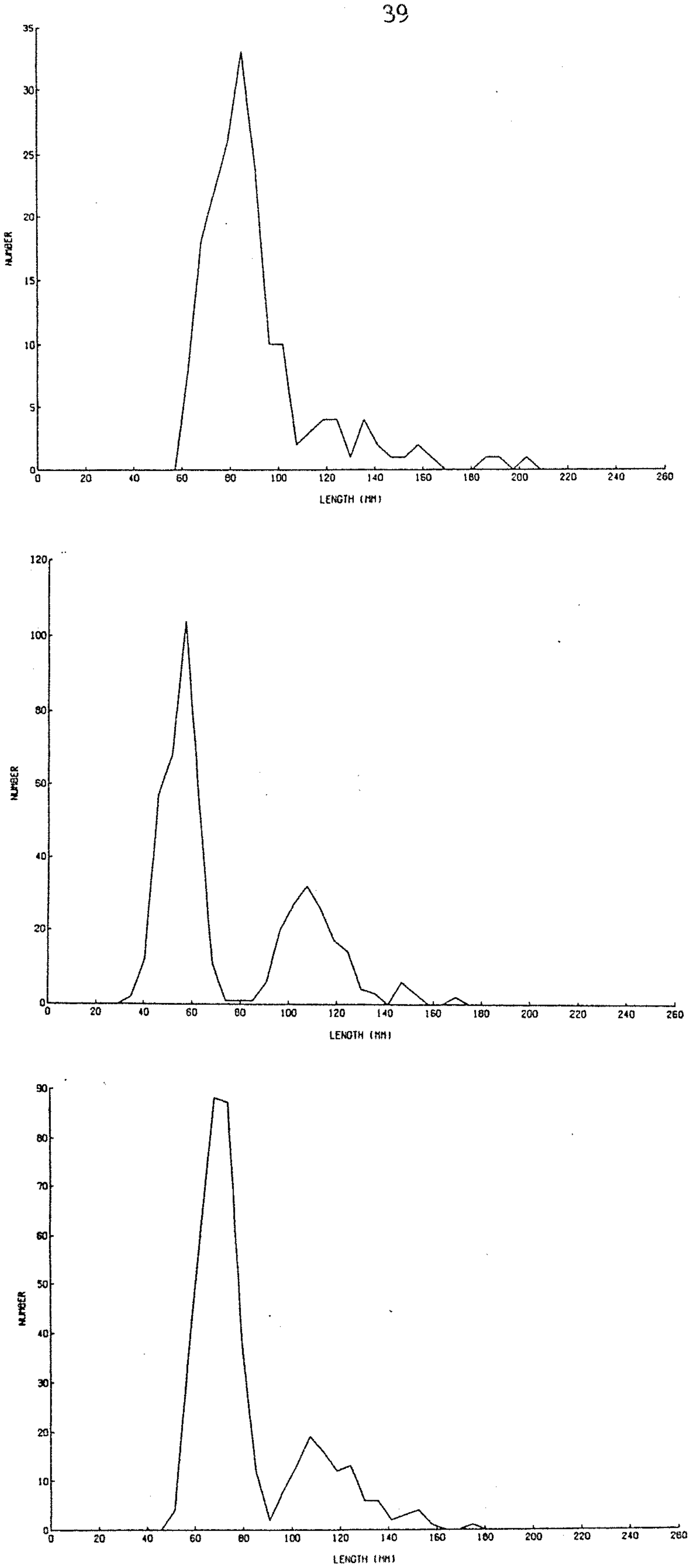

Fig. 11. Length-frequency distribution of trout in Octopus "B" Tributary, April, July, and October 1979.

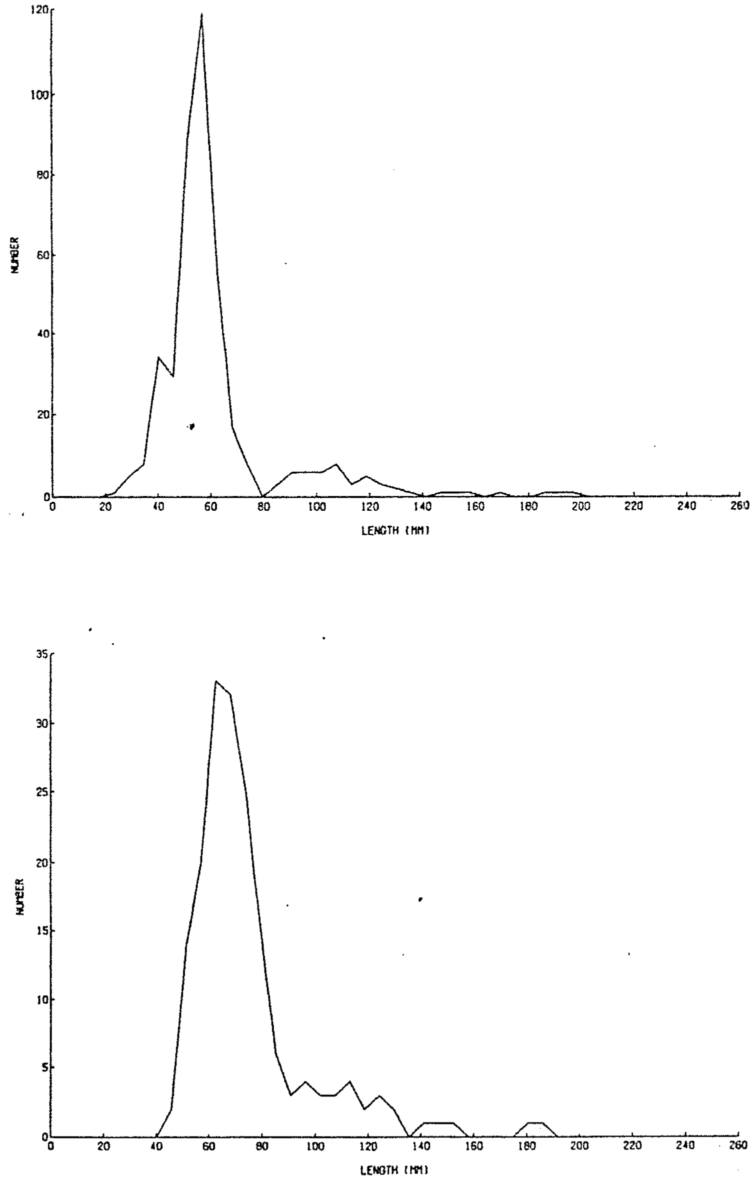

Fig. 12. Length-frequency distribution of trout in Honor Camp Creek, July and October 1978.

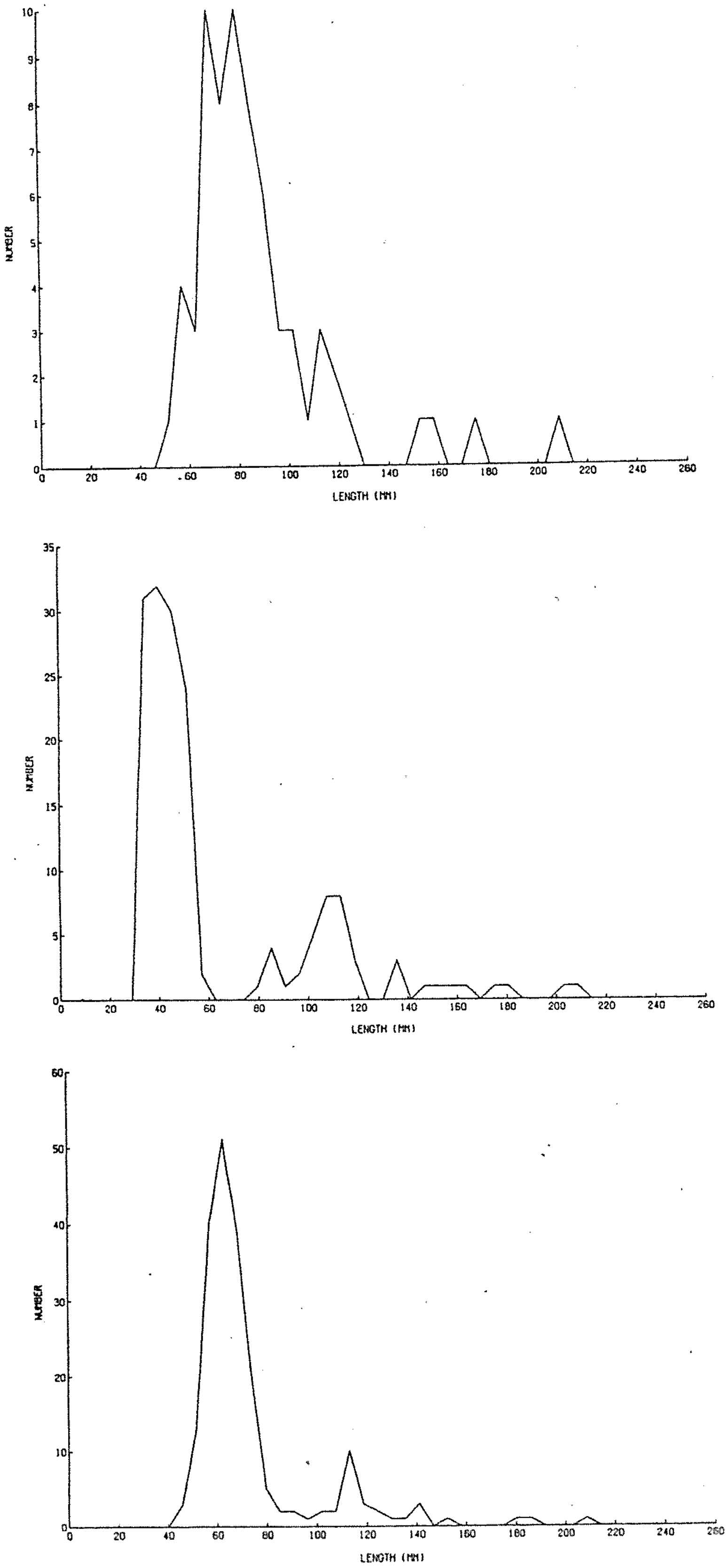

Fig. 13. Length-frequency distribution of trout in Honor Camp Creek, April, July, and October 1979.

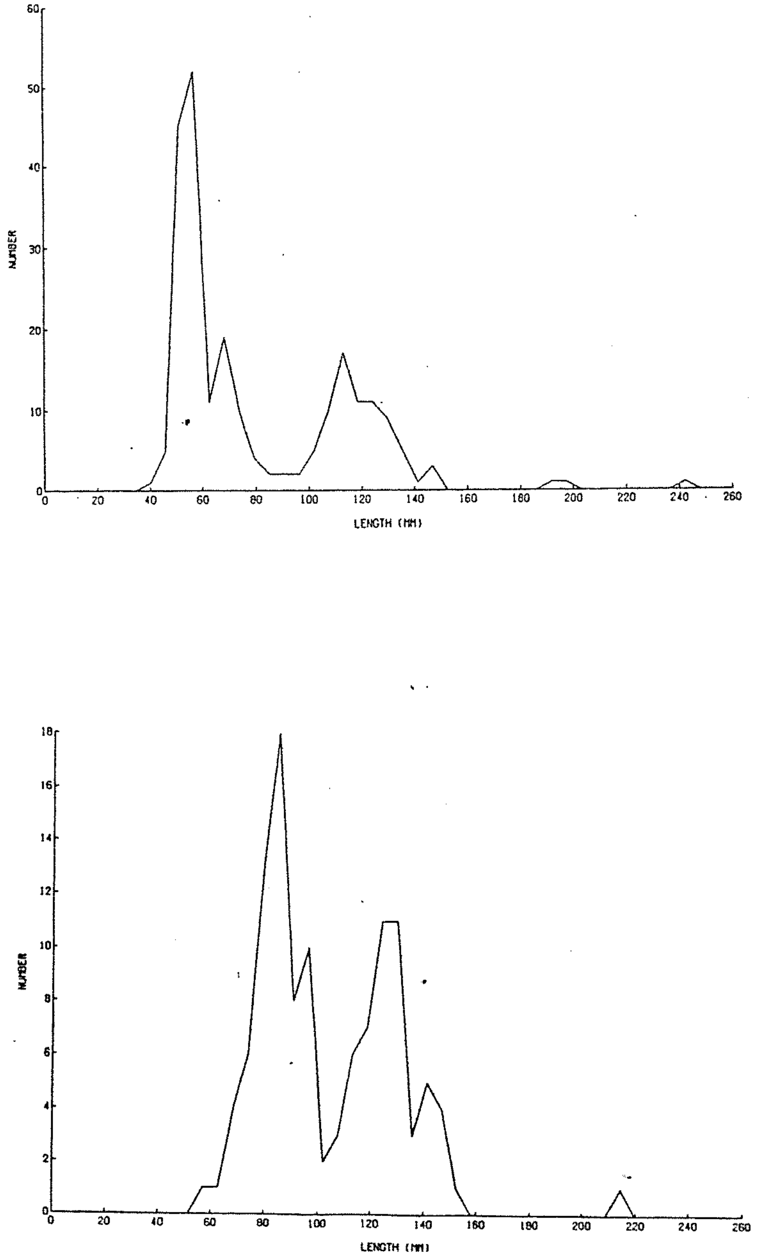

Fig. 14. Length-frequency distribution of trout in Christmas Creek, July and October 1978.

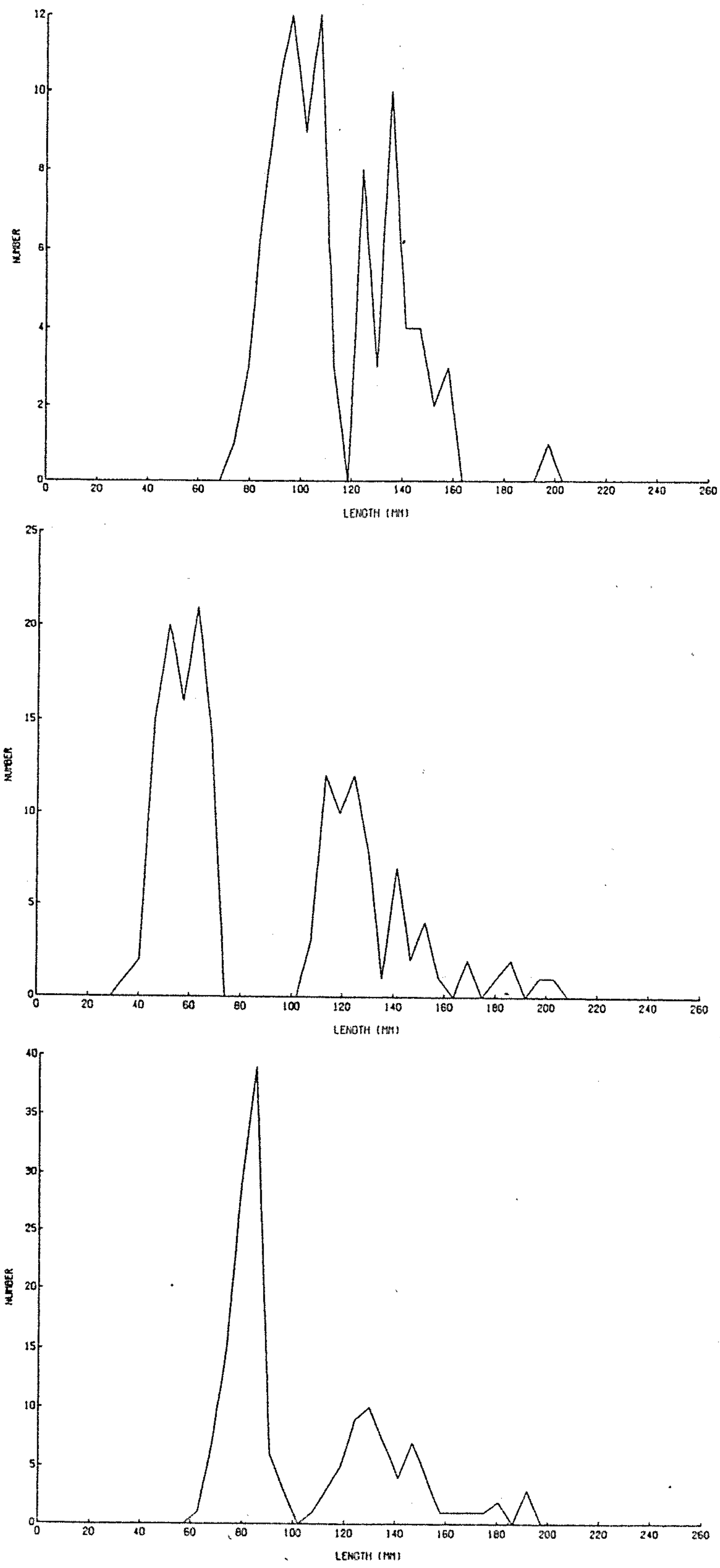

Fig. 15. Length-frequency distribution of trout in Christmas Creek, April, July, and October 1979.

DISCUSSION

Intensive Study

The population of cutthroat trout in East Fork maintained its size and age distribution over the course of the study in spite of logging operations in and across the stream channel. The amount of coarse forest debris in the stream channel remained unchanged as well. As previously stated in the Introduction, cutthroat trout have very high and strict requirements for suitable habitat. Since debris which was actually being used as habitat for the fish in the stream channel changed little, the population would be expected to change very little, if at all. Much of the "Actual" debris in East Fork in 1979 was not the same debris that was present in 1978, but the amount was comparable and in a form which was suitable for good trout production. Most of the 1978 material was washed downstream over the winter, and was replenished by bank sources. A problem arises in the form of the question, "What is going to replenish the bank sources if the stream is logged and all the forest debris is removed?" It has been shown that cutthroat populations can recover rapidly from removal of forest debris if the streams have a source from which to replenish the lost material (Lestelle 1978).

However, in East Fork the source with which to replenish lost material has been reduced. "Actual" coarse material remained unchanged, but "Potential" and "Bank Potential" sources were drastically reduced (Table 5). As the bank material is used up, eventually none will be left to replenish the habitat source for the fish (Swanson and Lienkaemper 1976b; Froehlich 1973). Fish populations may decrease and the stream will develop sluiced-out, uniformly straight, raceway-like channel morphology, very possibly never to recover (Dr. Jim Sedell, personal communication).

Other studies have discovered evidence consistent with the findings in East Fork (Sedell, personal communication). After a stream has been logged and the canopy removed, autocthonus production is increased, due to increased sunlight and temperature, and fish production is also increased (Fig. 16). Yet after a short period of time the habitat for fish production, in the form of forest debris, is exhausted from being washed out of the system or biodegrading. The fish production then decreases to a point below the level which was normal before logging. The stream stays in this state for many years or, possibly, indefinitely. Research, thus far, has shown this to be the case, but very long term studies have yet to be conducted. Streams which were logged many years ago and were depleted of forest debris are experiencing dramatically decreased productivity, fish populations and fish species diversity (Sedell, personal communication).

The only method of recovery is if coarse debris is introduced back into the stream by either natural regrowth of trees or via some other

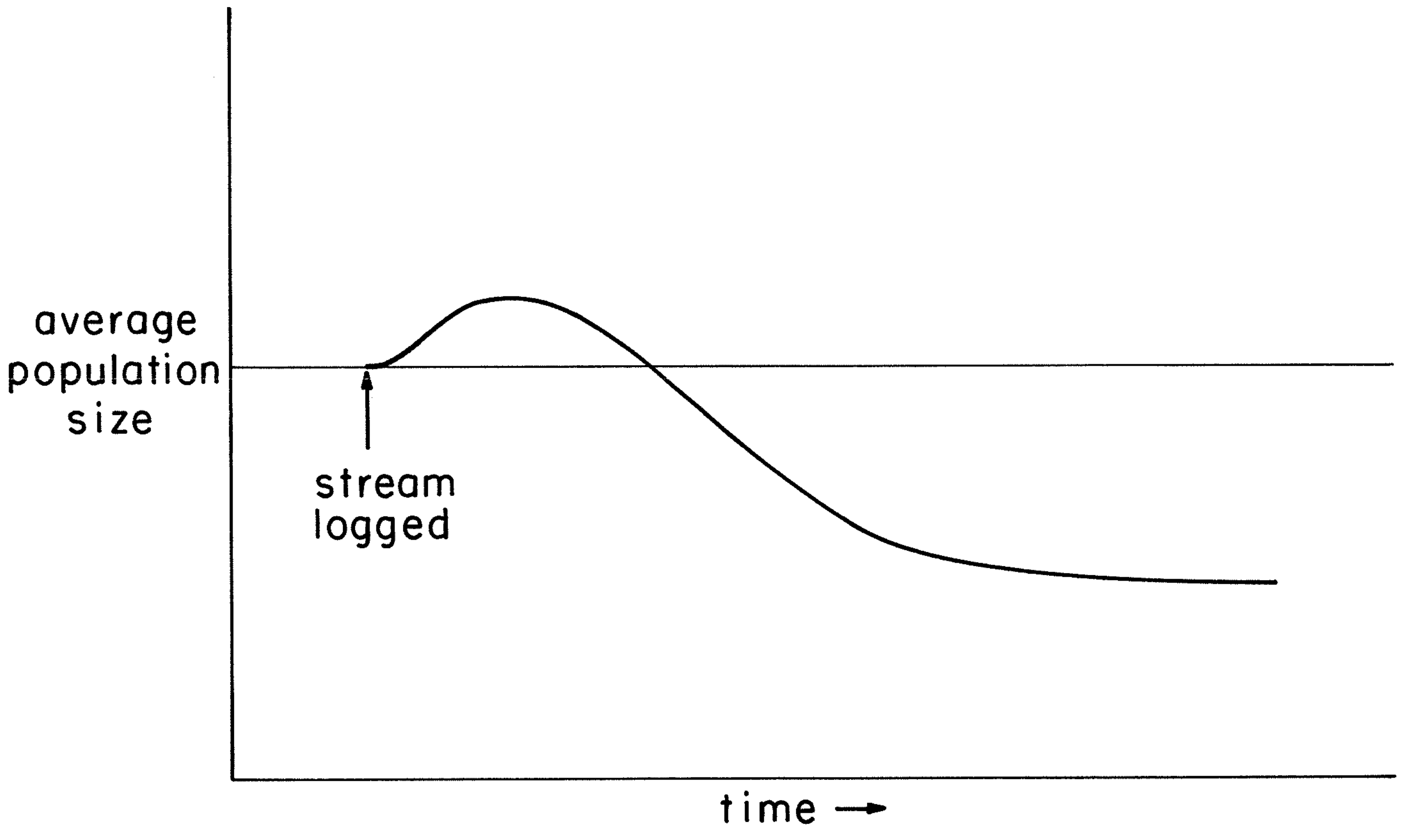

Fig. 16. Theorized effect of logging on population size.

vector. Many streams are damaged permanently and many miles of small, headwater streams have already been lost due to over-logging of organic debris along these streams.

Over-winter mortality was affected in East Fork as evidenced by the higher mortality rate between October 1978 and April 1979 (Table 6). Cutthroat trout prefer stable branch and root wad type material for over-winter habitat (Bustard 1973). Logging operations created unstable habitat which was, in turn, responsible for the higher mortality rates. Fish either left the stream for more suitable cover downstream, or were actually unable to survive the winter. Destruction of over-winter habitat seemed to have a deleterious effect upon the fish population in that stream.

Extensive Study

The extensive study showed that with proper logging techniques streams can support good populations of trout during the post-logging period. The substrate in the extensive study streams was not disrupted during yarding operations and, therefore, provided good, stable habitat conducive to good fish production.

The contradiction between the predicted logging effects in the intensive study streams and the observed effects in the extensive study streams can be explained by differences in habitat composition. The populations of trout in the intensive study streams, East Fork and West Fork, relied almost entirely upon forest debris for habitat. Very few large boulders or cobbles were present in the stream channels. Because of this heavy reliance upon forest debris for habitat these streams could be more greatly influenced by logging, as shown in East Fork, than the extensive study streams, Octopus 'B', Christmas, and Honor Camp creeks.

The primary form of habitat in the extensive study streams consisted of large boulders and cobbles. Very little forest debris was available or utilized by trout in these streams. Habitat consisting of boulders and cobbles seems to be more stable than that of forest debris and may be able to better withstand adverse effects associated with logging. However, it cannot be determined from this study which habitat type is better. West Fork, in its natural state, and East Fork both support good sized populations of trout, indicating that forest debris is a valuable component of cutthroat trout habitat.

Another factor contributing to the larger populations of trout in the extensive study streams is that anadromous searun cutthroat trout had access to the study sections, thus creating a larger pool from which new fish could be draw. Population strength and production seem to be maintaining a high level for up to 18 years after logging.

Logging appears to have had a beneficial effect on the extensive study streams to a certain extent. Population size is high, as well as is growth. Individual fish at any given time of the year are much larger in the extensive streams than in the intensive study streams. This is most likely due to moderately elevated water temperatures from canopy removal. Higher temperatures cause earlier emergence, a higher metabolic rate, and may increase the length of the growing season. Searun cutthroat also spawn earlier in the spring and therefore would emerge earlier than the resident cutthroat and would therefore have a longer growing period. A combination of these factors contributes to the larger individual fish. The advantages of being larger are many, such as decreased predation, greater feeding ability, and increase survival for anadromous fish.

MANAGEMENT RECOMMENDATIONS

1) Avoid overzealous removal of natural old-growth forest debris when performing stream clean-out.

2) Where provided by the Forest Practices Act (i.e., temperature sensitive criteria) leave a streamside management zone with some merchantable sized trees to act as a source of organic material for resupply to the stream and to provide shade.

3) Minimize occurrences of debris avalanches and hillside failures by improving cutting and yarding operations and road-building techniques.

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APPENDIX I

Water Categories

(1) "Type 1 Water" means all waters, within their ordinary highwater mark, as inventoried as "Shorelines of the State" under Chapter 90.58 RCW.

(2) "Type 2 Water" shall mean segments of natural waters which are not classified as Type 1 Water and have a high use and are important from a water quality standpoint for:

a) Domestic water supplies,
b) Public recreation,
c) Fish spawning, rearing or migration, or wildlife uses, or
d) Are highly significant to protect water quality.

(3) "Type 3 Water" shall mean segments of natural waters which are not classified as Type 1 or 2 Water and have a moderate to slight use and are moderately important from a water quality standpoint for:

a) Domestic use,
b) Public recreation,
c) Fish spawning, rearing or migration, or wildlife uses, or
d) Have moderate value to protect water quality.

(4) "Type 4 Water" shall mean segments of natural waters which are not classified as Types 1, 2, or 3. Their significance lies in their influence on water quality downstream in Types 1, 2, and 3 Waters. These may be perennial or intermittent.

(5) "Type 5 Water" means all other water, in natural water course, including streams with or without a well-defined channel, areas of perennial or intermittent seepage, ponds, and natural sinks. Drainage ways having short periods of spring runoff are considered to be Type 5 Waters.

APPENDIX IIa. Maximum-minumum temperature (^{o}F), June 1979.

Date	West Fork Stequaleho		East Fork Stequaleho		Octopus "B"		Christmas Ck.		Honor Camp Ck.	
1	48	47	52	48	62	51	66	51	50	48
2	49	48	53	49	63	52	68	52	51	48
3	48	48	53	49	61	53	66	54	50	49
4	48	48	50	50	56	54	57	55	49	49
5	48	48	51	50	56	53	57	52	49	49
6	48	48	50	48	55	51	58	50	48	48
7	48	46	51	47	58	48	61	47	49	46
8	50	48	52	48	59	50	61	48	50	47
9	50	48	52	48	60	50	65	52	50	48
10	49	48	52	48	59	51	64	54	49	48
11	48	48	51	49	55	50	57	51	48	47
12	49	47	52	48	59	49	62	48	48	46
13	48	47	50	48	54	50	58	50	48	47
14	48	46	50	48	54	49	58	49	48	46
15	48	48	50	48	53	50	53	51	48	48
16	48	47	50	48	53	50	55	50	48	47
17	47	47	48	48	53	50	56	51	47	47
18	48	47	50	48	53	51	54	52	48	47
19	48	48	50	49	56	51	58	52	48	48
20	48	47	50	48	56	50	59	52	48	47
21	48	46	49	48	57	48	58	48	48	46
22	48	47	49	48	61	50	58	50	48	47
23	48	48	50	48	62	52	65	52	50	48
24	50	47	53	48	61	51	67	52	50	47
25	50	48	54	49	62	52	68	53	51	48
26	61	49	54	50			66	53	50	48
27	51	49	54	51			67	55	50	49
28	50	49	52	51	58	54	60	52	49	48
29	50	49	51	51	54	52	56	54	49	49
30	49	49	50	50	55	52	58	54	49	48

APPENDIX IIb. Maximum-minumum temperature (^{o}F), July 1979.

Date	West Fork Stequaleho		East Fork Stequaleho		Octopus "B"		Christmas Ck.		Honor Camp Ck.	
1	49	49	50	49	54	50	56	51	48	48
2	48	47	50	49	53	50	55	51	48	48
3	49	48	50	48	57	50	60	50	49	48
4	49	48	49	49	54	52	56	54	49	48
5	49	48	51	49	58	51	60	52	49	48
6	49	48	52	49	54	52	64	52	50	49
7	49	48	51	50	54	52	58	53	50	50
8	50	48	52	50	54	54	53	52	50	49
9	51	49	51	51	56	52	54	51	50	50
10	50	50	51	50	53	52	56	50	50	49
11	49	48	50	49	53	51	53	50	49	49
12	48	48	50	48	53	50			48	48
13	48	48	49	49	52	50			48	48
14	49	48	51	49	58	50	63	52	50	49
15	50	48	52	50	60	51	66	54	51	49
16	49	49	54	52	62	53	67	56	52	50
17	52	51	55	52	63	55	67	56	52	51
18	52	51	55	52	63	54	68	58	52	51
19	52	50	55	51	64	55	64	57	53	52
20	53	52	55	52	63	55	63	56	54	52
21	52	52	55	52	61	55	66	54	53	50
22	52	50	54	51	60	50	67	56	52	50
23	52	50	55	51	62	53	68	56	52	50
24	52	50	55	52	64	54	68	58	54	51
25	52	50	54	52	64	54	62	57	54	52
26	52	50	54	51	64	54			54	52
27	51	51	54	52	62	56			53	51
28			54	52	62	53			52	50
29			54	52	62	53			52	50
30			54	52	64	54			52	50
31	52	50	55	53	65	56			52	50

APPENDIX IIc. Maximum-minumum temperature (°F), August 1979.

Date	West Fork Stequaleho		East Fork Stequaleho		Octopus "B"		Christmas Ck.		Honor Camp Ck.	
1	52	51	54	51	63	54			52	50
2	52	51	54	52	64	53			52	50
3	52	52	54	51	62	56			52	51
4	52	51	54	51	60	56			52	52
5	52	50	54	52	58	54			52	50
6	52	50	53	51	62	52			53	51
7	52	52	54	52	62	53			54	52
8			54	52	60	56			52	51
9			54	52	62	53			52	50
10			54	52					52	52
11			54	52						
12			53	50						
13	52	52	53	52	56	55	62	58	51	51
14	52	52	54	52	60	54	59	58	51	51
15	52	51	54	52	63	55	64	56	52	51
16	52	52	54	53	57	56	65	57	52	51
17	52	52	53	53	57	56	60	58	52	52
18	52	52	53	52	57	56	58	56	52	51
19	52	51	52	52	58	54	62	58	51	51
20	52	51	54	52	62	55	66	58	52	52
21	52	52	53	53			60	56	52	51
22	52	52	54	52			64	55	52	51
23	52	52	52	51			61	54	52	50
24	52	52	54	53			66	54	51	50
25	52	52	53	52			68	57	52	52
26	51	51	54	52			62	56	53	52
27	52	52	53	53	57	57	58	58	52	52
28	52	52	53	52	57	56	56	55	52	52
29	52	52	52	52	56	56	58	57	52	52
30	52	52	52	52	56	55	58	56	52	52
31	52	52	51	51	58	55	60	57	51	51

APPENDIX IId. Maximum-minumum temperature (^{o}F), September 1979.

Date	West Fork Stequaleho		East Fork Stequaleho		Octopus "B"		Christmas Cr.		Honor Camp Cr.	
1	52	52			58	56	60	58	52	51
2	52	52			56	55	58	57	52	52
3	52	52			56	55	57	56	52	51
4	52	52			54	54	56	55	52	51
5	52	52	52	51	54	54	57	54	52	52
6	52	52	50	50	54	53	56	54	52	52
7	52	52	51	50	56	53	58	54	52	51
8	52	52	51	51	54	54	55	55	51	50
9	51	51	51	50	52	51	54	53	52	50
10	50	50	52	49	54	50	55	50	50	49
11	50	50	52	50	54	50	56	50	51	50
12	50	50	50	48	55	50	57	50	52	50
13	50	50	50	48	50	51	58	51	52	50
14	51	50	50	48	58	52	60	52	51	51
15	50	50	51	50	57	54	60	55	51	51
16	51	50	50	50	57	52	60	54	52	51
17	50	50	52	49	58	51	59	54	50	50
18	50	50	52	50	58	52	61	54	51	50
19	50	50							50	49
20	50	50							50	49
21	50	50			56	52	61	55	50	49
22	50	50			55	52	68	53	51	51
23	50	50			56	50	60	50	51	50
24					58	51	61	51	52	50
25					57	52	58	54	52	52
26					54	53	56	55	52	52
27					52	52	54	54	52	52
28					54	51	57	52	51	50
29					53	51	55	52	50	50
30					54	51	57	52	52	51