CHANGES IN HABITAT AND POPULATIONS OF STEELHEAD TROUT, COHO SALMON, AND CHINOOK SALMON IN FISH CREEK, OREGON, 1983-87, AS RELATED TO HABITAT IMPROVEMENT

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Funded by
Bonneville Power Administration
Division of Fish and Wildlife
Kathy Anderson, Project Manager

Project No. 84-11

Contract No. DE-Al 79-84 BP 16726

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INTRODUCTION

Construction and evaluation of salmonid habitat improvements on Fish Creek, a tributary of the upper Clackamas River, began in 1982 as a cooperative venture between the Estacada Ranger District, Mt. Hood National Forest, and the Anadromous Fish Habitat Research Unit of the Pacific Northwest Research Station (PNW), USDA Forest Service. The project was initially conceived as a 5-year effort (1982-1987) to be financed with Forest Service funds. The habitat improvement program and the evaluation of improvements were both expanded in mid-1983 when the Bonneville Power Administration (BPA) entered into an agreement with the Mt. Hood National Forest to cooperatively fund work on Fish Creek.

Habitat improvement work in the basin is guided by the Fish Creek Habitat Rehabilitation-Enhancement Framework developed cooperatively by the Estacada Ranger District, the Oregon Department of Fish and Wildlife, and the Pacific Northwest Research Station. The framework examines potential factors limiting production of salmonids in the basin, and the appropriate habitat improvement measures needed to address the limiting factors.

Habitat improvement work in the basin has been designed to: 1) improve quantity, quality, and distribution of spawning habitat for coho and spring chinook salmon and steelhead trout, 2) increase low flow rearing habitat for steelhead trout and coho salmon, 3) improve overwintering habitat for coho salmon and steelhead trout, 4) rehabilitate riparian vegetation to improve stream shading to benefit all species, and 5) evaluate improvement projects from a drainage wide perspective.

The objectives of the evaluation include:

1) Drainage-wide evaluation and quantification of changes in salmonid spawning and rearing habitat resulting from a variety of habitat improvements.

2) Evaluation and quantification of changes in fish populations and biomass resulting from habitat improvements.

3) Benefit-cost analysis of habitat improvements.

The evaluation has confirmed the dynamic nature of limiting factors, and the usefulness of examining the historical record of habitat characteristics in a basin. Limiting factors vary from year to year, and can be different for each species of salmonids present in a basin. Historical records that describe the condition for fish habitats prior to intensive management activities in a basin are useful for assessing fish habitat potential and establishing an end point for rehabilitation efforts.

The projects completed during the first three years of the program were typically prototypes to see which were the most effective given the conditions found in Fish Creek. As a result none of the project areas were intensively treated. Therefore, the emphasis of the 1986 and 1987 field seasons was to intensively treat project areas in lower and middle Fish Creek with the objective of increasing habitat complexity. In 1986 and 1987 more than 300 structures were constructed in lower and middle Fish Creek. The structures built in 1986 and 1987 were combinations of logs and boulders anchored together and to the stream banks with cable and epoxy resin. The majority of the structures were placed along the stream margin rather than across the channel.

Implementation activities on Fish Creek are scheduled to be completed by 1988. At the end of the habitat improvement program, it is anticipated that at least 80 percent of the habitat available to anadromous fish will have been affected. A total of $165,300 was budgeted for planning, project implementation, and the Fish Creek evaluation in 1987.

This paper will focus on the projects completed in the basin in 1987, and the evaluation of projects constructed during the 1986-87 period. Coho salmon and steelhead trout smolt production, and changes in physical habitat structure and spawning gravel related to addition of boulders and large woody debris to the channel, will be emphasized.

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DESCRIPTION OF STUDY AREA

The Fish Creek basin lies in north central Oregon on the west slope of the Cascade Range and drains into the upper Clackamas River (Fig. 1). The watershed is 21 km long, averages approximately 10 km in width, and covers 171 km^2. The terrain is steep and mountainous with bluffs in the lower canyons typical of the Columbia River Basalt formation. The valley bottoms are typically narrow with incised stream channels and narrow floodplains.

Fish Creek heads near the summit of the Cascade Mountains at an elevation of about 1,400 m and flows generally north for about 21 km to its confluence with the Clackamas River, about 14 km east of North Fork Reservoir. The channel gradient is steep throughout this distance, generally exceeding 5 percent except for the lower 6 km where gradients average 2 percent. The steep gradient and volcanic geology create a stream with predominately riffle environment and boulder substrate. The mainstem of Fish Creek is 5th order as defined by Strahler (1957) and the annual flow variation near the mouth ranges from 0.5 m^3/set in late summer to more than 100 m^3/set during winter freshets.

One major tributary, Wash Creek, a 4th order system, heads in the southwest portion of the Fish Creek basin and enters Fish Creek at km 11. The Wash Creek subbasin covers 36 km^2 and has a mainstem length of 8 km. The stream heads at an elevation of about 1,200 m. The mainstem habitat of Wash Creek is steep bouldery riffle in a narrow incised channel. Average minimum summer flow is approximately 0.3 m^3/sec.

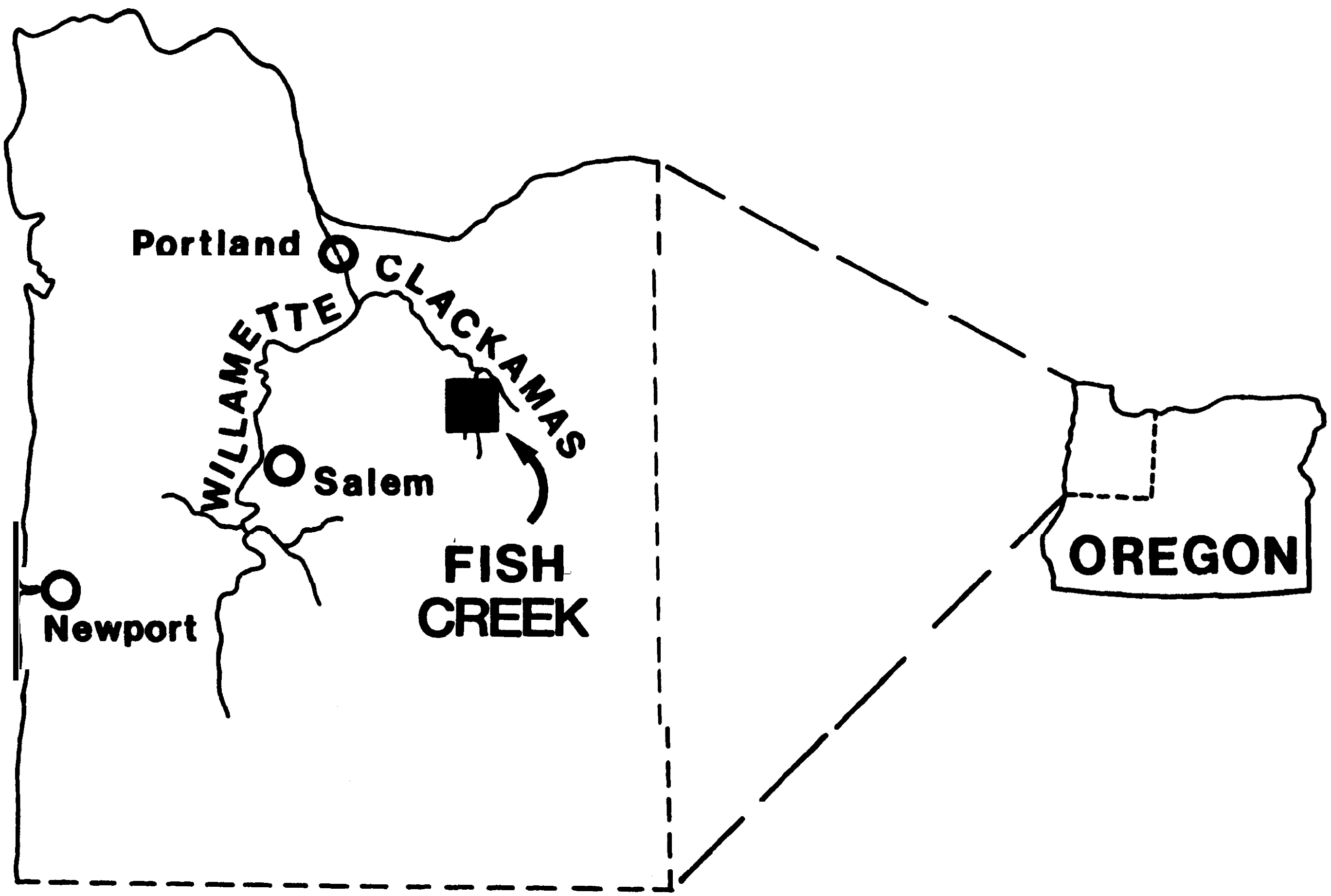

Figure 1. The Fish Creek basin is located in northwest Oregon.

The Fish Creek basin supports a significant population of anadromous salmonids, including summer and winter steelhead trout (Salmo gairdneri), spring chinook salmon (Oncorhynchus tshawytscha) and coho salmon (O. kisutch). Upper areas of the basin contain resident rainbow trout (S. pairdneri). Few resident salmonids are found within the range of anadromous fish and all rainbow trout sampled there were treated as steelhead trout. Approximately 16.7 km of habitat are used by anadromous salmonids, including the lower 4.7 km of Wash Creek. The upper reaches of both Fish and Wash creeks are blocked to anadromous salmonids by major waterfalls. About 20 km on Fish Creek and 8 km of habitat on Wash Creek are unavailable to anadromous salmonids, but provide good resident trout habitat. Culverts have blocked access to a total of 2 km of anadromous habitat on three small tributaries to Fish and Wash Creeks. Water temperatures in habitat used by anadromous fish are generally favorable for fish production, ranging from near 0°C at times in winter to about 20°C in most summers. In years with low summer streamflow and high summer temperatures, however, water temperatures can reach stressful levels for salmonids. For example, in early September 1980, temperatures in lower Fish Creek reached 24° C for several consecutive days. Future streamside management in the basin is expected to gradually reduce high summer temperatures and eliminate periodic summer thermal stress for juvenile salmonids as streamside vegetation recovers in areas where land management and natural events have created openings in the riparian zone.

The present habitat conditions in Fish Creek vary significantly from historical conditions. A survey of the Fish Creek basin in 1959 indicated that pools made up about 45 percent of the habitat in the range of anadromous salmonids. A resurvey of the basin in 1965, after the catastrophic flood of December 1964, indicated that pool habitat had been reduced to about 25 percent. Our studies from 1982-87 indicate that pool habitat averaged 11 percent (range 8-18) of total area during those years. The percentage of boulder habitat within the range of anadromous fish increased from 45 to 70 percent in the upper reaches of Fish Creek between 1959 and 1965, and from 25 to 60 percent on Wash Creek. Spawning habitat for anadromous salmonids declined by about one-third during the same time interval. The 1964 flood was followed by a vigorous logjam removal effort that was probably responsible for the observed decline in pool habitat.

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DESCRIPTION OF HABITAT MODIFICATIONS

Extensive modification of habitats in the basin was initiated in 1986 and continued at an accelerated pace in 1987. The objective of this work was to increase the complexity of habitats, particularily along the stream margins, in the mainstem reaches of Fish Creek. Plans called for placement of log and boulder structures along both edges of the stream to provide quiet complex edge habitats and a narrowed and deepened thalweg. The work was designed to benefit all species and age-classes of anadromous salmonids in the system in both summer and winter.

Habitat improvements in 1986 were concentrated at 3 locations (km 0.0, 0.6, and 7.8) in Fish Creek basin (Fig. 2). A total of 2 km of habitat was treated intensively. The complexity of these riffle-dominated areas was improved by adding a series of boulder and tree groupings that were anchored securely with cables and epoxy. The work was designed to improve low flow summer pool habitat, and the amount and complexity of winter habitat, for coho and spring chinook salmon and summer and winter steelhead trout.

The same type of habitat work was continued in 1987, but a larger area was treated. More than 5.5 km of habitat between km 1.5 and km 7.8 (Fig. 2) were intensively treated with boulder-log structures. The work in 1987 addressed the same objectives as the 1986 habitat modifications.

Evaluation of habitat improvements completed on Fish Creek in the summer of 1986 was continued in 1987. The 1986 and 1987 habitat modifications are described in more detail below.

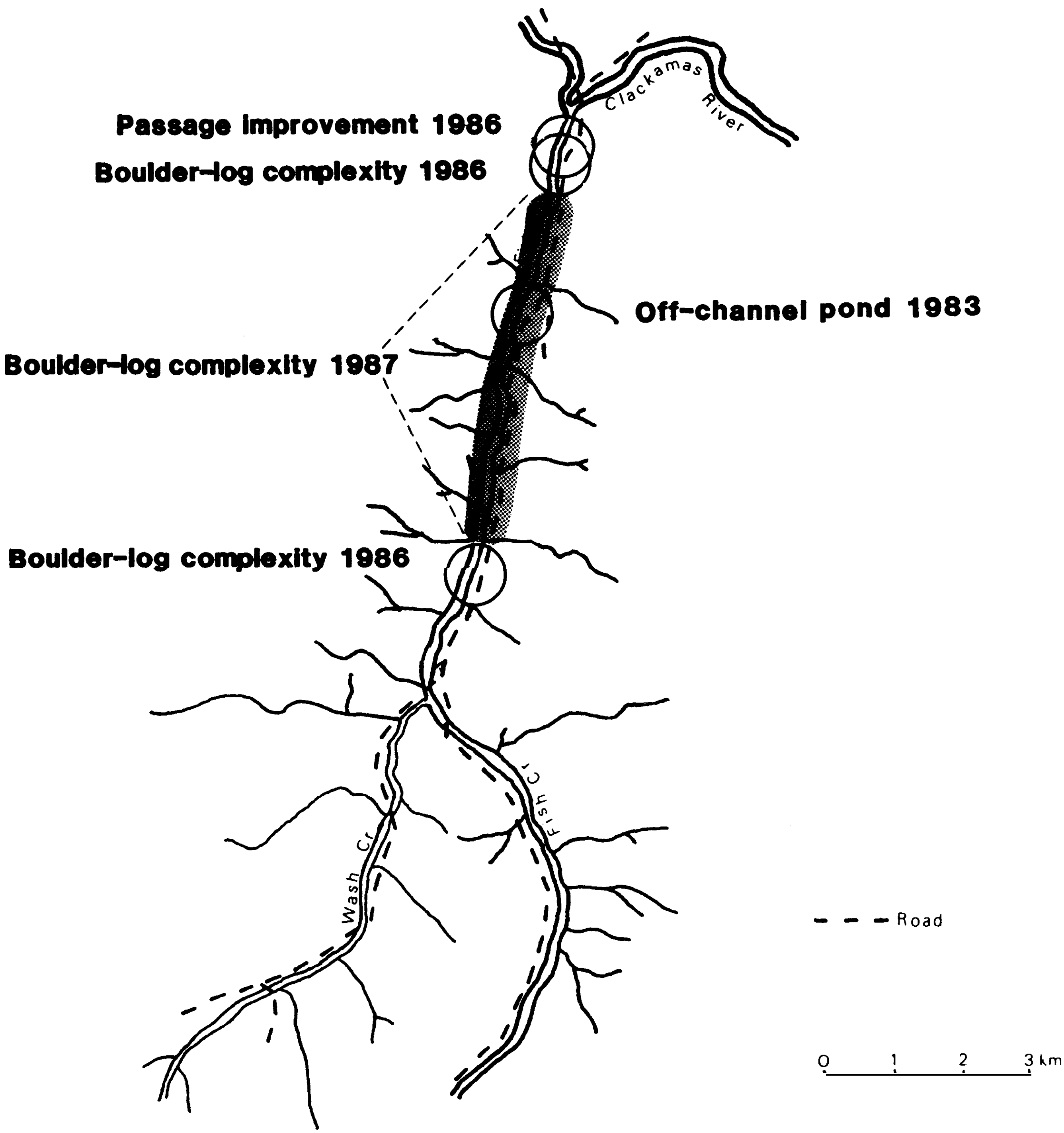

Figure 2. Habitat enhancement projects completed in the Fish Creek basin, 1986-1987.

1986 and 1987 Habitat Modifications

Approximately 94 trees were felled and more than 300 boulders were used to construct 110 structures along 2 km of stream at sites located at km 0.0, 0.6, and 7.8. The work was designed to increase the habitat complexity in boulder dominated riffles and increase effective cover in existing pools to improve low flow rearing habitat. The addition of large structural elements to the channel also will improve shelter for overwintering salmonids and provide additional spawning habitat through gravel entrapment.

The work in 1986 also presented an opportunity to rehabilitate access sites used by heavy equipment during previous years of the project.

The implementation of the projects in 1986 and 1987 was divided into four stages, 1) boulder haul, 2) tree falling, 3) backhoe operation, and 4) cabling/securing:

Boulder Haul: To minimize the disturbance of boulders already incorporated in the channel large numbers (250 in 1986 and 500 in 1987) of boulders were hauled to the project area and stockpiled at storage sites. Transportation of boulders from the stockpile sites to individual work sites was done by a backhoe. In addition to the boulders moved to the site, boulders located along the floodplain of the project area were used also. The boulders were placed individually and in groups to act as scouring agents in riffles, to provide cover in pools, and to act as anchoring points for logs.

Tree Falling: A professional tree faller was hired to drop trees throughout the project area (94 were felled in 1986 and 280 in 1987). The trees, which were pre-selected and marked, ranged in size from 0.6 m to 1.8 m in diameter. In order to protect the streambanks and stream shading, bankside trees were avoided. Trees that were felled were back from the bank and were dropped between standing trees. With a large portion of the felled tree on the bank and wedged between standing trees, displacement during high flows is less likely. Also, the trees were anchored by cable to standing trees and to boulders in the channel. The majority of the trees were left whole, with the limbs on, and were used as debris collectors, cover logs in pools, and as flow deflectors in riffles.

Backhoe Operation: A large excavator/backhoe was rented to construct log-boulder structures, excavate pools, and reconstruct the west beaver pond (Everest et al. 1987). When a boulder was placed it was stabilized by seating it in an excavation in the substrate. Boulders used as scouring agents were seated low enough to allow flows to pour over the top of the boulder to assist the scouring action. Boulders used as anchors were placed on the upstream side of felled trees to prevent the logs from floating and coming to rest on top of the boulders. Also, the backhoe was used to pull on-site boulders and downed logs along the banks into the channel. As the backhoe left the project area it ripped and placed barrier rock across the spur roads to restrict vehicle access to these areas. Areas of disturbed soil were planted with grass seed upon the completion of the project.

Cabling/Securing: The anchoring system employed a pneumatic drill and polyester resin. One or more pair of 20 to 25 cm deep holes were drilled into each boulder and partially filled with polyester resin. One end of the 12 mm cable was inserted into one hole of the pair and the cable was wrapped around the log and the other end inserted into the other hole. The resin takes a few minutes to set up and can bear a full load in approximately 90 minutes. The bank end of the log was cabled to standing trees and stumps with 12 mm cable and cable clamps.

Habitat improvement objectives for the 1987 project area were similar to those of the 1986 project. The primary difference was that the 1987 project area was situated in more difficult terrain to access and improve, and therefore required a more aggressive approach for improvement. An articulated backhoe was used to access and place structures in 2.1 km of the most difficult terrain. In 1987 the intent was to incorporate as much of each felled tree into the channel as possible so at least part of the tree remained in contact with water during low flow periods. Post project monitoring of 1986 improvements indicated that some of the wood was placed too high to affect habitat at low flow. Consequently, structures built in 1987 were lower in the channel and included more rock to provide ballast.

It was anticipated that, because so much more of each log was in the channel, the structures would tend to move during high flow events, simulating the behavior of natural blowdown. Approximately 55 percent of the estimated 600 pieces of wood placed in 1987 moved during the December 1987 high flow event. Of those that moved, 94 percent were still meeting project objectives. Only 6 percent of the mobile wood was moved out of the channel, either deposited too high on the edge to be effective fish habitat or floated out of the system.

The rate of success is felt to be quite satisfactory, given the fact that the structure design and intensity were very aggressive and incorporated varying degrees of risk of failure.

METHODS AND MATERIALS

An important part of the habitat enhancement evaluation on Fish Creek was basin-wide documentation of pre-improvement habitat characteristics and fish populations. Once these characteristics were established, changes in habitat and fish numbers associated with habitat improvement within the basin could be documented. Physical and biological surveys also were made before and after habitat improvements at specific sites.

Habitat Surveys 1982-1984

The composition of physical habitat was measured by compiling the results of habitat surveys in five 0.5 km reaches in the basin. Three reaches were located on mainstem Fish Creek between Wash Creek and the mouth, and one each was located on Wash Creek and Fish Creek above the confluence of Wash Creek. Each reach was selected because it was believed to be representative of overall habitat conditions in Fish Creek and yet covered as much area planned for habitat enhancement projects as possible.

Five distinct habitat types were found in the reaches. These were riffles, pools, side channels, alcoves, and beaver ponds. Side channels in Fish Creek are found primarily above canyon constrictions and tributary junctions where sediments have accumulated for centuries. The stream often spreads out at high flow and forms multiple channels in these areas. The side channels are active at high flow in winter and spring, but many are intermittent or dry in Fish Creek during the summer. Those that remain active in summer have characteristically slow water velocity and low stream flow, but water temperature remains favorable for fish production.

Alcoves, found along the edges of the main channel, are quiet-water habitats formed at high flows by eddy currents below cascades, downed trees, or boulders. Beaver ponds are rare in the system and are found only in areas with side channels that are active in summer. These five habitat types are occupied preferentially by the three anadromous fish species present in Fish Creek (Everest et al. 1986).

Physical habitat was measured by compiling results of the five 0.5 km reach surveys in the basin. Surface area and water volume of the five habitat types in each reach were measured. The sampling scheme inventoried about 15 percent of the basin. Results were extrapolated to the rest of the basin accessible to anadromous fish to estimate total habitat in each category available to anadromous fish.

Habitat Surveys 1985-1987

The habitat surveys conducted in 1985-1987 differed from those made from 1982-1984. The edge habitat type previously called "alcove" was dropped from the survey because independent observers showed inconsistency in identifying and quantifying this habitat type. A habitat type called "glide" (Bisson et al. 1982) was added to the survey. Glides are shallow habitats with little turbulence and low velocity. In the 1982-84 surveys glides were included primarily with riffles. The 1985 survey identified five types of habitat: pools, riffles, glides, side-channels, and beaver ponds.

The habitat surveys done in 1985-1987 covered the entire area of the basin used by anadromous fish, rather than the five half-kilometer (km) reaches used previously. Every habitat unit in the 16.7 km of anadromous habitat was classified according to the five habitat types and its length, width, and mean depth was estimated. In addition, at every 5th pool and glide, and every 10th riffle, the length, width at 4 to 5 points along the length of the unit, and depth at 25, 50, and 75 percent of the width, were measured. The estimated and measured area and volume of a given habitat type were compared and a correction factor, which reflected the bias introduced by the estimator, was calculated. Estimated area and volume of each unit were multiplied by the correction factor. The total area and volume in each section of the basin were the sums of the areas and volumes of the individual units in that section. The techniques initiated in 1985 are more reliable than those used prior to 1985 because habitat of anadromous fish in the entire basin is sampled, rather than a few selected reaches.

Fish Population Estimates 1982-1984

Fish population estimates for the portion of the basin accessible to anadromous salmonids were made by sampling juvenile salmonids in individual habitat types at 8 locations in the basin. Fish populations were estimated separately for 36 habitat units (one habitat unit is one riffle, pool, side channel, alcove, or beaver pond) and then extrapolated to the basin based on previous estimates of total available habitat.

Populations of juvenile salmonids in each habitat unit were determined by installing 0.47 cm^2 mesh block-nets at the upstream and downstream boundaries of each site and either electrofishing with Smith-Root Type VII or XI D.C. Shockers, or by snorkel divers actually counting the number of fish.

Population estimates by electrofishing were calculated by the Moran-Zippen method (Zippen 1958). which is a multiple pass removal method. Each pass included electrofishing from the downstream block-net to the upstream net and return. The sampling concluded when the succeeding catch was less than one-half of the previous catch.

Each salmonid captured by electrofishing was measured to the nearest millimeter (fork length) and the first 25 of each species at each site were weighed to the nearest tenth of a gram on an Ohaus Dial-O-Gram balance. Weights of additional fish were calculated from a length/weight frequency relationship based on the involving the first 25 fish weighed and measured. Estimates of biomass in sections counted by divers were made by extrapolation of length-weight data obtained by electrofishing in similar habitat units nearby.

Diver counts of fish were made in riffles and pools that were either too swift or too deep for effective electrofishing (about 50 percent of the area sampled). The habitat unit to be counted was divided in half longitudinally wherever this technique was used. Two divers, each in a predetermined half of the unit, moved simultaneously upstream recording the number of fish by species and age-class. After the first count the divers switched halves and each counted the opposite side on a second pass. The diver counts were then averaged to estimate the fish population in the section.

Fish Population Estimates 1985-1987

Fish numbers in 1985, 1986, and 1987 were estimated by direct observation with a mask and snorkel and by electrofishing. Direct observations were made by a team of two divers in twenty percent of the pools and glides and ten percent of the riffles. The units in which observations were made were determined by systematic sampling (Hankin and Reeves in prep.). In 1987 counts were made on a total of 23 riffles, 57 pools, and 26 glides. The divers began at the downstream end of a unit and proceeded slowly upstream. Each diver identified and enumerated the different species and age-classes of salmonids. When a unit was too large to be sampled effectively in this manner, it was partitioned and each diver identified and counted fish on one side only. The presence of non-salmonids was noted but no attempt was made to quantify them.

Electrofishing verification was conducted at 26 of the diver count sites (Hankin and Reeves in prep.) Population size was estimated by the Moran-Zippen method (Zippen 1958). Populations of juvenile salmonids in each habitat unit were determined by installing 0.47 cm^2 block-nets at the upstream and downstream boundaries of each site. A pass was defined as electrofishing from the downstream block-net to the upstream net and return. Sampling concluded when the succeeding catch was less than 25 percent of the previous catch. This change from methods used in 1982-84 was done to narrow the confidence intervals around estimates.

Fish captured by electroshocking were measured to the nearest millimeter (fork length). All fish were weighed. Weight measures were made to the nearest 0.1 g with an Ohaus digital balance. The standing crop of fish at a site was estimated by multiplying the mean weight of a species or age-class times the estimated number of individuals.

Smolt Production Estimates

Smolt production of steelhead trout and coho and chinook salmon in 1985-1987 was quantified by use of a floating smolt trap. The trap (Fig. 3) is a catamaran configuration consisting of two 0.6 x 0.6 x 7 m pontoons straddling a traveling screen powered by a paddle wheel. The 1.5 m wide traveling screen (4 mm mesh) is fitted with seven 50 x 50 mm baskets that extend across the entire width of the screen at equal intervals. The screen can be lowered into the water to any desired depth between the surface and within about 20 cm of the bottom. The paddlewheel is powered by the streamflow passing by the trap and turns the traveling screen at speeds up to 15 cm/sec.

The trap was fished 0.3 km upstream from the mouth of Fish Creek by positioning it with cables in high velocity water at the stream thalweg (Fig. 4). Downstream migrant salmonids, moving primarily at night, are impinged on the subsurface portions of the traveling screen and baskets move continuously upward. As the screen rotates around

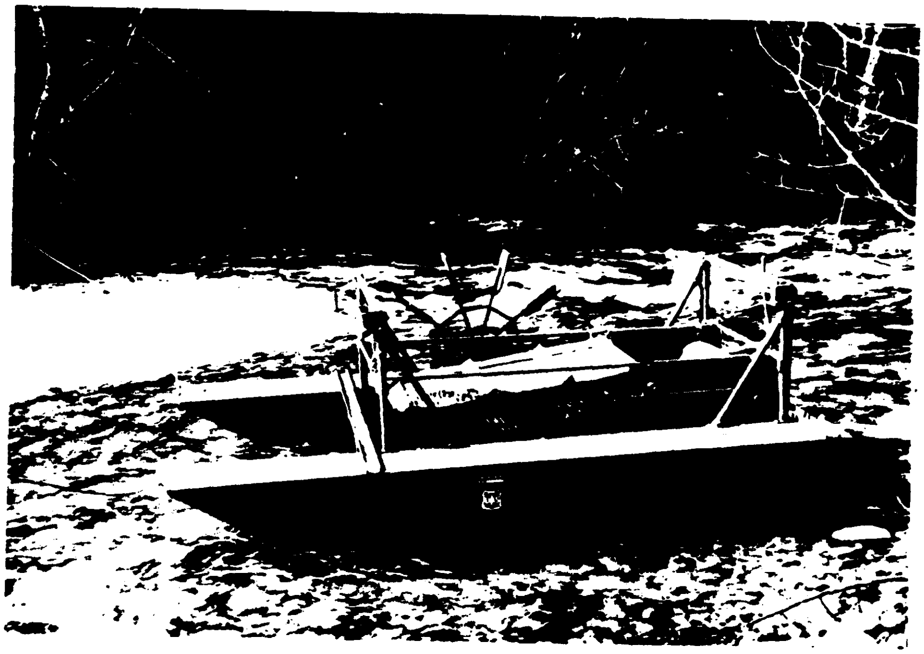

Figure 3. Modified Humphrey trap used to sample downstream migrant salmonid smolts on Fish Creek.

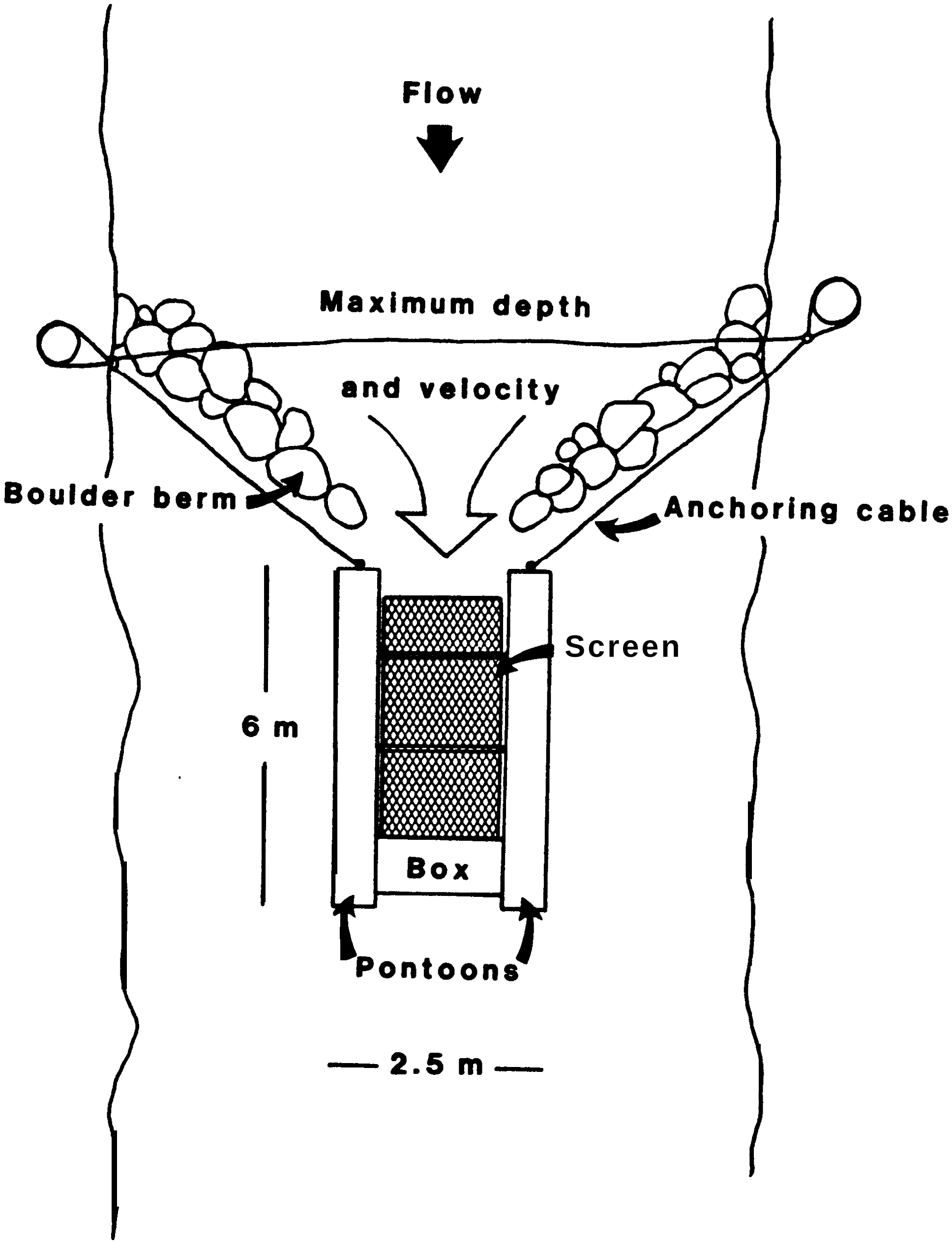

Figure 4. Schematic diagram of Humphrey trap in operating position.

the upper axle, the fish drop by gravity into a holding box that can maintain more than 100 fish for several days.

The trap samples only a portion of the cross-sectional area of the stream and so its efficiency must be calibrated. The efficiency is determined by releasing a known number of marked migrants upstream of the trap and assessing the capture rate of these fish. Since capture efficiency changes with flow level, efficiency checks must be made at all levels of flow experienced while the trap is fishing. The trap must be tended daily or twice daily when large numbers of fish are migrating downstream.

In 1985 an attempt was made to fish the trap continuously from the installation date of April 15 until mid-November, to monitor both spring and fall movement of juvenile salmonids. Except for a few scattered days when the trap was out of operation because of mechanical problems, it fished from April 15 until August 25 when streamflow became too low for operation. The trap was started again in late September and fished until mid-November when it was removed from the stream before the onset of winter freshets.

In 1986, the trap was fished continously from March 13 until the end of June. No fall trapping was attempted because of the abundance of floatable woody debris in the channel following habitat enhancement activities in August and September.

In 1987, the trap was fished continuously from Feburary 17 until June 8. Mechanical problems and low stream flow precluded trapping on 20 days during this period.

Smolts leaving the eastside off-channel pond at km 3 were captured in a trap at the head of the fish ladder at the pond outlet. A rotating drum screen diverts all downstream migrants into a screen trap box adjacent to the ladder.

Spawning Habitat Surveys

An inventory of spawning habitat in the basin was made in 1982, 1984, and 1987. The 1982 and 1987 surveys covered the entire area used by anadromous salmonids. Usable gravel was quantified separately for each species. In 1984 only gravels used by chinook salmon were quantified. Only gravels of the correct size in the correct position for spawning and with the proper water depth and velocity at the correct time of year were included for each species. A slight change in survey techniques was made between 1982 and 1987. All usable gravel areas 1 m^2 or greater in size within the range of steelhead trout and coho salmon were quantified as spawning habitat in 1982, but the minimum area was increased to 2 m^2 in 1987. Several years of observations of spawning behavior of steelhead and coho in Fish Creek indicate that while these fish can use gravel areas of <2 m^2, they rarely do so. The minimum area counted as chinook salmon spawning habitat was 2 m^2 in all years.

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RESULTS

Habitat Availability 1982-1987

The surface area of major habitat types for anadromous salmonids in Fish Creek has been estimated in late summer each year from 1982 through 1987. The differing techniques used in the 1982-84 period, and since 1985, resulted in some changes in estimates of area for the various habitat types (Table 1). The improved method for estimating habitat area used since 1985 is believed to be more accurate than the techniques used previously because habitats have been sampled throughout the entire range of anadromous fish in the basin.

Table 1. Area (m2) of habitat available to anadromous salmonids on Fish Creek, September 1982-1987.

	Habitat Types						
Year	Pools	Riffles	Glides	Side Channels	Alcoves	Beaver[1/] Ponds	Total
1982	18,450	138,590	--	4,250	2,270	190	159,310
1983	20,850	219,360	--	6,200	2,450	300	249,160
1984	19,180	161,700	--	5,320	2,280	270	188,750
1985	26,380	93,770	21,030	2,580	--	190	143,950
1986	27,470	114,400	27,380	0[2/]	--	190	169,440
1987	29,660	79,700	23,980	940[3/]	--	190	134,470
Mean	239665	134,587	24,130	3.858	29333	222	174,180

1/ Does not include enhanced off-channel ponds.
2/ All side channels were dry when habitats were quantified in September.
3/ All side channels nearly dry in 1987 and were not sampled for fish.

The area of habitat types in summer has varied with minimum streamflow between 1982 and 1987. A rough average of the total area in each habitat type measured during the 1982-84 period was: riffles, 86 percent; pools, 10 percent; side channels, 3 percent; alcoves, 1 percent; and beaver ponds, 0.1 percent. Alcoves were eliminated as a habitat type beginning in 1985. Glides were added as a habitat type in 1985, and the ratio of habitat types appeared to change because glides previously had been included primarily with riffle habitat. The average percentage of each habitat type in the 1985-87 period was: riffles, 64 percent; pools, 19 percent; glides, 16 percent; side channels, 1 percent; and beaver ponds, 0.1 percent. No side channels with water were observed in September 1986. All had been blocked by gravel and/or debris deposits from the February 1986 high flow event.

The total area of summer habitat in the system varied directly and significantly with streamflow (Fig. 5). There is no stream gage on Fish Creek, but the adjacent Molalla River basin to the west has a USGS gage and can be used as an index to flow in Fish Creek. Fish Creek and the Molalla River head in the same area and share common precipitation characteristics. Using 1982 as the base year with a flow index of 1, mean flows during habitat sampling periods on Fish Creek in 1983, 1984, 1985, 1986, and 1987 were, 2.12, 1.00, 0.50, 0.55, and 0.46, respectively. Total habitat available to anadromous salmonids on Fish Creek in late summer is related directly to these indices. The higher the minimum streamflow, the greater the area and volume of available habitat.

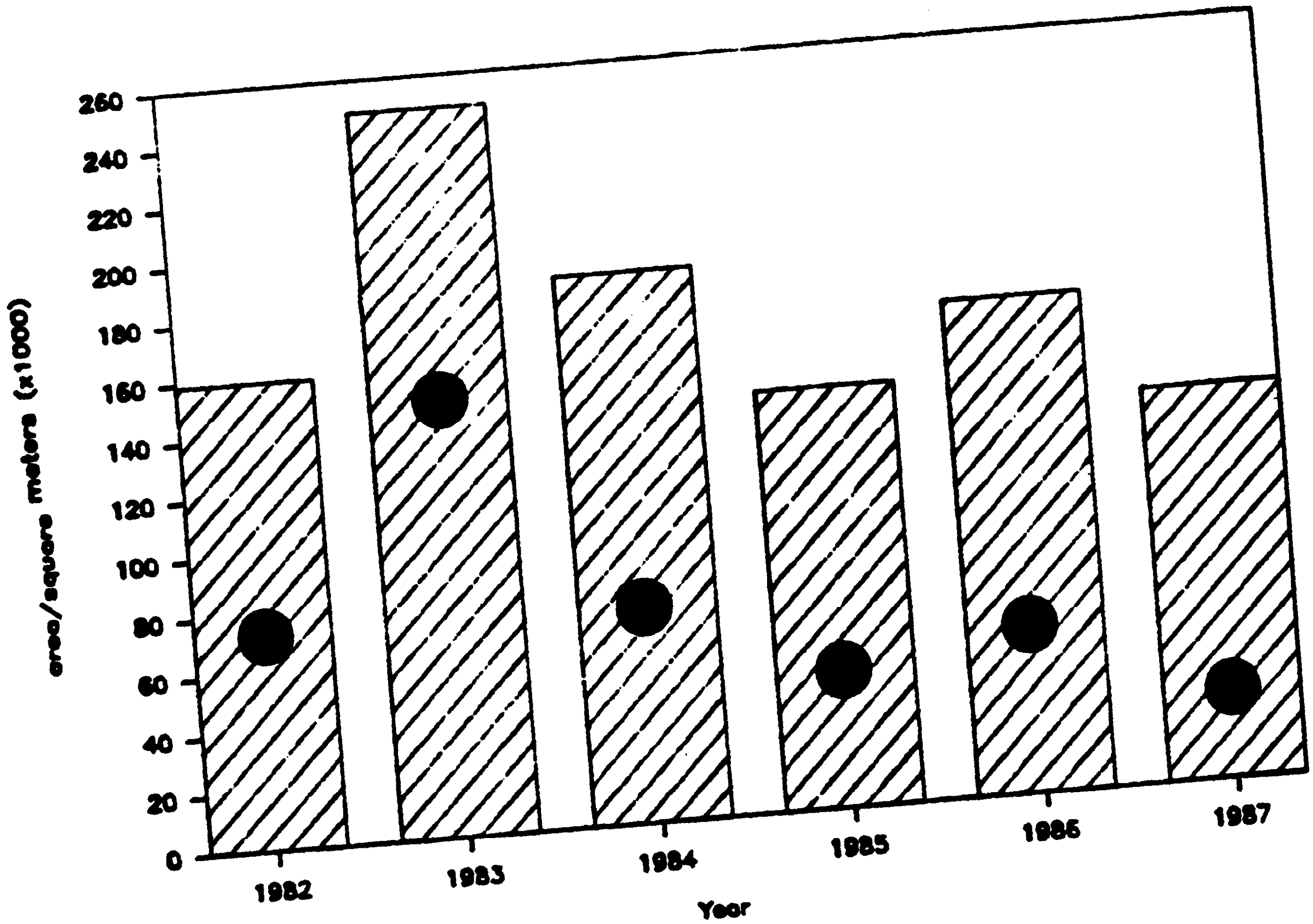


Figure 5. Area of summer rearing habitat available to anadromous salmonids on Fish Creek varies according to streamflow during sampling periods. Dots represent index to streamflow.

A record drought in the summer and fall of 1987 resulted in the lowest summer streamflows and habitat areas observed in the basin since the evaluation began in 1982. Summer rearing habitat decreased a total of 21 percent from 1986, with the greatest decrease (30 percent) in riffle area. Pool area increased 8 percent in 1987 because some habitats classified as glides in previous years were classified as pools during the extreme low flow conditions of 1987. Also, habitat work completed in the summer of 1986 resulted in a small increase in pool area.

The distribution of habitat used by rearing juvenile anadromous salmonids varies by species (Fig. 6). Steelhead trout use the entire area accessible to anadromous salmonids while chinook and coho salmon use only a portion of the system. During the period 1982-86 chinook and coho salmon used about the lower one-third of the habitat area available to anadromous fish, but both species expanded their rearing range by about 20 percent in 1987. The expansion in rearing range was directly related to an extension of spawning distribution by adult chinook and coho salmon during the 1986-87 spawning season. Access improvement at the mouth of Fish Creek, early fall freshets, and moderate steady stream flow in the winter of 1986-87 allowed chinook salmon to utilize more than 8.5 km of the mainstem of Fish Creek, an increase in range of nearly 3 km. Coho salmon spawning activity extended from the mouth of Fish Creek to the confluence of Fish and Wash Creeks (9 km), also a range expansion of about 3 km. The area of each habitat type available to the salmon species for the period

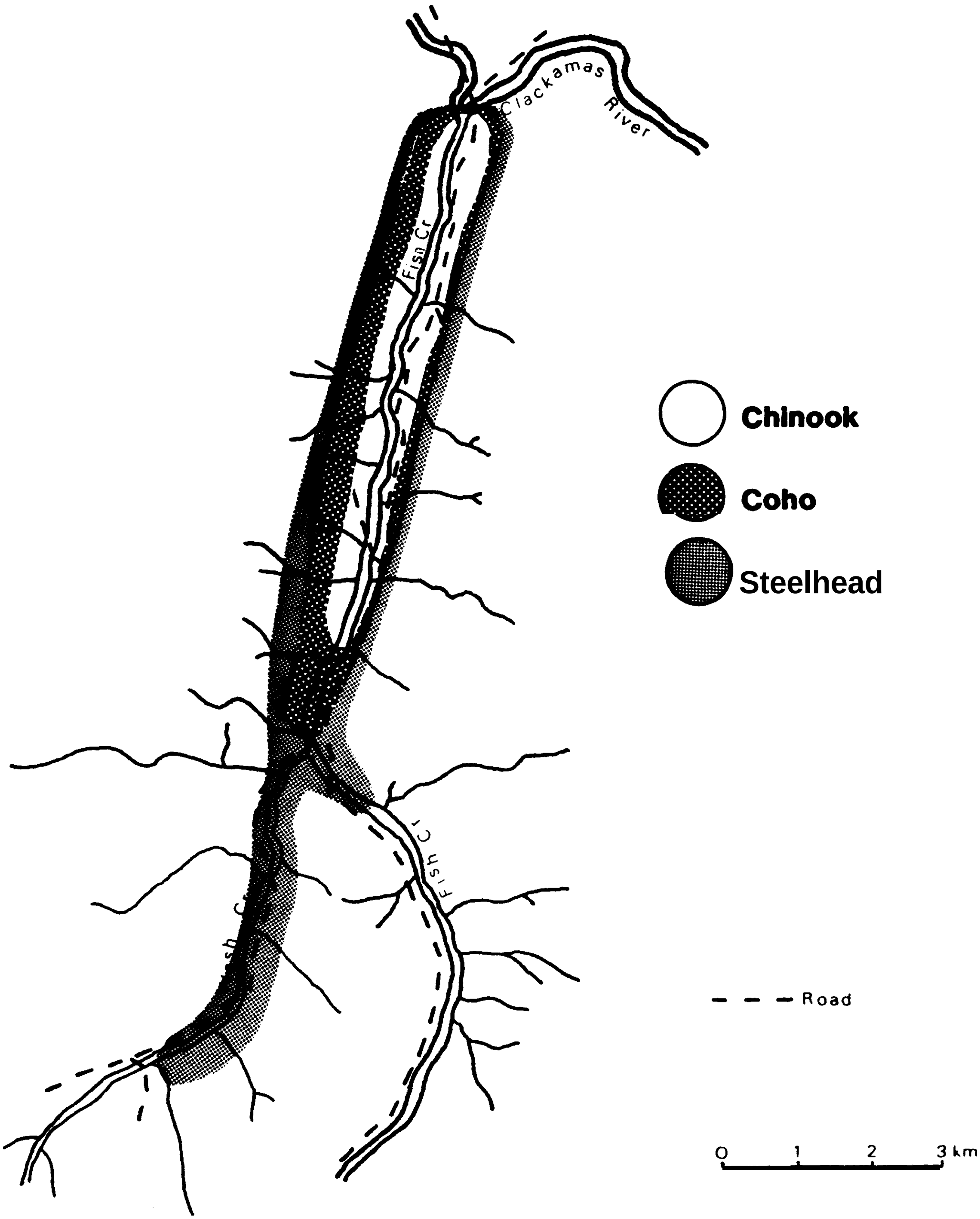


Figure 6. Distribution of juvenile anadromous salmonids in Fish Creek.

Table 2. Area (m^2) of habitat types utilized by coho and chinook salmon on Fish Creek, summer 1982-1987.

	Habitat Types						
Year	Pools	Riffles	Glides	Side channels	Alcoves	Beaver[1/] ponds	Total
1982	8,110	70,350	--	1,600	1,080	190	81,330
1983	9,160	104,820	--	2,230	1,170	300	117,680
1984	8,430	81,610	--	2,000	1,080	270	93,390
1985	11,840	55,810	13,450	2,300	--	190	83,590
1986	7,166	62,944	13,749	0[2/]	--	--	83,829
1987	20,260	58,940	20,370	940[3/]	--	190	100,700
Mean	10,828	72,412	15,856	1,512	1,110	228	93,420

1/ Does not include enhanced off-channel habitat.
2/ All side channels were dry when habitats were quantified in September.
3/ All side channels nearly dry in 1987 and were not sampled for fish.

1982-87 is listed in Table 2. An annual summary of habitat availability and use by salmonids for the 1982-87 period is presented in Appendix I.

Salmonid Populations and Habitat Utilization 1982-1987

The number of juvenile anadromous salmonids in the Fish Creek basin in the summer of 1987 was above the five year mean for 1982-86, but the structure of the fish community had shifted from previous years. Steelhead trout were the dominant species of anadromous salmonids in Fish Creek during the 1982-87 period. Age 0+ and 1+ juveniles accounted for 90 to 98 percent of the total salmonid population in 1982-86, but only about 60 percent in 1987 (Table 3). Underyearling (0+) steelhead were the dominate age-class in all years, ranging from 52 to 79 percent of the total salmonid population. Coho salmon contributed 2 to 8 percent to the total salmonid population in the 1982-86 period, but increased to 33 percent in 1987. Chinook numbers ranged from 0.1 to 3 percent of the total standing stock of salmonids in the basin in 1982-86, but jumped to 5.5 percent in 1987 (Table 3).

Populations of 0+ steelhead trout have been highly variable during the 6 years of the evaluation, averaging about 87,200 fish (+ ~ 30 percent) annually (Table 3). The reasons for the high variability are complex and related to seeding rates (Fig. 7) and environmental variables, and perhaps intra-stock competition. Numbers

Table 3. Estimated numbers of juvenile anadromous salmonids in Fish Creek, September, 1982-1987, and percent of total population.

	0+ Steelhead		1+ Steelhead		Coho Salmon		Chinook Salmon		
Year	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Total
1982	87,810	78.7	21,680	19.4	1,910	1.7	120	0.1	111,520
1983	60,030	66.5	21,670	24.0	7,430	8.2	1,140	1.3	90,270
1984	88,060	73.1	23,800	19.8	8,290	6.7	290	0.2	120,440
1985	115,770	76.9	18,500	12.3	11,980	7.9	4,350	2.9	150,620
1986	117,870	82.8	20,670	14.1	3,560	2.5	200	0.1	142,300
1987	53,400	47.0	15,970	14.1	37.880	33.4	6,290	5.5	113,540
Mean	87,157	70.8	20,382	17.3	11,842	10.1	2,065	1.7	102.525

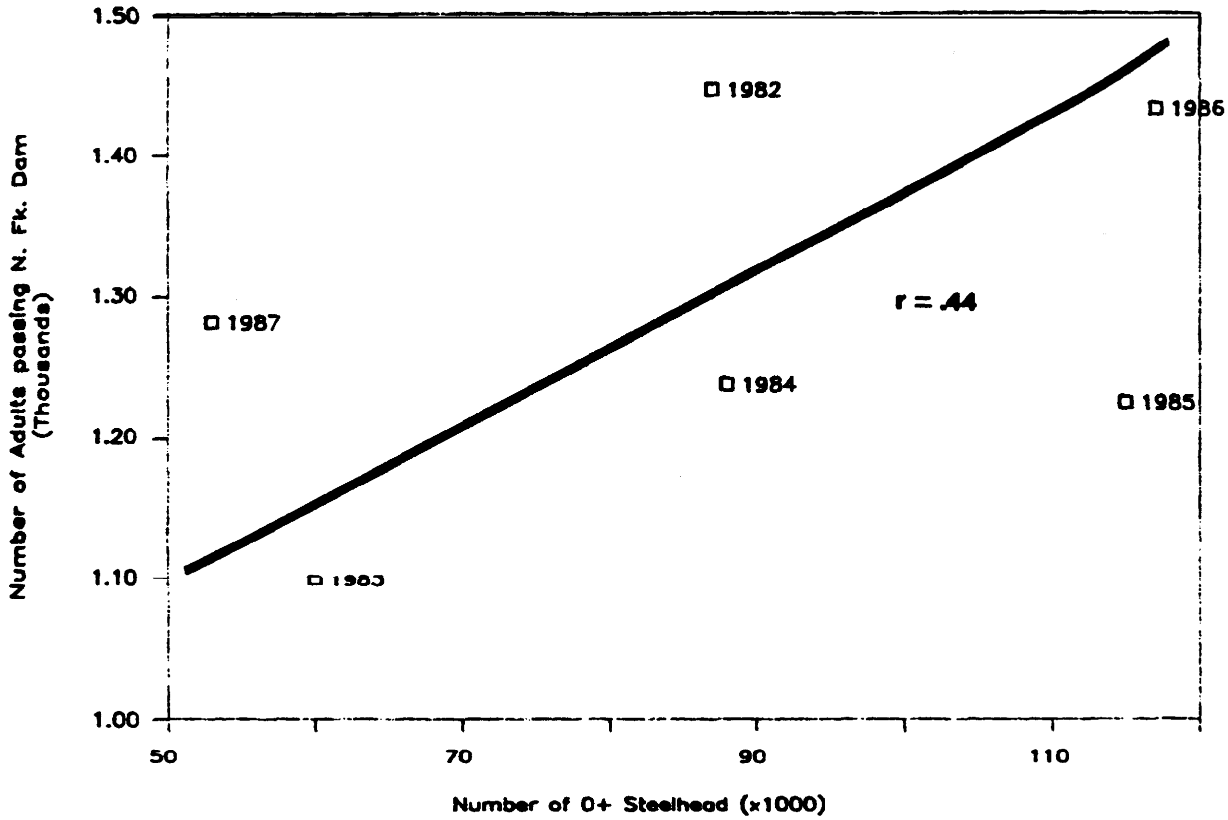


Figure 7. Parent-progeny relationship for winter steelhead trout in Fish Creek, 1982-1987.

of steelhead trout fry show a weak direct correlation ($r = 0.44$) with the number of adult winter steelhead trout passing North Fork Dam the previous winter and spring. Environmental variables such as high spring flows and extreme low summer flows might also cause 0+ steelhead populations to vary from year to year. Another possible confounding factor is the recent increase in stocked summer steelhead in the upper Clackamas River. An aggressive Oregon Department of Fish and Wildlife hatchery program has developed a large run of Skamania stock summer steelhead in the upper Clackamas River. Adult summer steelhead are frequently seen in Fish Creek in summer and are presumed to spawn there. Inter-stock competition by fry for early rearing habitat could reduce survival of post-emergent native winter steelhead fry. Also, since introduced summer stocks are probably less well-adapted to Fish Creek, they might suffer higher early-rearing mortality rates than native stocks. The net result could be reduced survival for both summer and winter stocks.

Underyearling steelhead trout make significant use of all habitat types in the system, except for beaver ponds (Table 4). From 1982 to 1985, and in 1987, densities (fish/m^2) of 0+ steelhead trout were generally highest in quiet shallow habitats such as glides, alcoves, and side channels, but substantial use of quiet riffle and pool margins also occurred. In 1986, however, densities were greatest in riffles. This may have been attributable to changes in habitat availability (loss of side channel habitat) and quality following the high flow event of February 1986. Also, the highest absolute numbers

Table 4. Density of 0+ steelhead trout (fish/m^2) by habitat type, Fish Creek, 1982-1987.

Year	Habitat Types: Pools	Riffles	Glides	Side channels	Alcoves	Beaver 1/ ponds	Mean
1982	0.28	0.54	--	1.20	0.97	0.00	0.55
1983	0.18	0.25	--	0.28	0.25	0.03	0.24
1984	0.20	0.50	--	0.45	0.36	0.00	0.47
1985	0.76	0.78	0.96	0.88	--	0.53	0.80
1986	0.51	0.83	0.35	0.00 2/	--	-- 3/	0.70
1987	0.58	0.26	0.64	-- 4/	--	0.03	0.40
Mean	0.42	0.53	0.65	0.56	0.53	0.12	0.53

1/ Does not include enhanced off-channel ponds.
2/ All side channels were dry in September 1986.
3/ Not sampled in 1986.
4/ Side channels were nearly dry in 1987 and were not sampled for fish.

of 0+ steelhead observed during the study occurred in 1986, possibly forcing underyearlingsinto riffle environments. Densities of 0+ fish were low in beaver pond habitat except in 1985 when steelhead trout spawned in the tributary to the beaver pond at km 3 and emerging fry moved downstream into the pond.

The absolute numbers of 0+ steelhead trout in the system during the summers of 1982-87 were highest in riffles. A major decrease in 0+ numbers in riffles occurred in 1987 when riffle areas were greatly reduced because of drought. Pools, glides, and side-channels are also important habitats for 0+ steelhead (Table 5). Availability and

Table 5. Estimated numbers of 0+ steelhead trout by habitat type, Fish Creek, 1982-1987.

	Habitat Types						
Year	Pools	Riffles	Glides	Side channels	Alcoves	Beaver[1/] ponds	Total
1982	5,170	75,240	--	5,100	2,200	0	87,810
1983	3,780	53,870	--	1,760	610	10	60,030
1984	3,850	81,010	--	2,370	830	0	88,060
1985	20,180	72,960	20,270	2,260	--	100	115,770
1986	13,970	94,410	9,490	0	--	--[2/]	117,870
1987	17,150	21,010	15,230	--[3/]	--	10	53,400
Mean	16,083	66,417	14,997	2,300	1,210	24	87,157

1/ Does not include habitat created by enhancement projects.
2/ Not sampled in 1986.
3/ Side channels nearly dry in 1987 and were not sampled for fish.

quality of quiet stream margins in late spring and early summer appears to be a key habitat need for post-emergent steelhead fry.

Age 1+ pre-smolt steelhead trout populations in late summer were remarkably consistent during the 1982 to 1986 period, averaging about 22,300 fish (+ ~ 10 percent, Table 3). The lowest numbers of age 1+ steelhead (16,000) observed since the study began occurred in the summer of 1987. The abundance of 1+ steelhead trout shows a positive correlation (r = 0.63) with summer streamflow, indicating that as wetted habitat area increases in summer, carrying capacity for age 1+ fish also tends to rise. This relationship helps explain the low numbers of age 1+ steelhead in Fish Creek in 1987, but several other factors could also be responsible. Age 1+ steelhead were highly vulnerable to angling during the low flow period in 1987, over-winter survival might have been reduced by the large freshet of February 1986, and some age 1+ fish might have moved out of lower Fish Creek in the summer of 1987 in response to high turbidity caused by habitat improvement activities upstream.

Age 1+ steelhead trout show a preference for deep, rocky pools but also use deep boulder-rubble riffles, glides, side channels, and beaver ponds in descending order (Table 6). Preferred pool habitats for this age-group in summer, as determined by density of fish per m^2 of habitat, are in short supply, making up only 10-19 percent of total habitat. Populations of l+ steelhead trout are highest in riffles since riffles make-up 80 to 90 percent of the habitat in Fish Creek in most years (Table 7). Pools contain the second highest numbers of 1+ fish in summer followed by glides, side channels, and beaver ponds.

The numbers of juvenile coho salmon in the Fish Creek basin have generally increased since 1982, and reached an all-time high in 1987 (Table 3). Populations in 1987 were IO.6 times higher than in 1986. The increase in juvenile coho salmon during the period 1982-1985 was not related to increased seeding since the numbers of adult coho salmon passing North Fork Dam (Table 8) and entering the upper Clackamas basin declined from 1982-83 to 1984-85. It is possible that the numbers of adult coho salmon spawning in Fish Creek increased during that period, even though the total numbers passing North Fork

Table 6. Density of l+ steelhead trout (fish/m^2) by habitat type, Fish Creek, 1982-1987.

Year	Pools	Riffles	Glides	Side channels	Alcoves	Beaver ponds	Mean
	Habitat Types						
1982	0.21	0.12	--	0.11	0.05	0.00	0.14
1983	0.13	0.11	--	0.05	0.04	0.00	0.09
1984	0.25	0.12	--	0.08	0.05	0.09	0.13
1985	0.14	0.14	0.09	0.09	--	0.00	0.13
1986	0.24	0.09	0.12	0.00 1/	--	-- 2/	0.12
1987	0.20	0.07	0.13	3/	--	0.00	0.12
Mean	0.20	0.11	0.11	0.07	0.05	0.02	0.12

1/ All side channels were dry in September 1986.
2/ Not sampled in 1986.
3/ Side channels nearly dry in 1987 and were not sampled for fish

Table 7. Estimated numbers of l+ steelhead trout by habitat type, Fish Creek, 1982-1987.

Year	Pools	Riffles	Glides	Side channels	Alcoves	Beaver ponds	Total
	Habitat Types						
1982	3,840	17,260	--	460	120	0	21,680
1983	2,800	23,760	--	340	90	0	26,900
1984	4,820	18,420	--	440	110	10	23,800
1985	3,610	12,880	1,800	230	--	0	18,520
1986	6,620	10,820	3,230	0 1/	--	-- 2/	20,670
1987	5,850	6,760	3,360	2 3	--	0	15,970
Mean	4.590	14,983	2,797	290	110	2.0	21.257

1/ All side channels were dry in September 1986.
2/ Not sampled in 1986.
3/ Side channels nearly dry in 1987 and were not sampled for fish.

Table 8. Counts of adult anadromous salmonids at North Fork Dam, 1981-82 to 1986-87.

	Steelhead trout			Coho salmon		Spring chinook salmon	
Year	Summer	Winter	Total	Total	Jacks	Total	Jacks
1981-82	4,138	1,446	5.584	1,282	(112)	3,119	(209)
1982-83	1,948	1,099	3,047	2,949	(405)	2,685	(102)
1983-84	11,062	1,238	12,300	1,599	(78)	2.835	(87)
1984-85	5.549	1,225	6,674	694	(83)	1.693	(140)
1985-86	7.422	1.432	8,854	3,315	(592)	1,960	(163)
1986-87	4.367	1,282	5,639	4.376	(214)	1,214	(291)
Mean	5,748	1,287	7,019	2,369	(247)	2,251	(165)

Dam declined. However, this was not substantiated by counts of adult fish or redds in Fish Creek because weather and water conditions precluded accurate counts during the spawning period. The decline in 1986 probably was due to loss of redds from scour and siltation during the February 1986 high flow event. The remarkable increase in numbers of juvenile coho salmon in 1987 is apparently related both to increased numbers of adults returning to the basin, and to habitat improvement in the lower and middle basin since 1983. The run of adult coho salmon over North Fork Dam in 1986-87 was about 25 percent (1,000 fish) higher than in 1985-86 and some of the additional fish undoubtedly spawned in Fish Creek. Also, the first group of adult coho returning from smolts produced in the off-channel pond at km 3, spawned during the 1986-87 season and contributed to the high numbers of 0+ fish seen in the summer of 1987. Habitat work completed in the summer of 1986 also increased rearing capacity for 0+ juveniles and contributed to the high numbers of coho in the basin in 1987.

Beaver ponds are the preferred habitat of juvenile coho salmon in the Fish Creek basin in summer, as measured by density of fish per m^2 (Table 9). Glides, side channels, and pools are also important habitats, but received only a fraction of the use per m^2 that was observed for beaver ponds. Coho salmon prefer moderately deep quiet habitats on the stream margins or out of the main channel.

The greatest absolute numbers of coho salmon in the system in summer occurred in riffle habitats (approximately 80 percent of total habitat) from 1982 through 1984 (Table 10). even though the densities

Table 9. Density of 0+ coho salmon (fish/m^2) by habitat type, Fish Creek, 1982-1987.

	Habitat Types						
Year	Pools	Riffles	Glides	Side channels	Alcoves	Natural Beaver ponds	Mean
1982	0.04	0.01	--	0.11	0.13	1.37	0.02
1983	0.16	0.05	--	0.06	0.19	0.80	0.06
1984	0.22	0.04	--	0.96	0.28	2.19	0.09
1985	0.13	0.07	0.43	0.26	--	1.37	0.14
1986	0.18	0.00 1/	0.16	0 2/	--	-- 3/	0.04
1987	1.10	0.10	0.42	-- 4/	--	2.40	0.38
Mean	0.31	0.05	0.34	0.35	0.20	1.63	0.12

1/ Actual density 0.0006 fish/m^2
2/ All side channels were dry in September 1986.
3/ Not sampled in 1986.
4/ Side channels nearly dry in 1987 and were not sampled for fish.

in this environment were low. In 1986, the estimated number in riffles declined dramatically. This probably was due to the over-all reduction in numbers of coho salmon. Riffles are the least preferred habitat of coho salmon and would be the last to be utilized. Quieter, less turbulent glides were found to be the component of habitat that contained the majority of 0+ coho salmon. Pools and glides held the largest numbers of coho in 1987.

The system appeared to be nearing carrying capacity for coho salmon in 1987. The summer population was estimated at about 38,000 fish, three times higher than previously observed during the study. While numbers of coho had increased dramatically, there was a corresponding decrease in the mean size of fish. Juvenile coho

Table 10. Estimated numbers of 0+ coho salmon by habitat type, Fish Creek, 1982-1987.

	Habitat Types						
Year	Pools	Riffles	Glides	Side channels	Alcoves	Beaver[1/] ponds	Total
1982	290	1,040	--	180	140	260	1,910
1983	1,500	5,340	--	130	220	240	7,430
1984	1,840	3,310	--	1,920	630	590	8,290
1985	1,550	3,850	5,720	600	--	260	11,980
1986	1,350	41	2,170	0[2/]	--	--[3/]	3,560
1987	22,750	6,160	8,520	--[4/]	--	450	37,880
Mean	4,880	3,290	5,470	570	330	360	11,842

1/ Does not include enhanced off-channel habitat.
2/ All side channels were dry in September 1986.
3/ Not sampled in 1986.
4/ Side channels were nearly dry in 1987 and were not sampled for fish.

averaged 4.6 g/fish in the summer of 1986, but only 3.4 g/fish in 1987, indicating increased competition for food and space.

Age 0+ chinook salmon are less abundant in the Fish Creek system than other species of anadromous salmonids because most fry emigrate to the Clackamas River soon after emergence. Those fish that do remain in Fish Creek apparently prefer pools and glides for summer rearing (Table 11). The absolute numbers of 0+ chinook have been generally highest in pools, although in 1985 near equal numbers occurred in pools, riffles, and glides (Table 12).

Estimated numbers of juvenile chinook salmon in the basin in 1987 were the highest since the study began, due to a range expansion and good spawning conditions in the basin in 1986, and increased complexity in rearing areas from habitat improvement in the summer of 1986. Numbers in the basin the previous summer (1986) were low, probably due to low redd survival from the high flow event in February 1986. The number of adult chinook salmon spawning in Fish Creek appears to be related largely to the timing of fall freshets (Everest et al. 1985). Late arrival of fall rains and runoff can impede entry of spawners, although channel improvement at the mouth in 1986 has alleviated this problem to some degree. Early rains and runoff provide easy access for adult chinook salmon. Our data show no apparent relationship, however, between the number of spawners using the system in the fall and the number of juveniles rearing in Fish Creek the following summer.

* * *

Table 11. Density of 0+ chinook salmon (fish/m^2) by habitat type, Fish Creek, 1982-1987.

Year	Pools	Riffles	Glides	Side channels	Alcoves	Beaver ponds	Mean
	Habitat Types						
1982	0.01	0.00	--	0.00	0.01	0.00	0.001
1983	0.07	0.01	--	0.00	0.01	0.00	0.010
1984	0.03	0.00	--	0.00	0.00	0.04	0.003
1985	0.10	0.03	0.11	0.00	--	0.00	0.050
1986	0.01	0.00	0.01	0.00 1/	--	-- 2/	0.002
1987	0.16	0.03	0.07	-- 3/	--	0.00	0.06
Mean	0.06	0.01	0.06	0.00	0.01	0.01	0.021

1/ All side channels were dry in September 1986.
2/ Not sampled in 1986.
3/ Side channels were nearly dry in 1987 and were not sampled for fish.

Table 12. Populations of 0+ chinook salmon by habitat type, Fish Creek, 1982-1987.

Year	Pools	Riffles	Glides	Side channels	Alcoves	Beaver ponds	Total
	Habitat Types						
1982	110	0	--	0	10	0	120
1983	640	490	--	0	10	0	1,140
1984	280	0	--	0	0	10	290
1985	1,240	1,620	1,490	0	--	0	4,350
1986	100	0	100	0 1/	--	-- 2/	200
1987	3,200	1,640	1,450	3	--	0	6,290
Mean	928	625	1,013	0	10	2	2,065

1/ All side channels were dry in September 1986.
2/ Not sampled in 1986.
3/ Side channels nearly dry in 1987 and were not sampled for fish.

Coho Salmon Smolt Production, Fish Creek

The coho salmon smolt migration from Fish Creek was monitored closely from 1985 through 1987 with a floating smolt trap located at km 0.3. The trap was operated from April 15 until August 25, in 1985 when streamflow became too low for effective operation. Coho salmon smolts were captured at the trap between April 18 and June 19, with the peak outmigration occurring on May 19 (Fig. 8). A total of 1,095 coho salmon smolts were captured. The total 1985 smolt migration was estimated at 3,099 fish (Table 13).

In 1986, the smolt trap was installed on March 14 and fished until July 18. Coho smolts were first captured on March 15, about one month earlier than the previous year, indicating that some early migrants

Table 13. Coho salmon smolts captured in a floating trap at km 0.3 on Fish Creek, and estimates of trap efficiency and total smolt migration by two-week intervals, April 15-June 23, 1985.

Dates	Smolts captured	Marked smolts released[1]	Marked smolts recaptured	Trap efficiency percent	Estimate[1] total smolts
04/15-04/28	76	83	38	46	165
04/29-05/12	217	115	55	48	452
05/13-05/26	631	497	235	47	1,342
05/27-06/09	171	281	43	15	1,140
06/10-06/23	0	2	0	--	--
Totals	1.095	978	371	--	3.099

[1] Includes smolts from off-channel pond at km 3.0

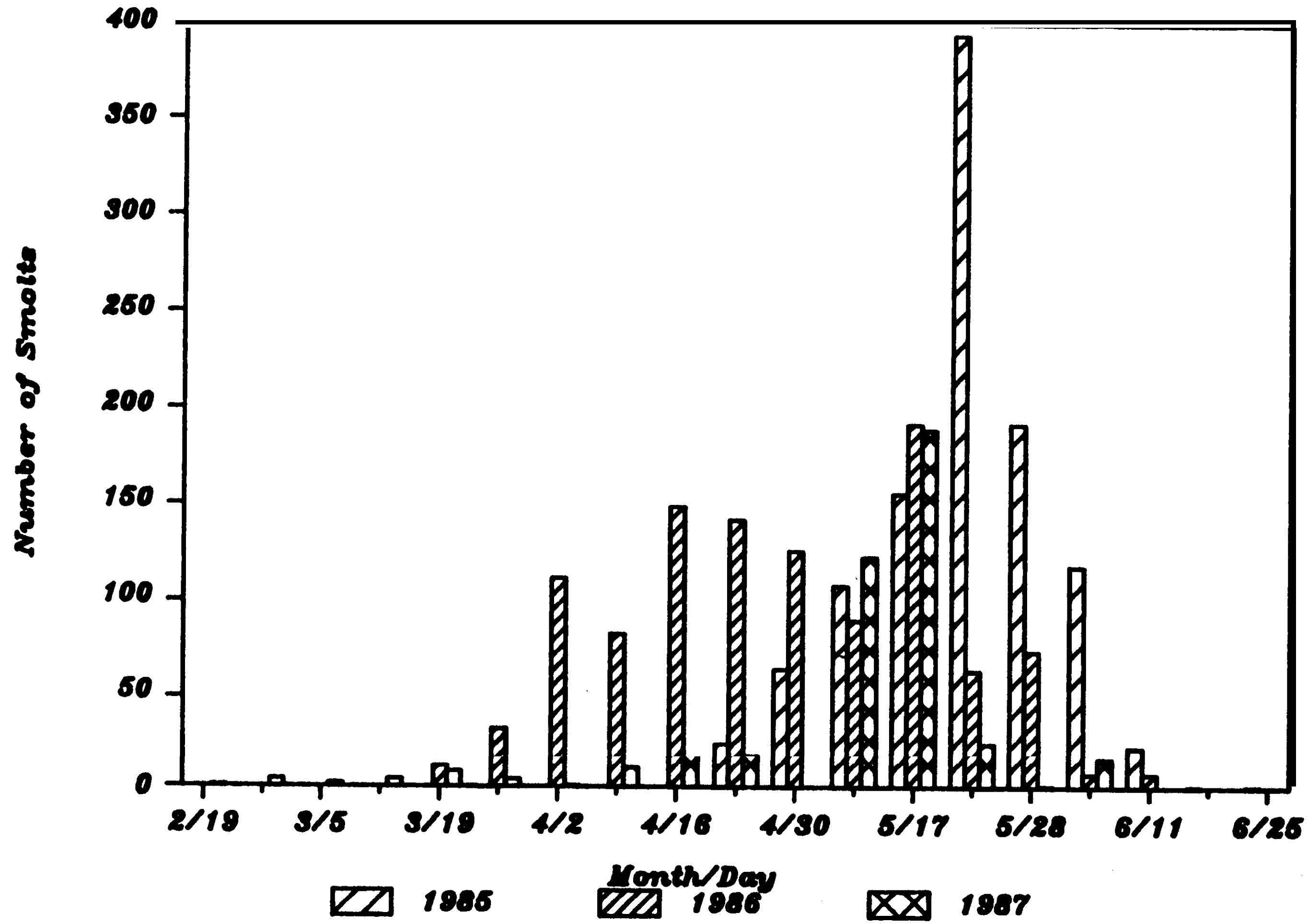


Figure 8. Timing of the coho salmon smolt migration from Fish Creek at the floating trap at km 0.3, 1985, 1986, and 1987.

might have left the system before trapping began in 1985 l
Consequently, the 1985 data should be considered a minimum estimate of coho salmon smolt production for that year.

The 1986 migration apparently began earlier and peaked earlier than was observed in 1985 (Fig. 8). Total numbers of coho salmon smolts leaving the system in 1986 (2,371 fish), however, were 23 percent lower than in 1985 (Table 14).

1987 was a difficult year for smolt trapping because of low stream flow during much of the trapping season. An attempt was made to operate the trap continuously from February 13 through June 9, but mechanical breakdowns, low flows, and vandalism resulted in periodic

Table 14. Coho salmon smolts captured in a floating trap at km 0.3 on Fish Creek, and estimates of trap efficiency and total smolt numbers by weekly intervals, March 14 - July 18, 1986.

Dates	Smolts captured	Marked smolts released	Marked smolts recaptured	Trap efficiency percent	Estimated total smolts
03/14-03/26	47	46	13	28	168
03/27-04/02	112	115	59	51	220
04/03-04/09	83	127	73	57	146
04/10-04/16	149	131	61	47	317
04/17-04/23	142	220	137	62	229
o4/24-04/30	126	195	98	50	252
05/01-05/07	90	115	54	47	191
05/08-05/14	192	236	133	56	343
05/15-05/21	64	185	79	43	149
05/22-05/28	74	161	50	31	239
05/29-06/18	14	81	10	12	117
Totals	1,093	1,612	767	--	2,371

loss of data (Table 15). Estimated total smolt production (2,600) was similar to previous years (Table 15). Trapping efficiency (15 percent) was reduced in 1987 primarily because of low stream flow. As in previous years, the peak migration in 1987 occurred in the early to mid-May period.

Coho smolts from Fish Creek in 1985 averaged about 114 mm fork length and ranged from 96 mm to 140 mm. The mean size of smolts varied somewhat on a daily basis, but showed no distinct seasonal trends (Fig. 9). Coho smolts were smaller in 1986, averaging only 107 mm, and ranging from 82 mm to 134 mm, and again showed no distinct seasonal trends (Fig. 10). The flood event of February 1986 (Everest

Table 15. Coho salmon smolts captured in a floating trap at km 0.3 on Fish Creek, and estimates of trap efficiency and total smolt numbers by two-week intervals, February - June 1987.

Dates	Smolts captured	Marked smolts released	Marked smolts recaptured	Trap efficiency percent	Estimated total smolts
02/15-02/28	5	0	0	11[1/]	45
03/01-03/14	8	0	0	11[1/]	73
03/15-03/28	10	0	0	11[1/]	91
03/29-04/11	14	9	0	11[1/]	127
04/12-04/25	28	113	7	6	467
04/26-05/09	42	604	92	15	280
05/10-05/23	161	481	53	11	1,252
05/24-06/06	7	65	9	14	50
06/07-06/20	0	0	0	0	0
Totals	275	1,272	161	--	2.597

[1/] Estimated efficiency

et al. 1986). combined with a relatively cold winter, might account for some of the variation in size between years. Smolts averaged 111 mm in 1987 (range 82 to 171 mm) (Fig. 11).

Coho salmon smolts were not only smaller in 1986, but also much lighter in weight than the 1985 cohort. In 1985, smolts averaged about 20 g while the 1986 migrants averaged about 14 g. Smolt weights ranged from 7 to 33 g in 1985 with a near normal distribution (Fig. 12); in 1986 smolts ranged from 7 to 31 g with the distribution skewed heavily toward the lighter weights (Fig. 13). In 1987 smolts averaged 14 g in weight and the weight distribution was more normally distributed (Fig. 14) as in 1985 (Fig. 12).

The behavior of downstream migrant coho salmon smolts in Fish Creek was similar to that reported by other workers. Nearly all downstream movement occurred at night, apparently without regard to moon phase. Judging from the position of the trap and depth of the traveling screen, most fish moved downstream in the upper half of the water column near the thalweg.

Fish Creek is a low producer of coho salmon smolts when compared to other west coast streams. Marshall and Britton (1980) have summarized data on coho smolt production from 21 western rivers and streams of various sizes. Smolt outputs ranged from about 360 fish/km for the smallest streams to 3,000 fish/km in large streams. Streams the size of lower Fish Creek typically produce from 1,500 to 3,000 smolts/km. Fish Creek currently produces from 200 to 500 smolts/km and ranks far lower as a coho producer than other comparably sized

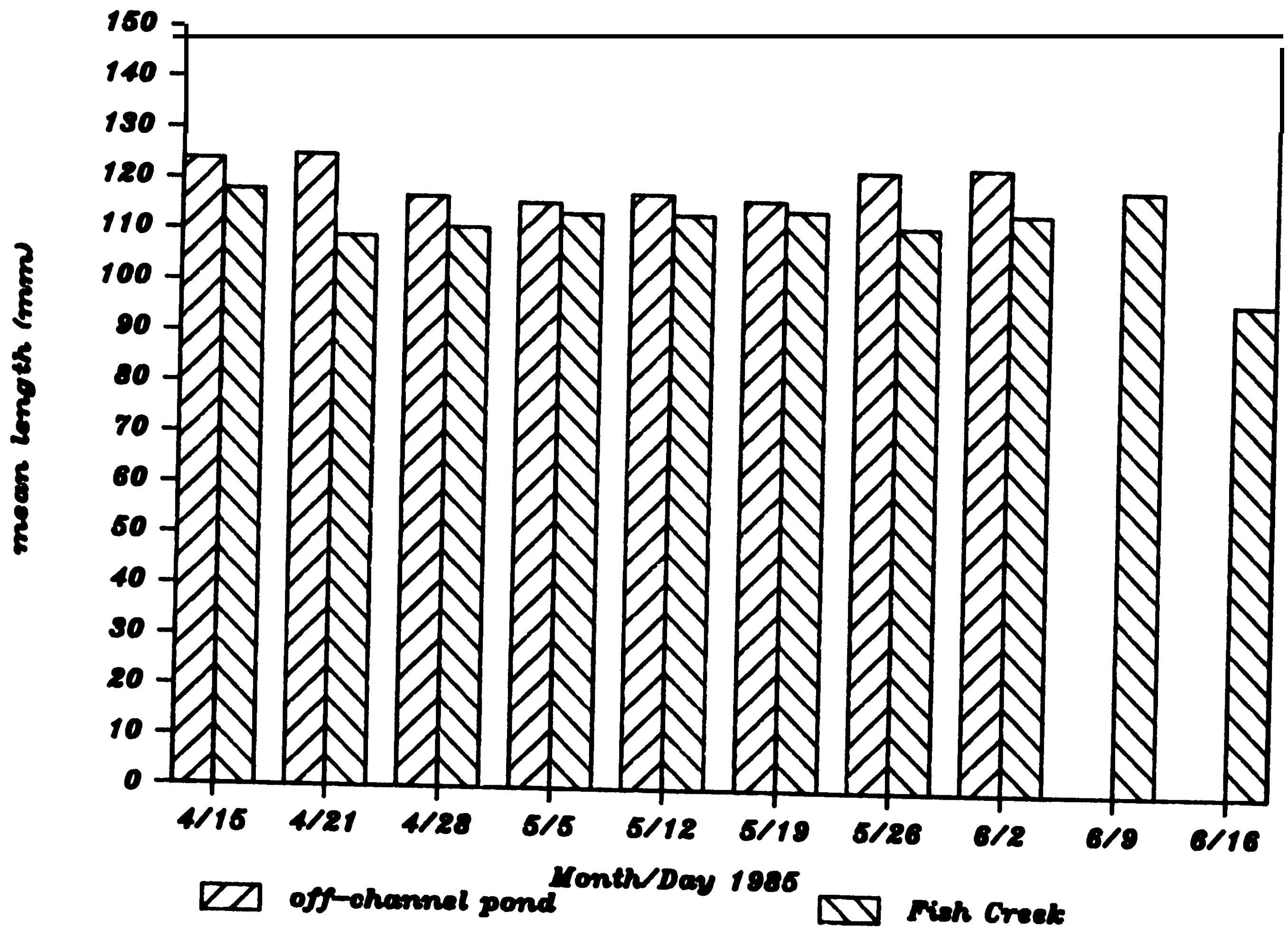


Figure 9. Mean length of coho salmon smolts emigrating from Fish Creek and off-channel pond at km 3, April 15 through June 23, 1985.

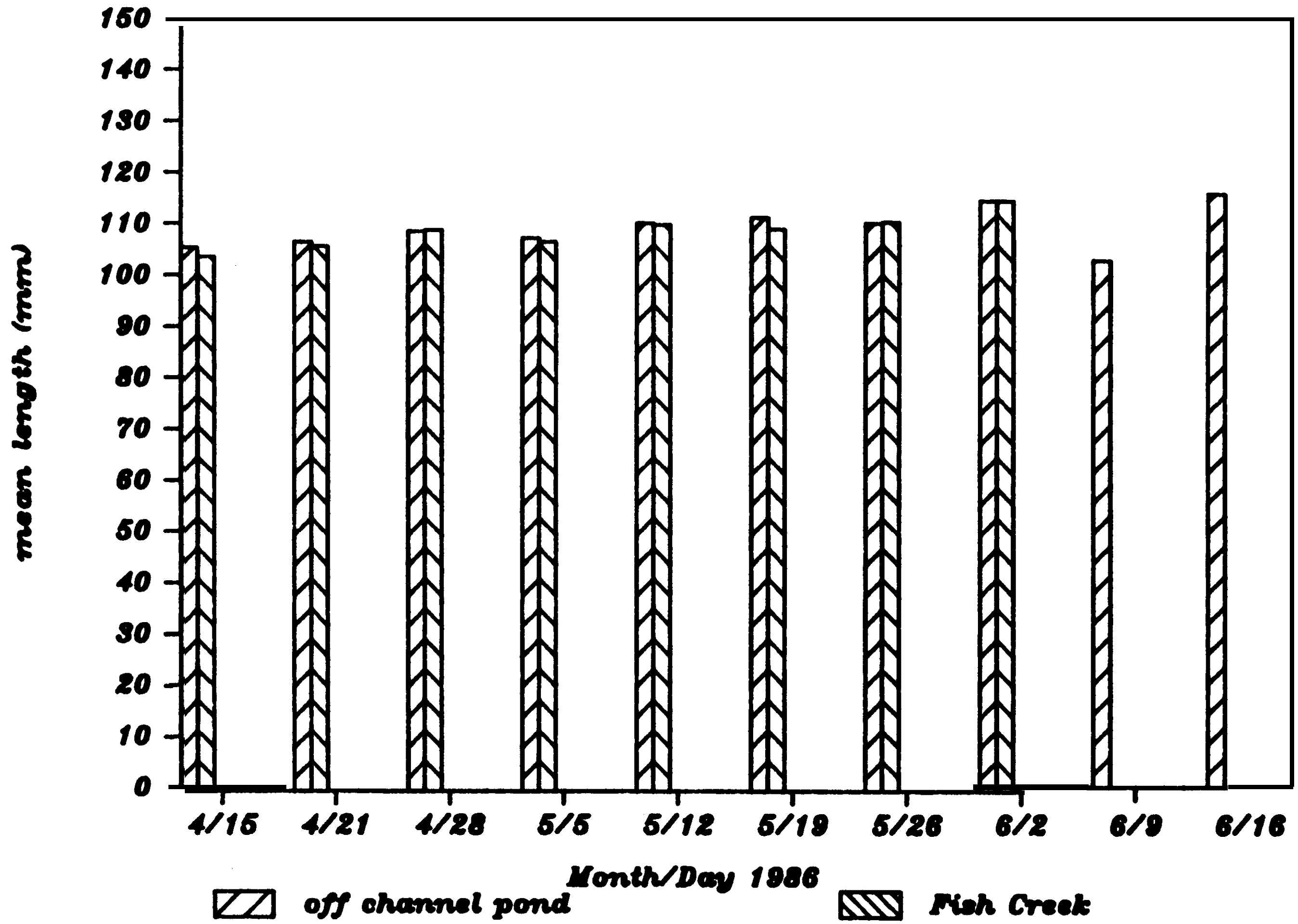


Figure 10. Mean length of coho salmon smolts emigrating from Fish Creek and off-channel pond at km 3, April 15 through June 23, 1986.

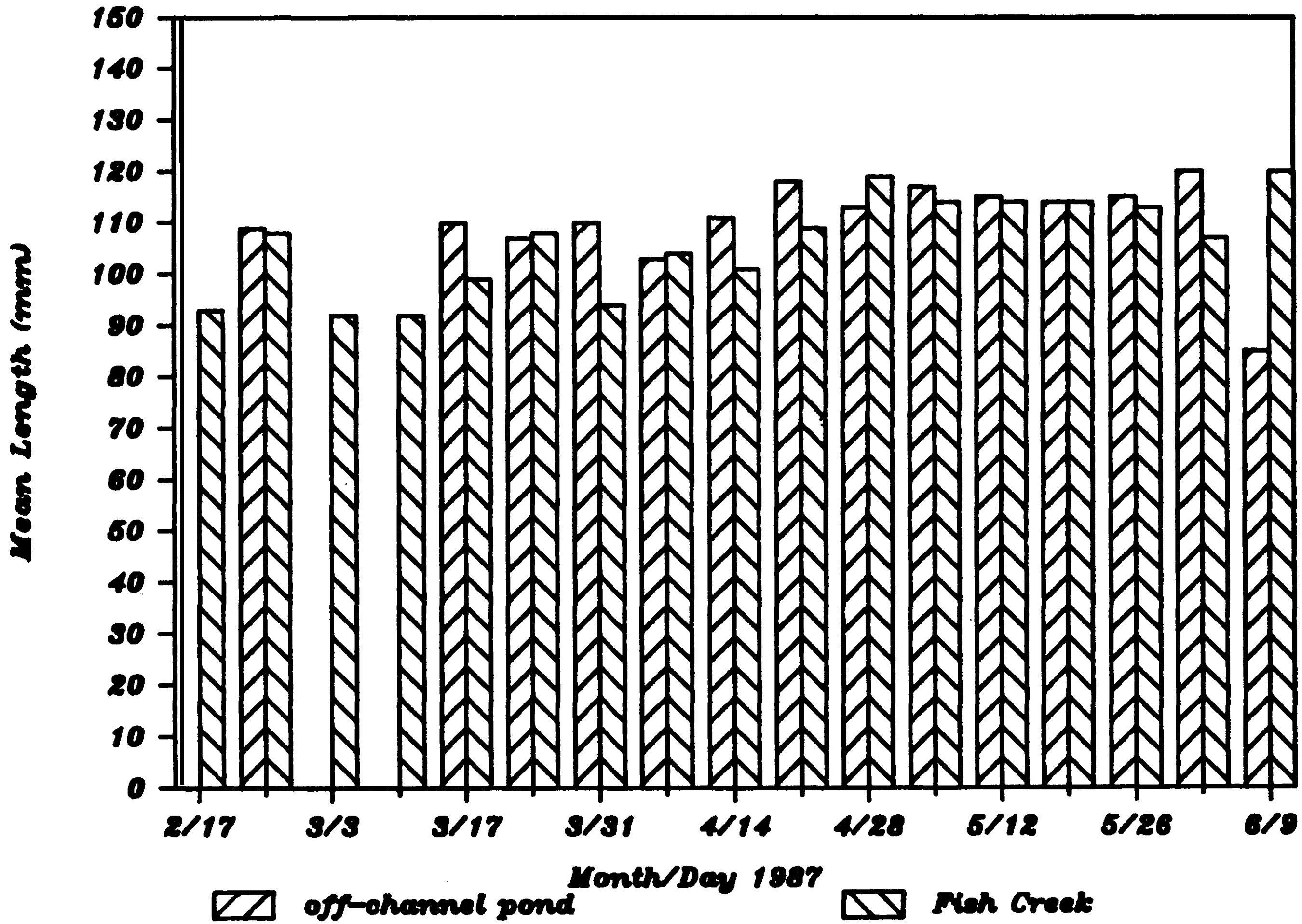


Figure 11. Mean length of coho salmon smolts emigrating from Fish Creek and off-channel pond at km 3, February 17 through June 9, 1987.

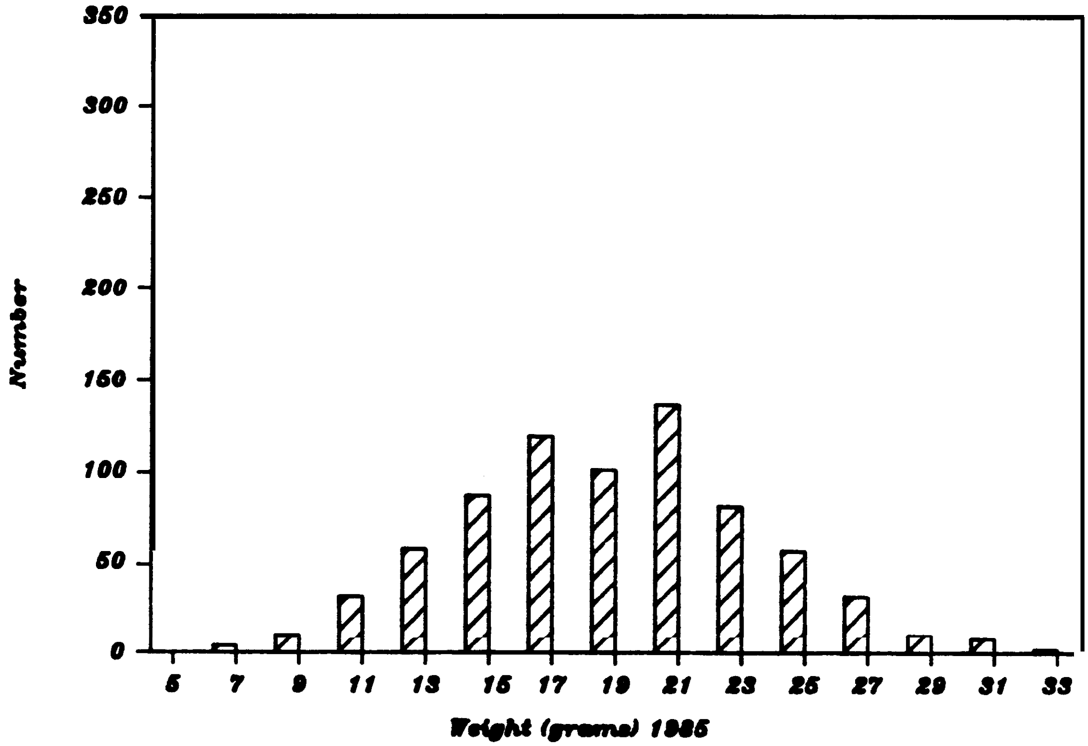


Figure 12. Weight distribution of coho salmon smolts from Fish Creek in 1985.

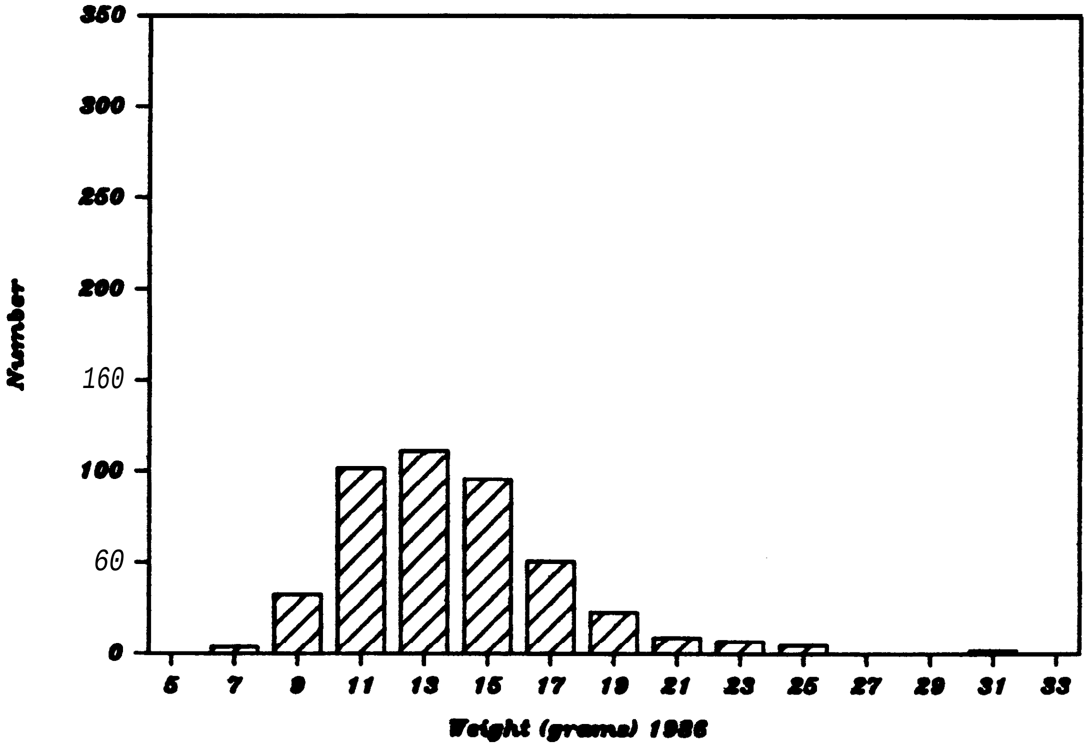


Figure 13. Weight distribution of coho salmon smolts from Fish Creek in 1986.

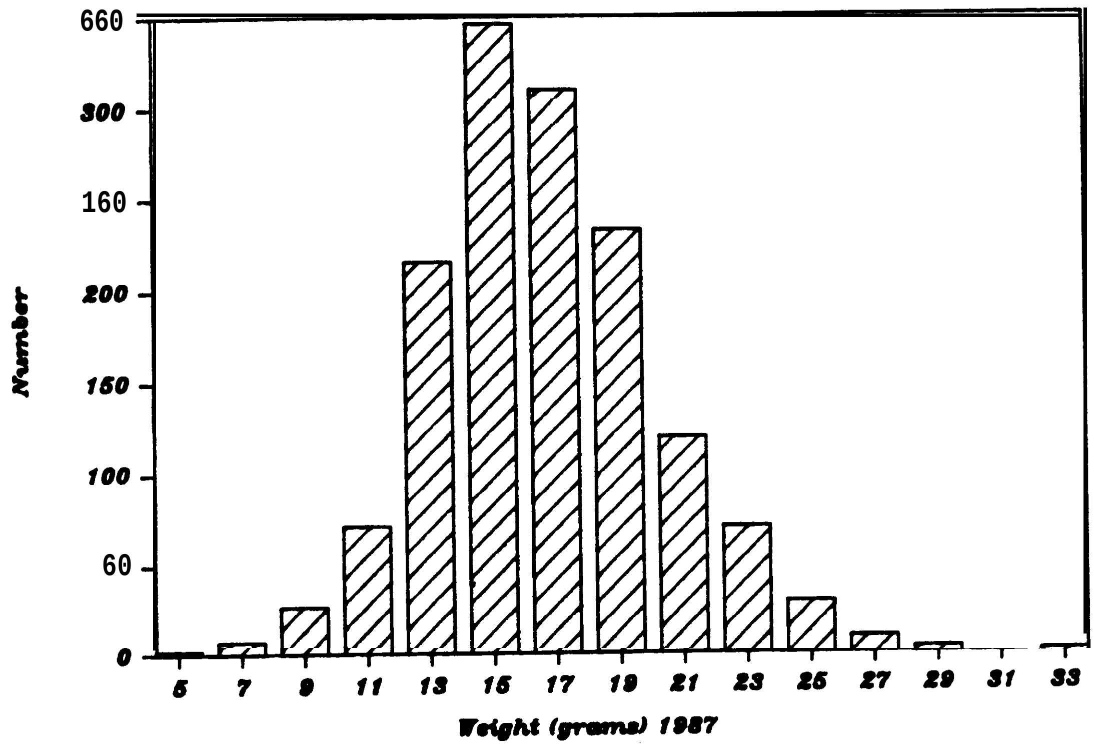


Figure 14. Weight distribution of coho salmon smolts from Fish Creek in 1987.

streams. The reason for this is the high gradient, incised channel that provides little of the margin and off-channel habitat preferred by coho in summer and winter. The 1964 flood, road encroachment, timber harvest in the basin, and intensive debris removal from the channel over the past 20 years have reduced coho habitat in the basin. However, much of the habitat work completed in Fish Creek in 1986 and 1987 will increase the complexity of stream edge habitats and directly benefit coho salmon.

Coho Salmon Smolt Production, Off-Channel Pond

Smolt production from the eastside off-channel pond, constructed on a flood terrace adjacent to Fish Creek at km 3.0 in 1983, was evaluated each spring from 1985 through 1987. A total of 1,326 coho salmon fry were electrofished from the margins of Fish Creek between March 30 and July 5, 1984 and placed in the pond. The fry exhibited rapid growth and ten 0+ smolts averaging 86 mm fork length left the pond between July 20 and August 16, 1984. The presence of 0+ smolts in natural coho salmon populations is rare. An unknown number of additional coho salmon fry entered the pond in the spring of 1984 from natural reproduction in the north inlet of the pond.

A total of 493 smolts from the introduced and naturally produced fry left the pond between April 15 and June 8, 1985. The timing of the coho salmon smolt migration occurred during the same time interval as that observed on Fish Creek (Fig. 15). but peak migration from the pond occurred the first week in June. Smolts from the pond were significantly larger than smolts from Fish Creek. Mean length of smolts leaving the pond was 125 mm, while Fish Creek smolts averaged 114 mm. Pond smolts also were much heavier than smolts reared in Fish Creek (Fig. 16). The primarily nocturnal migration of smolts leaving the pond was also similar to the behavior of coho leaving Fish Creek.

Fry were not introduced to the pond in 1985, but in January 1985 seven adult female coho salmon and five males were trapped at North Fork Dam and transported to the pond. The fish spawned naturally in the inlets and an unknown number of emergent fry migrated downstream

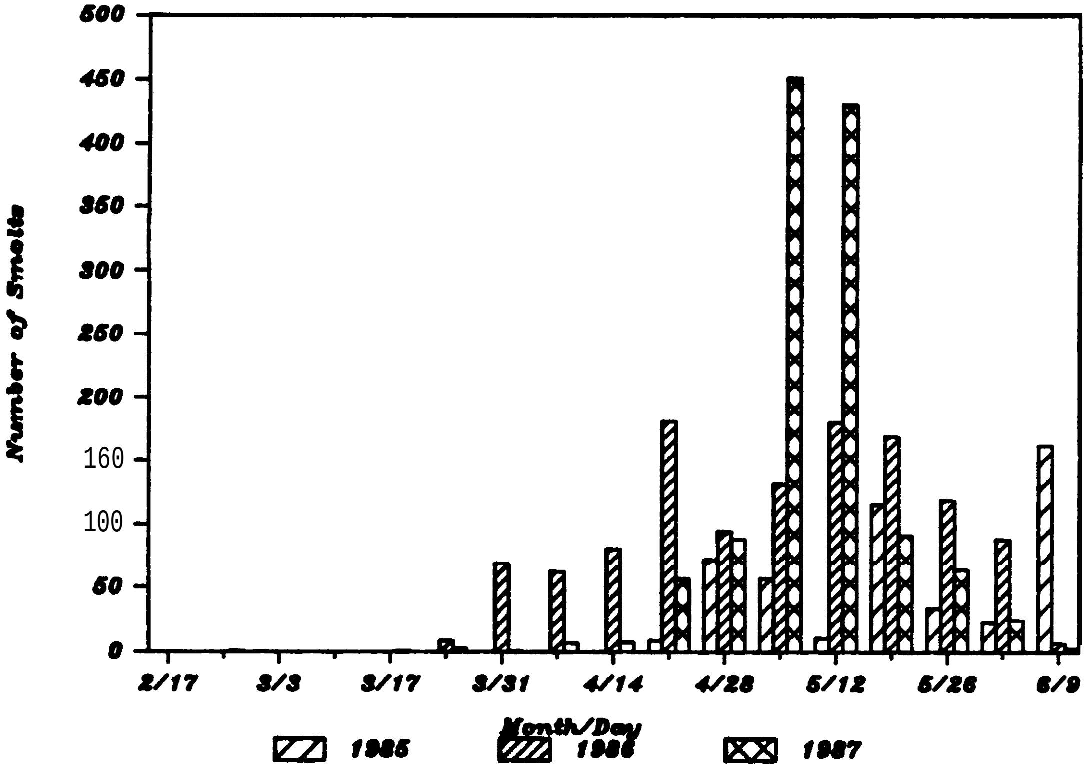


Figure 15. Timing of the coho salmon smolt migration from the off-channel pond at km 3, 1985, 1986 and 1987.

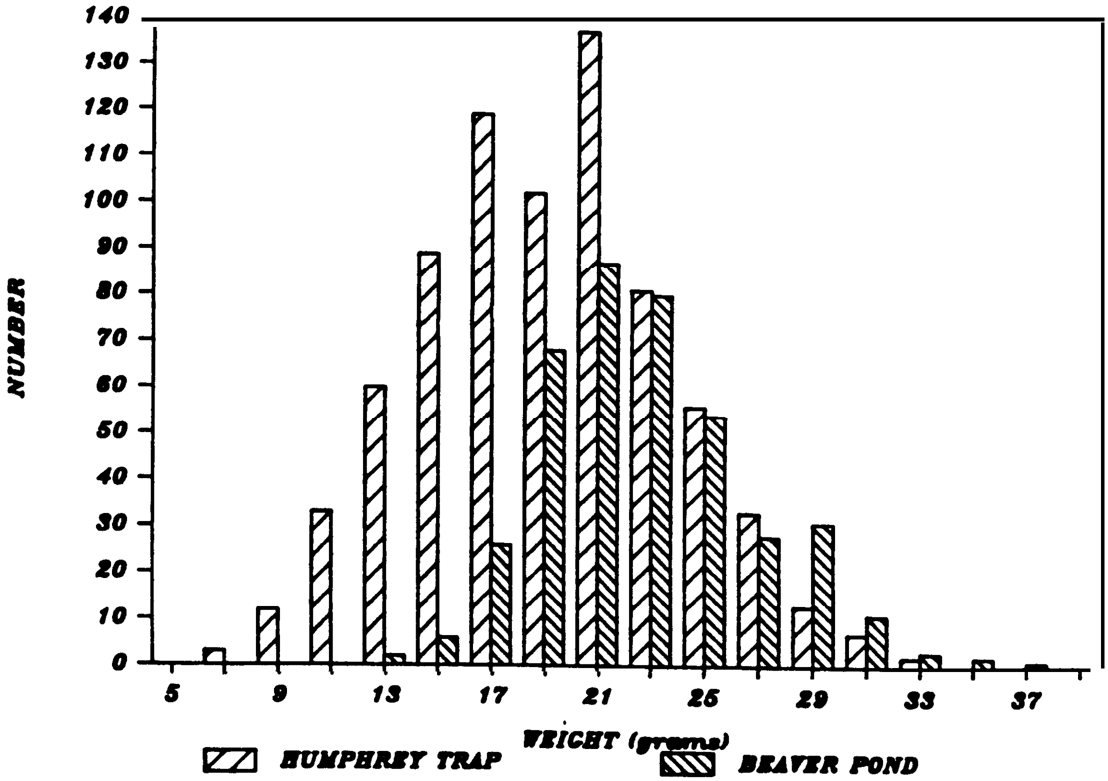


Figure 16. Comparison of coho salmon smolt weight distributions from the Fish Creek Humphrey trap and the off-channel (beaver) pond at km 3, 1985.

into the pond in the spring of 1985. The 1986 smolt migration resulting from the natural reproduction was impressive. Between March 14 and July 18, 1986, 1,196 coho salmon smolts left the pond (Fig. 15), approximately triple the number of 1985 emigrants. The migrants leaving the pond in 1986 were smaller in length (mean 108.5 mm) and weight (Fig. 17, 18) than in 1985. The mean length (pond 108.5 mm; Fish Creek 105.0 mm) and weight (Fig. 19) of smolts leaving the pond in 1986 was more similar to those leaving Fish Creek than in 1985. Increased numbers of young coho in the pond in

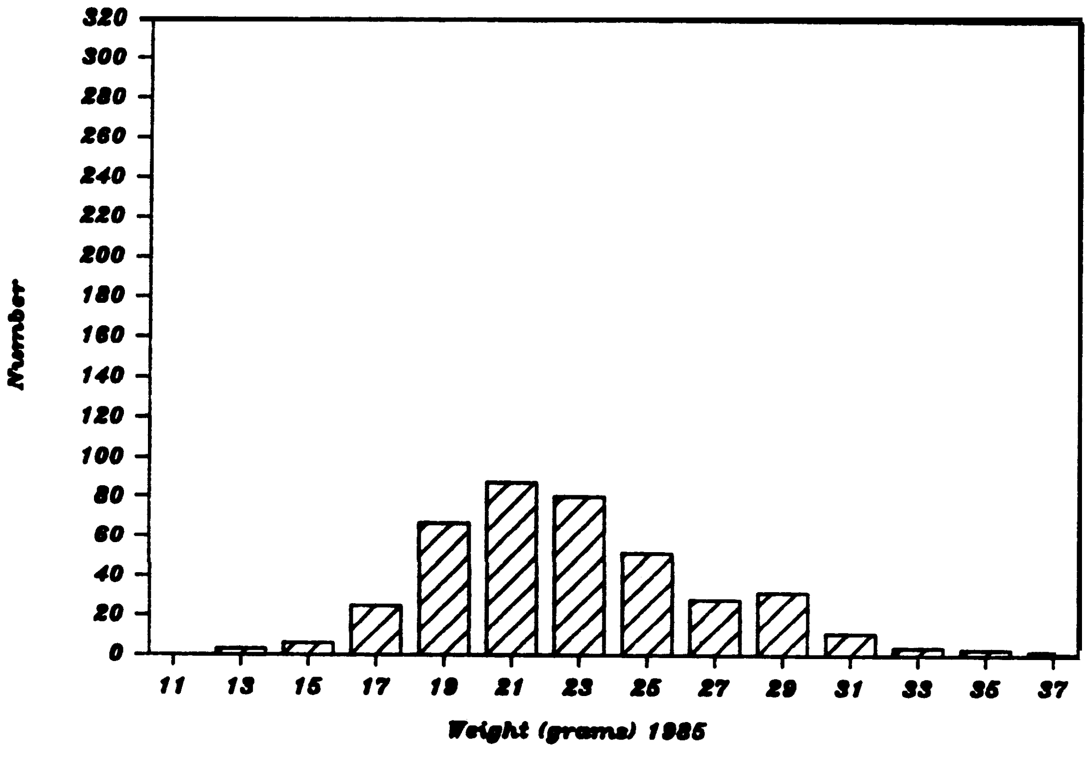


Figure 17. Weight distributions of coho salmon smolts leaving the off-channel pond at km 3 in 1985.

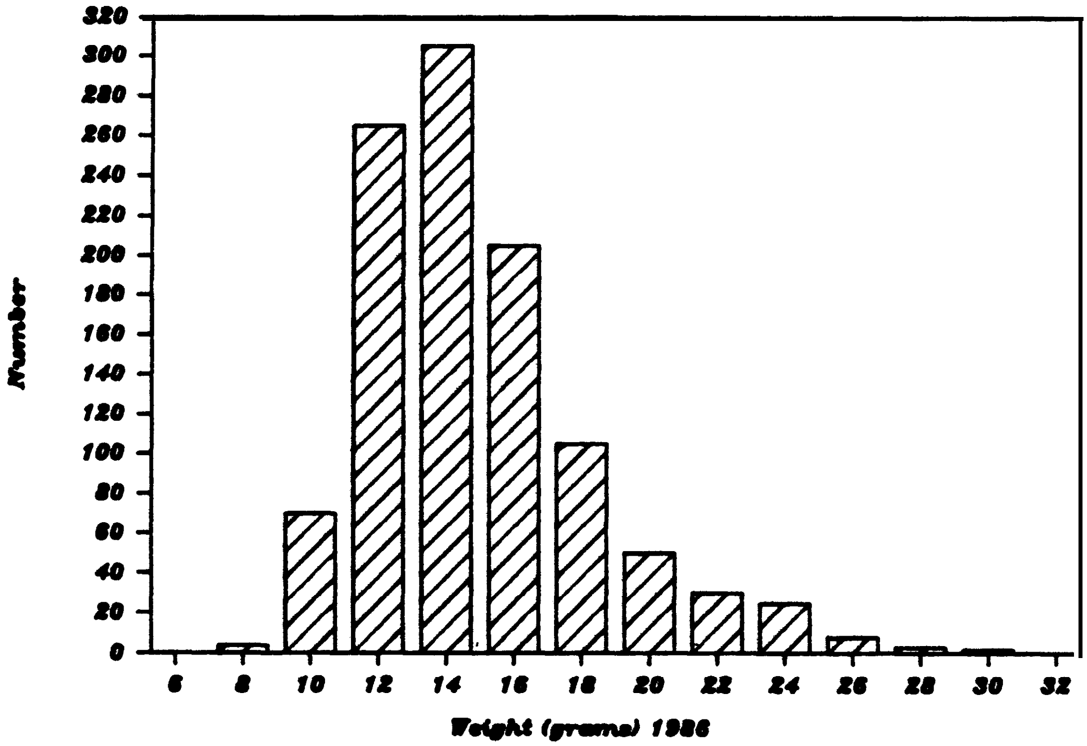


Figure 18. Weight distributions of coho salmon smotls leaving the off-channel pond at km 3 in 1986.

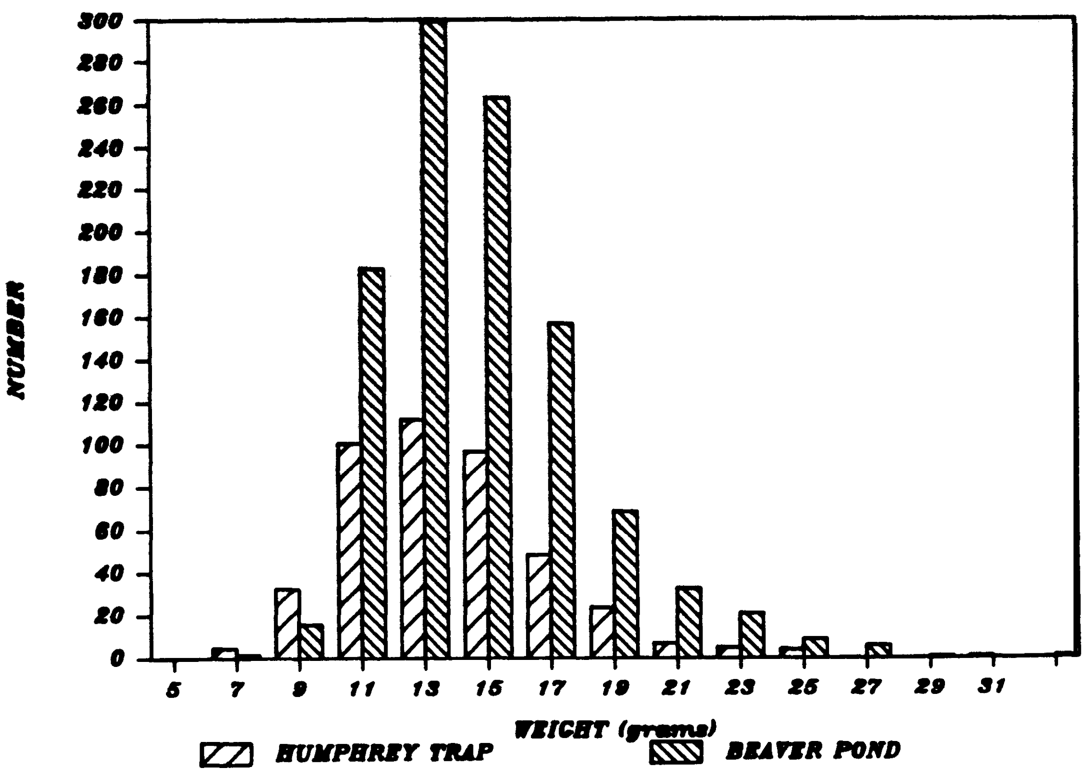


Figure 19. Comparison of coho salmon smolt weight distributions from the Fish Creek Humphrey trap and the off-channel (beaver) pond at km 3, 1986.

1986 grew more slowly than the lesser numbers present in 1985, however, the pond was still probably below carrying capacity.

Smolt production from the pond in 1987 was also impressive. On June 24, 1986, the pond was stocked with 5,035 Clackamas stock coho salmon fry from Clackamas Hatchery. The fish averaged 1.7 grams in weight at time of release. A total of 1,234 smolts from the introduced fry left the pond between February 20 and June 5, 1987. Peak outmigration occurred in early May, similar to previous years. Smolts averaged 116 mm in length, 5 mm larger than those rearing in Fish Creek, and 16.9 grams in weight (Fig. 20, 21), slightly heavier than smolts produced in the pond in 1986. About 25 percent of the fry stocked in the pond in 1986 survived the winter and left the pond as smolts in the spring of 1987.

The off-channel pond, even though never fully stocked with fry, made a significant contribution to coho salmon smolt production in Fish Creek in 1985-1987 period. Fish Creek, excluding the pond, produced 2,606 coho salmon smolts in 1985 while the pond contributed 493, an 18.9 percent addition to the run. In 1986, Fish Creek produced 1,175 smolts while the pond produced 1,196, a 102 percent addition to the smolt migration. In 1987, Fish Creek produced 2600 coho smolts and the pond produced 1,234, a 49 percent addition to the total (Fig. 22, A and Fig 22, B). These contributions are particularly remarkable since the pond represents only about 2.5 percent of the habitat area of Fish Creek. The total carrying capacity of the pond remains unknown, but potential coho smolt

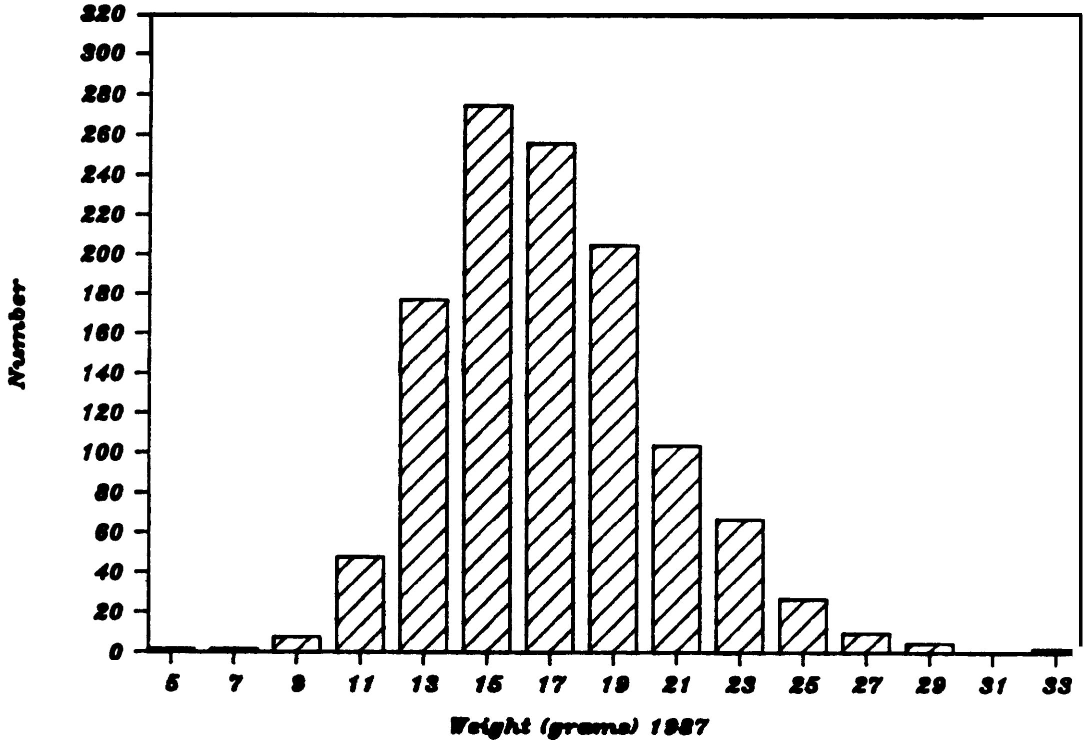


Figure 20. Weight distributions of coho salmon smolts leaving the off-channel pond at km 3 in 1987.

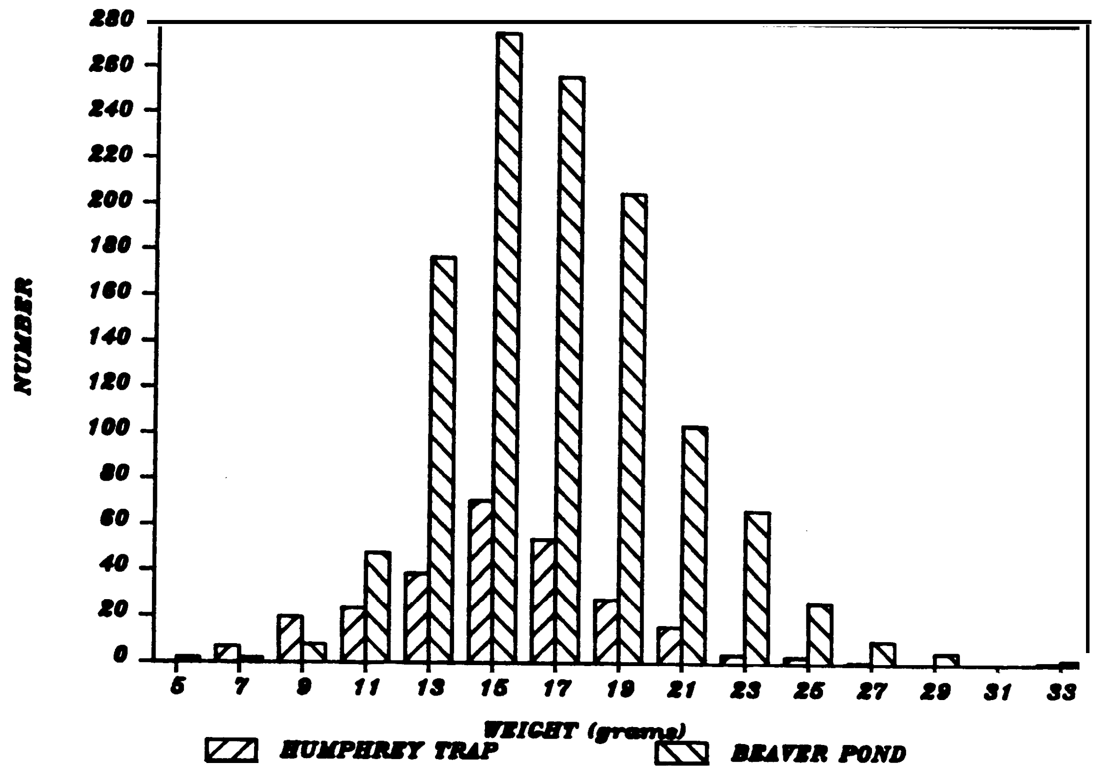


Figure 21. Comparison of coho salmon smolt weight distributions from the Fish Creek Humphrey trap and the off-channel (beaver) pond at km 3. 1987.

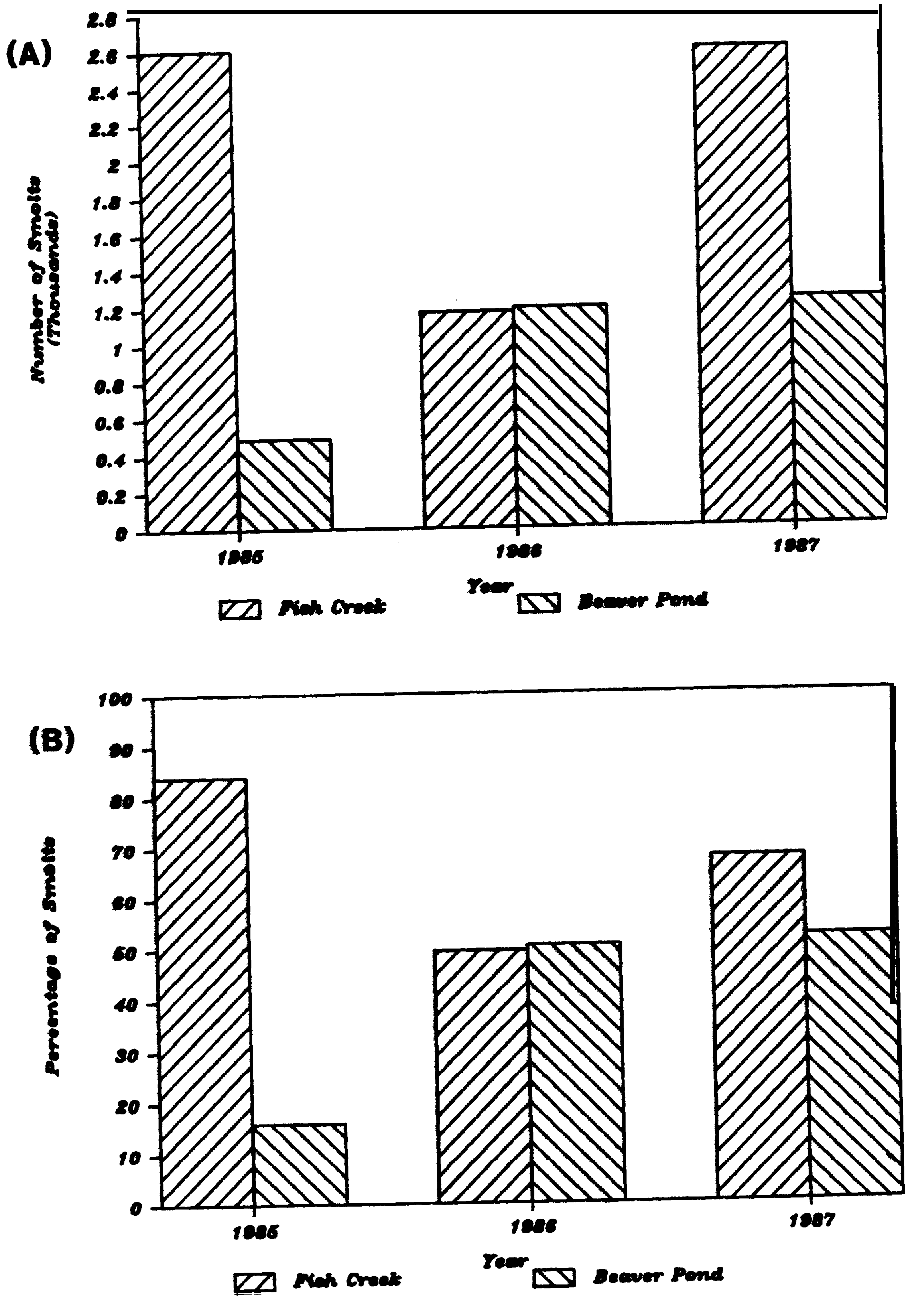


Figure 22. Contribution of mainstem Fish Creek and the off-channel pond at km 3 to total coho salmon smolt production from the Fish Creek basin, (A) by number of smolts, and (B) by percent of total migration, 1985, 1986, and 1987.

production probably is substantially greater than that observed to date. The stocking level was increased to 10,000 0+ coho salmon fry from Clackamas Hatchery in the summer of 1987 in an attempt to determine the maximum smolt production capability of the pond .

***

Preliminary Benefit-Cost Analysis of Eastside Off-channel Pond

The eastside off-channel pond was constructed in 1983 at a cost of $24,030. Additional work to enhance spawning habitat was completed in 1984 at a cost of $300. Total construction costs were $24,330, and an annual maintenance cost of $lOO/year is expected.

Benefits were calculated for the first time in 1986, based on coho salmon smolt production of 1,200 fish (1987 production was approximately the same), and the following procedure:

1,200 smolts x 7.5% smolt to adult survival[1/] = 90 adults,

90 adults x 7:1 catch:escapement ratio[2/] = 79 adults harvested,

79 adults x 64% commercial harvest[2/] = 51 adults in commercial harvest,

51 adults x 7 pounds x $1.47/pound = $525 commercial benefit annually,

79 adults x 36% sport harvest[2/] = 28 adults in sport harvest,

28 adults x $107/adult[2/] =$2,996 sport benefit annually, and

$525 commercial benefit + $2,996 sport benefit = $3,521 annual benefit.

1/ Oregon Dept. of Fish and Wildlife, 1.981.

2/ Meyer, 1982.

The benefit-cost ratio is 1.6/l, and 1.2/l, at discount rates of 4 and 7 percent, respectively, figured on a project life of 20 years (calculations per Everest and Talhelm 1982). Benefits begin to accrue in the third year of the project when the first year-class of smolts recruits to the fishery. The actual realized benefits will be higher because the pond has not yet been seeded to capacity. These preliminary data indicate that the eastside pond is a cost-effective project, and will become more so with full seeding.

* * *

Overwinter Survival of Coho Salmon on Fish Creek

The smolt trap has provided a means of estimating winter survival of coho salmon juveniles in Fish Creek for three consecutive years beginning in the winter of 1984-85. Winter survival during that period has been highly variable, ranging from 10 to 73 percent. Quantity and quality of winter habitat and the severity of winter freshets seem to be the key variables controlling winter survival of juvenile coho salmon in Fish Creek.

The total number of coho salmon in the system in September 1984 was estimated at 8,290 and the total estimated smolt production from mainstem Fish Creek (excluding smolts from the off-channel pond) was 2,606. From these data, overwinter survival was estimated at 31 percent. While data on winter survival of pre-smolt coho salmon are not abundant for other western streams, it appears that 31 percent is below average.

The low winter survival of coho rearing in the mainstem of Fish Creek in 1984 can be attributed to the general lack of quiet edge habitats and side channels during winter. Diving observations in the winters of 1984 and 1985 showed that 0+ coho salmon prefer to winter in quiet backwaters with heavy cover. Habitats meeting these criteria are rare within the distributional range of coho salmon in the basin.

Problems with overwinter survival of coho salmon in the system were confirmed following a large flood event in February 1986. Juvenile coho salmon in the system were estimated at 11,980 fish in September 1985, and smolt production from the mainstem was estimated at 1,175 fish in the spring of 1986. Overwinter survival was estimated at 10 percent. The low survival in the winter of 1985-86 is attributed directly to lack of suitable winter habitat during the scouring flood event of February 1986.

The importance of flow conditions on winter survival was further confirmed in the winter of 1986-87. The coho salmon population in Fish Creek in the summer of 1986 was estimated at 3,560 fish. Production of smolts in the spring of 1987, after one of the mildest winters on record, was 2,597 fish. Overwinter survival was estimated at 73 percent. The high survival rate was attributed to a lack of significant winter freshets and the substantial amount of habitat modification completed in the summer of 1986.

The off-channel pond, with moderate water temperatures and abundant quiet water, food, and cover, provides more stable winter habitat for juvenile coho salmon than the mainstem of Fish Creek. The number of coho salmon in the pond has never been quantified in late summer, so no direct calculations of winter survival have been possible. Fry to smolt survival, however, ranged from 25 to 35 percent during the 1985-87 period, which might indicate winter survivals of greater than 50 percent.

Steelhead Trout Smolt Production

The production of steelhead trout smolts from the Fish Creek basin has been monitored each spring since 1985. Production has averaged about 5,400 fish per year (+ 30 percent). Availability of winter habitat and the magnitude of winter freshets have strong influences on smolt production.

In 1985, the steelhead trout smolt migration from Fish Creek was monitored from April 15 through June 28, when movement of smolts ceased. The migration was in progress when the trap was installed on April 15, and based on observations made in March 1986, several hundred smolts could have left the basin before the trap was activated in 1985. Two distinct peaks of movement occurred in 1985 (Fig. 23). A low steady catch rate averaging 10-12 smolts/day occurred between April 15 and April 27. During the following week the catch increased

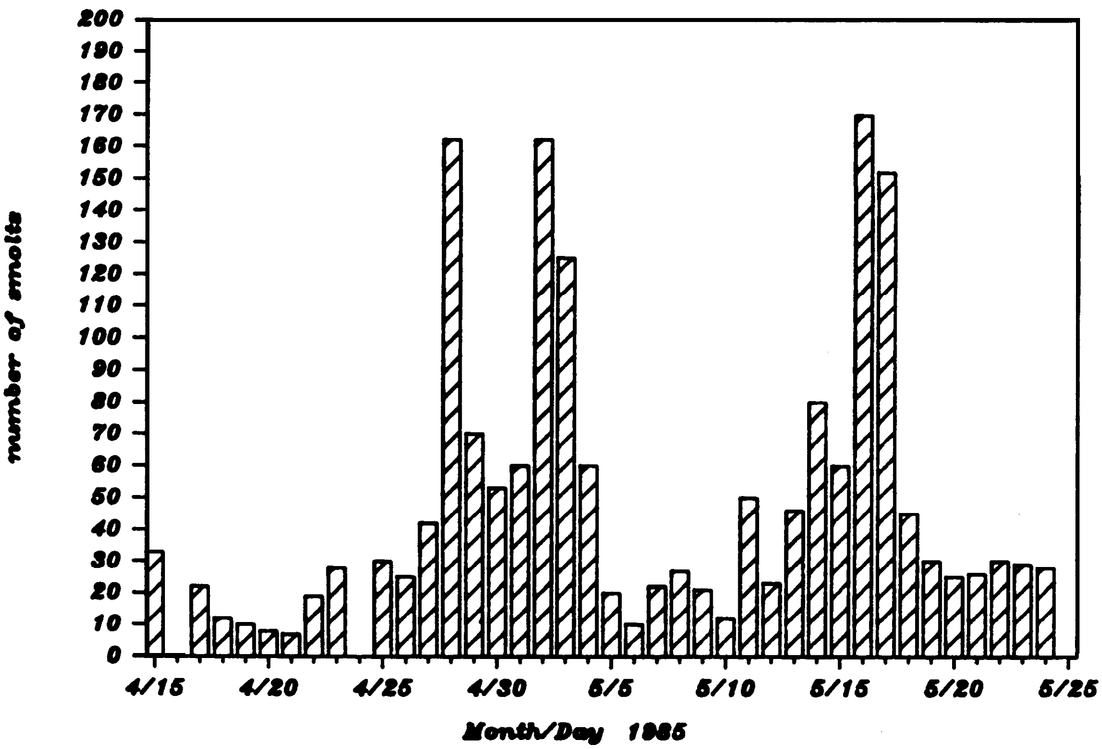


Figure 23. Daily catch of steelhead smotls at the floating fish trap at km 0.3 on Fish Creek, April 15 to June 15, 1985.

markedly, averaging 100 smolts/day, and a peak catch of 159 smolts/day occurred on May 2. The catch dropped to an average 14 smolts/day from May 5 through May 10 and peaked again at 171 smolts/day on May 16. The catch declined rapidly after May 17 and the final smolt of the season was caught on June 28.

The total number of smolts moving downstream between April 15 and June 28, 1985 was estimated at 7,473 (Table 16). It is assumed that the migration had been in progress for at least 15 days before trapping began. Based on the mid-April catch rate, an average of 10 smolts/day would have been trapped during this period. Using an estimated efficiency of about 30 percent for this 15 day period, a total of about 500 smolts probably left the system before trapping

Table 16. Catch of steelhead trout smolts, recapture of marked smolts, estimates of trap efficiency, and total number of smolts, leaving Fish Creek by 2-week intervals, April 15 to June 28, 1985.

Dates	Smolts captured	Marked smolts released	Marked smolts recaptured	Trap efficiency percent	Estimated total smolts
04/15-04/28	382	49	15	31	1,232
04/29-05/12	708	115	47	41	1,727
05/13-04/26	787	155	57	37	2,127
05/27-06/09	103	82	10	12	858
06/10-06/23	166	122	14	11	1,509
06/24-06/30	2	--	--	10	20
Totals	2,148	523	143	--	7,473

commenced. Therefore, the total. smolt migration is assumed to be about 8,000. The size of smolts ranged from 123- 242 mm fork length, and varied during the trapping season. The average size was about 160 mm, and the approximate minimum threshold size for smolts was 140 mm, although a few smolts were smaller (Fig. 24). The average size of smolts remained fairly constant from mid-April to mid-May and then decreased from mid-May to mid-June (Fig. 25). Smolt weights ranged from 25 to 125 grams and averaged about 50 grams in weight (Fig. 26). Scale analysis from a small sample of early migrants, both smolts and non-smolts, indicated that the group was composed primarily of age 2+ fish, the normal age of most steelhead trout smolts in western

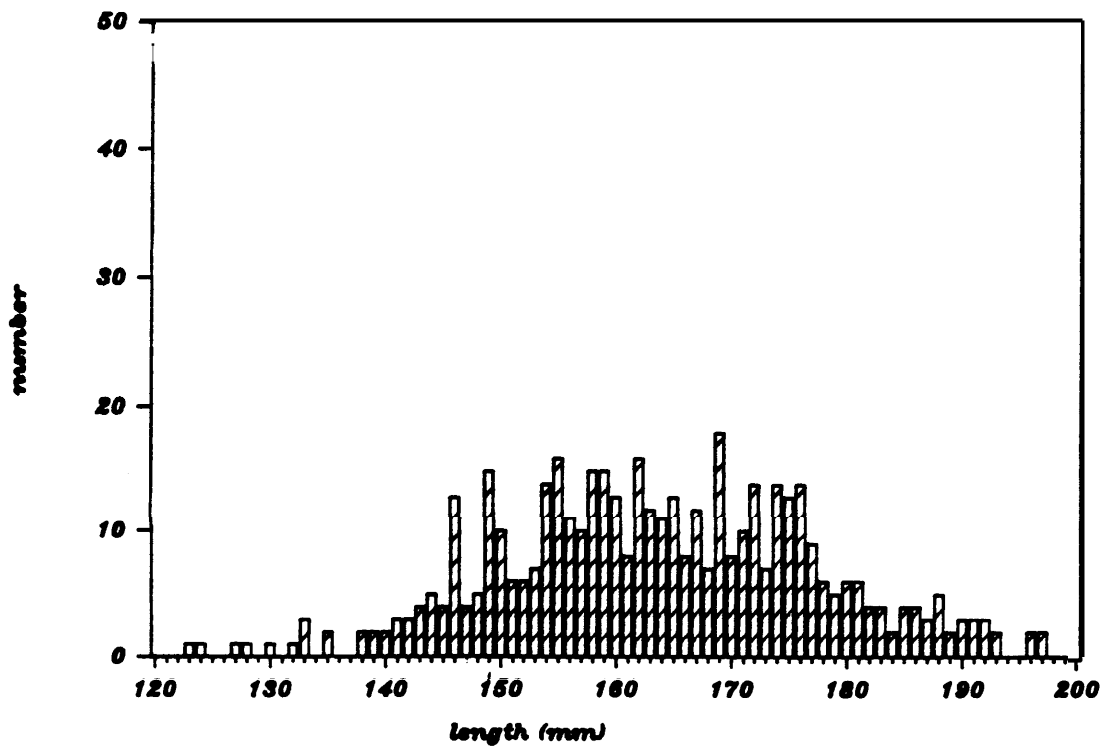


Figure 24. Size frequency of steelhead trout smolts from Fish Creek, 1985.

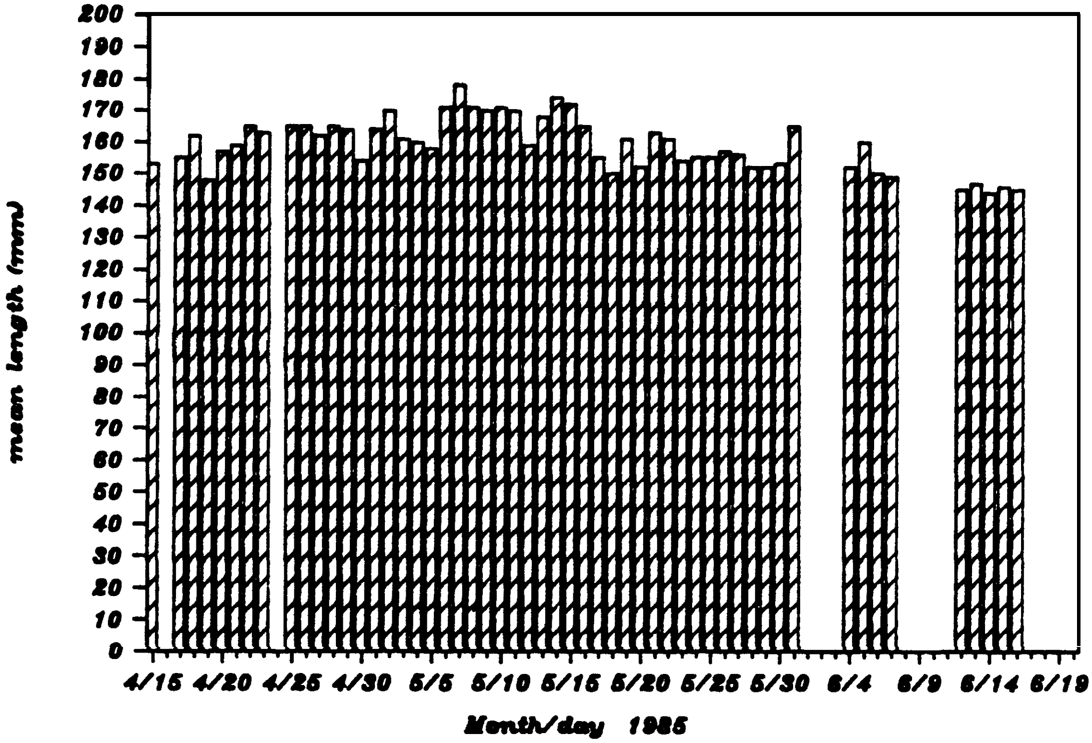


Figure 25. Mean daily lengths of steelhead trout smolts leaving Fish Creek between April 15 and June 15, 1985.

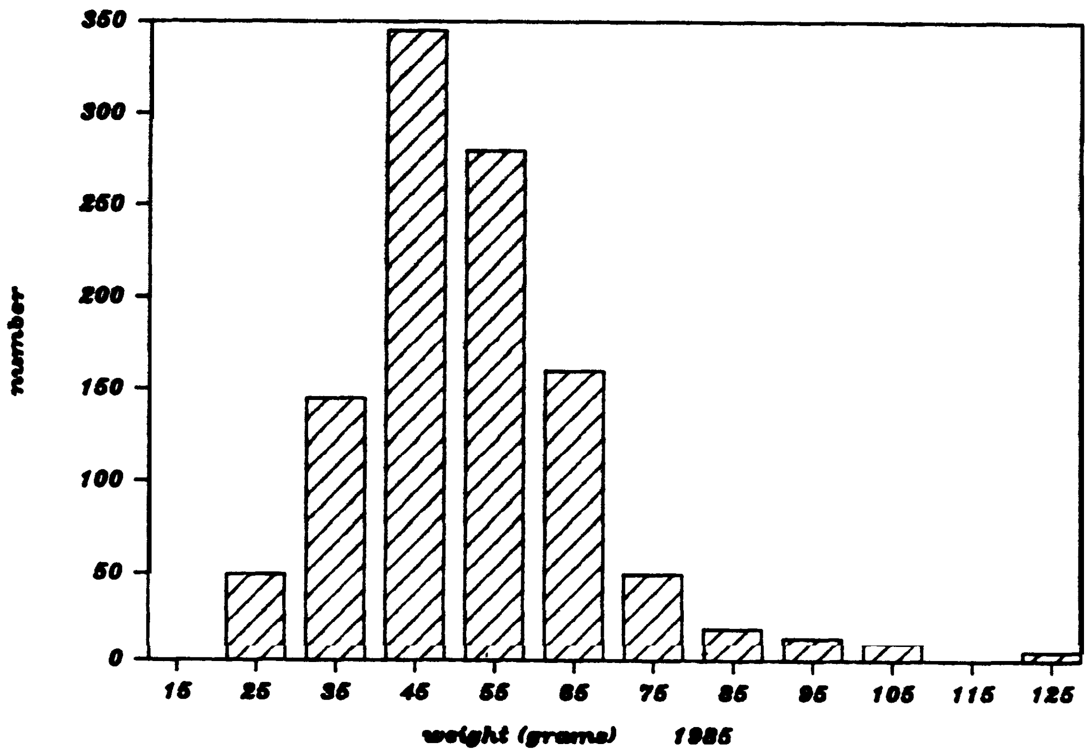


Figure 26. Weight distribution of steelhead smolts captured at the floating trap at km 0.3, 1985.

Oregon. The smaller June migrants might have been a mix of smaller 2+ smolts, and socially dominant, fast growing l+ smolts.

A generalized growth pattern of juvenile steelhead trout is shown in Figure 27. This figure was developed from examination of the growth pattern observed on scales and by back-calculating the length of fish at the time of annulus formation. The estimated mean length at the time of formation of the first and second snnulus was 82 mm and 125 mm, respectively. Thus, we speculate that in order for a fish to reach the minimum size to smolt, 140 mm, it must have attained a length of 120 mm by the end of the growing season the previous fall.

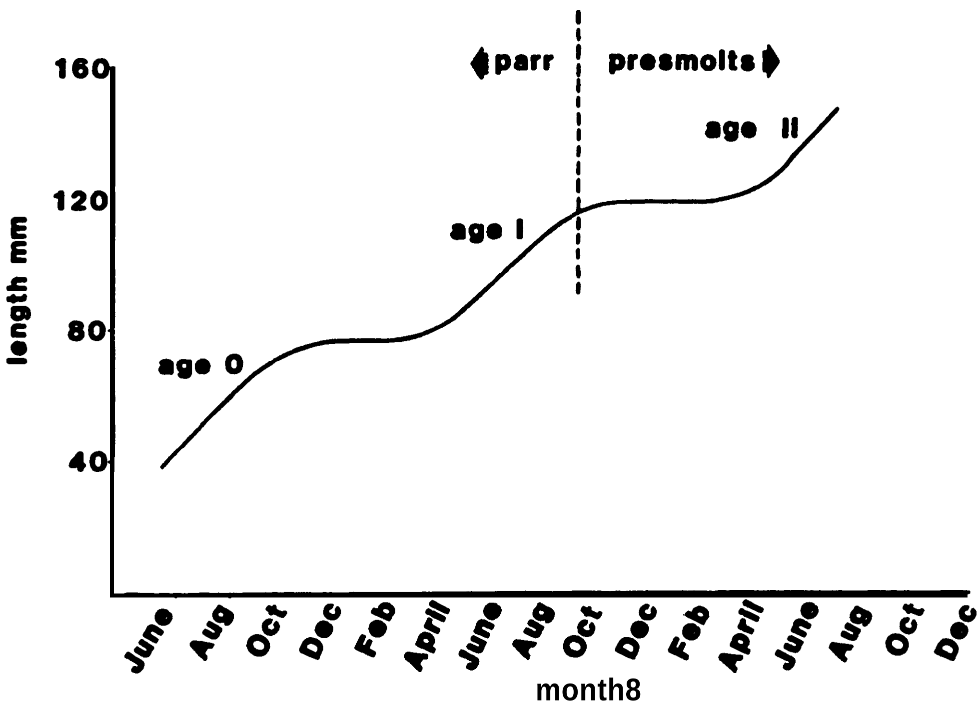


Figure 27. Generalized growth pattern of juvenile steelhead trout in Fish Creek. Emergence occurs primarily in June and smolts leave in May of their second year. Presmolts must be 120 mm fork length to smolt the following spring.

It is probably unlikely that fish less than 120 mm would reach the 140 mm threshold by the following spring. Overwinter survival of pre-smolt steelhead trout appeared to be favorable in Fish Creek in 1985. In the summer of 1984 the Fish Creek basin contained an estimated 23,800 age one and older steelhead trout. Approximately 50 percent of these fish, 11,900, were a minimum length of 120 mm by the fall of 1984 (Fig. 28). Since about 8,000 smolts left the basin in 1985, overwinter survival is estimated at about 70 percent. An additional contribution could be expected from age 1+ parr that remain in the system for another growing season.

In 1986, steelhead trout smolts were trapped in Fish Creek between March 14 and June 14. A few fish were migrating when the trap was installed in March, but because of cold water temperatures in the system prior to trap installation, it is unlikely that many smolts left before trapping commenced. Several peaks of movement related to changing water temperatures and flows occurred in 1986 (Fig. 29). Catch during March was fairly consistent at 10 to 20 fish/day with a peak of 27 fish on March 30. Major peaks of movement occurred on April 18 and 27 when about 70 fish/day were caught. Peaks also occurred on May 3 and 14 at 35 and 47 fish, respectively. After May 14 catch of smolts declined rapidly and ceased on June 14.

The total steelhead trout smolt migration in 1986 was estimated at 3,781 fish, approximately half of the number of migrants in 1985 (Table 17). The smolts were about the same length and weight as

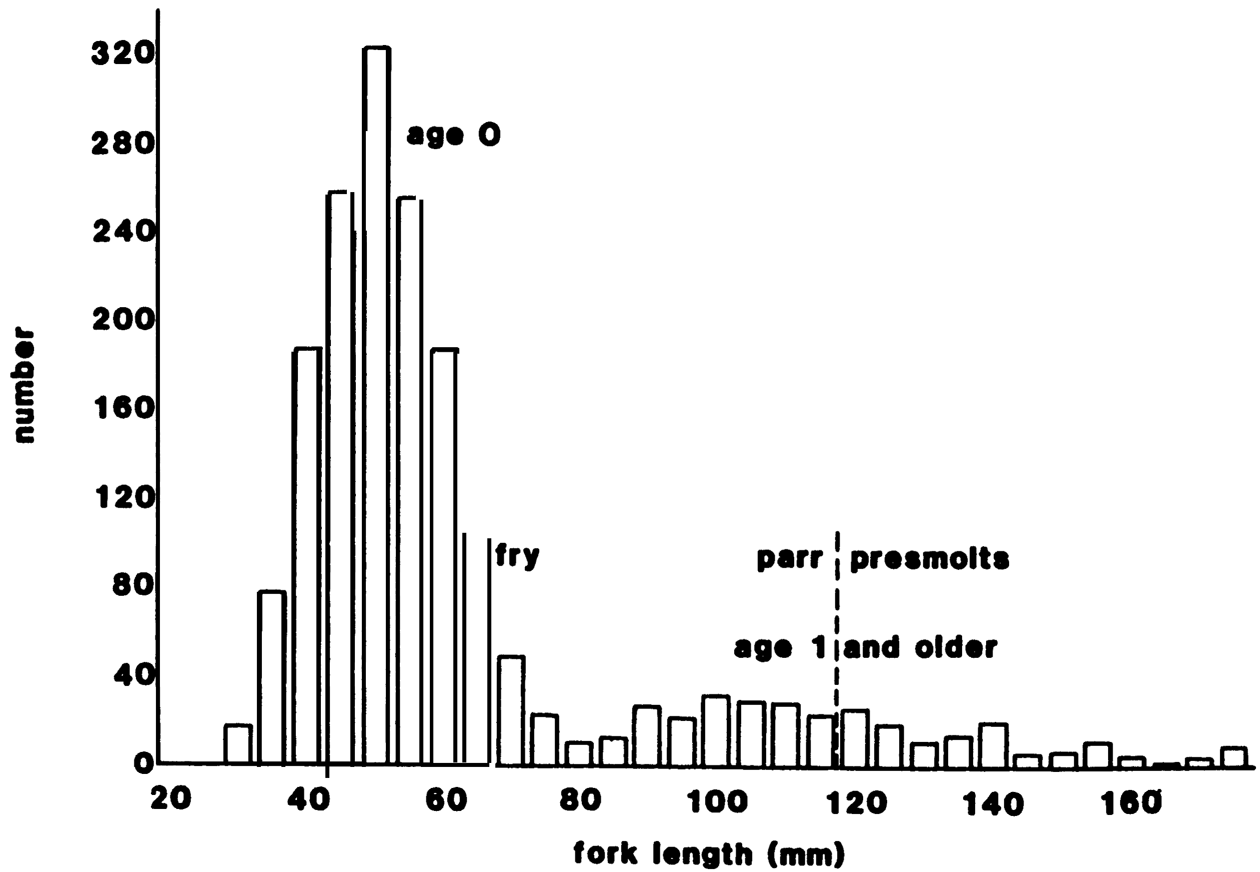


Figure 28. Size frequency of juvenile steelhead trout in Fish Creek, September 1985. Only fish larger than about 120 mm will smolt the following spring.

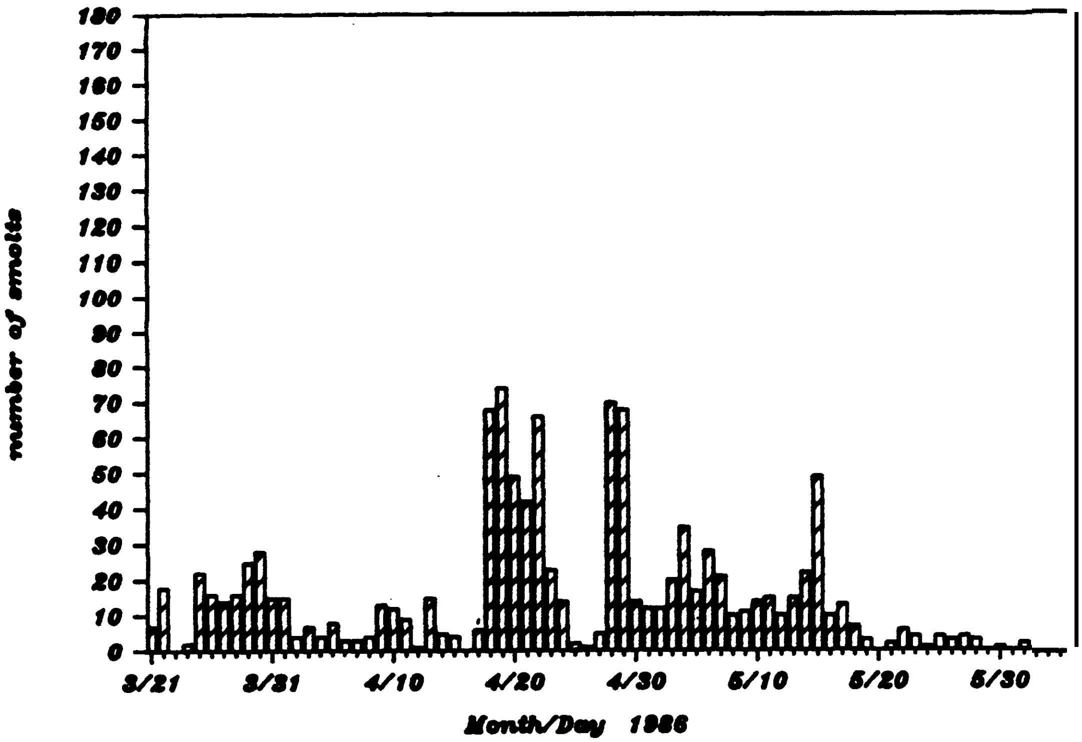


Figure 29. Daily catch of steelhead smotls at the floating fish trap at km 0.3 on Fish Creek, March 14 to June 15, 1986.

1985 migrants, averaging about 154 mm fork length and 37.7 g. Smolt lengths ranged from 135 mm to 217 mm, and weights ranged from 16.1 to 94 g (Figs. 30, 31). The average size of smolts remained fairly constant througout the migration period (Fig. 32).

Overwinter survival of juvenile steelhead trout in Fish Creek was lower in 1986 than in 1985. Approximately 18,520 age one and older steelhead trout were present in the basin in September 1985 and 3,781 smolts left the basin in the spring of 1986. Overwinter survival is estimated at about 40 percent, as compared to about 70 percent in 1985 l The flood event of February 1986 probably is responsible for the difference. Steelhead trout overwintering in the substrate could

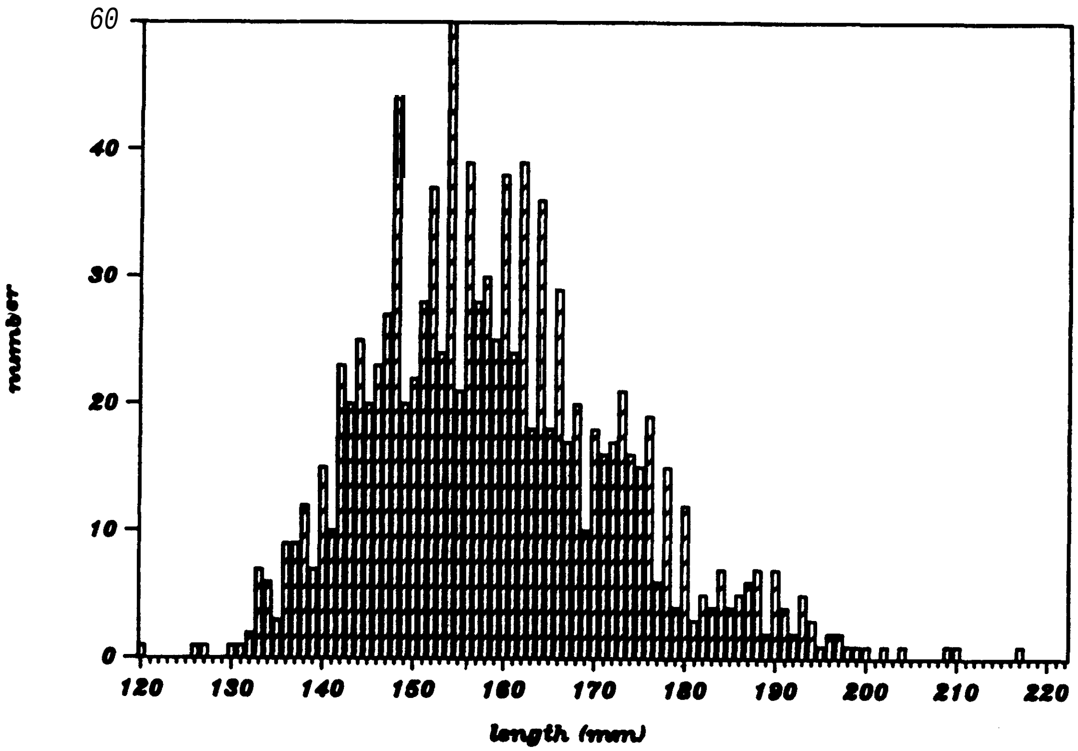


Figure 30. Size frequency of steelhead trout smolts from Fish Creek, 1986.

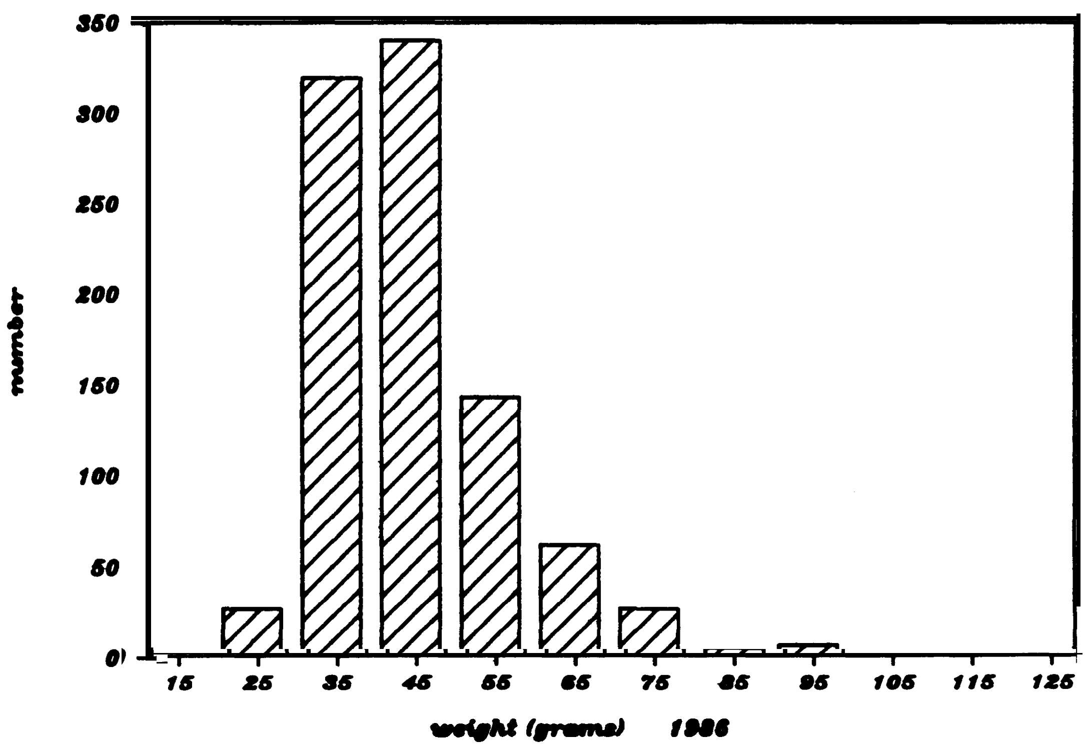


Figure 31. Weight distribution of steelhead smolts captured at the floating trap at km 0.3, 1986.

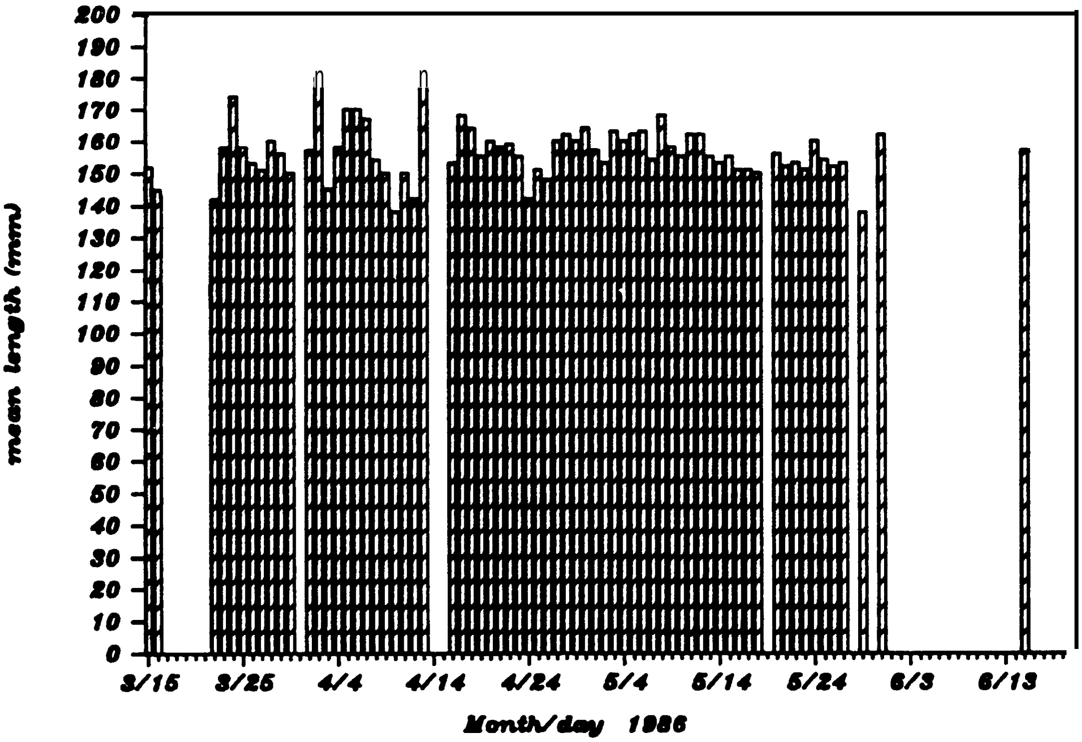


Figure 32. Mean daily lengths of steelhead trout smolts leaving Fish Creek between March 14 and June 15, 1986.

Table 17. Estimated number of steelhead trout produced in Fish Creek, March 14 to June 5, 1986.

Dates	Smolts captured	Marked smolts released	Marked smolts recaptured	Trap efficiency percent	Estimated total smolts
03/14-03/27	92	51	12	24	383
03/28-04/10	142	137	26	19	747
04/11-04/24	364	191	61	32	1,137
04/25-05/08	304	175	65	37	822
05/09-05/22	151	101	25	25	604
05/23-06/05	22	22	0	~25	88
Totals	1,075	677	189	28	3.781

have been killed by the overturning of the streambed during the flood or entombed by smaller bedload particles that filled interstitial spaces in the boulder-cobble streambed and prevented escape of overwintering steelhead trout.

Trapping of steelhead trout smolts in the spring of 1987 was marginally successful because of low streamflow and mechanical difficulties with the trap. An attempt was made to operate the trap between February 17 and June 8, but the trap was out of operation for several days during this period (Fig. 33). Only 304 smolts were captured during this period, with peak movement of 57 smolts on April 13. Trapping efficiency was greatly reduced in 1987 because of low streamflow, and the estimate of total smolt production is therefore believed to be less reliable than in previous years (Table 18).

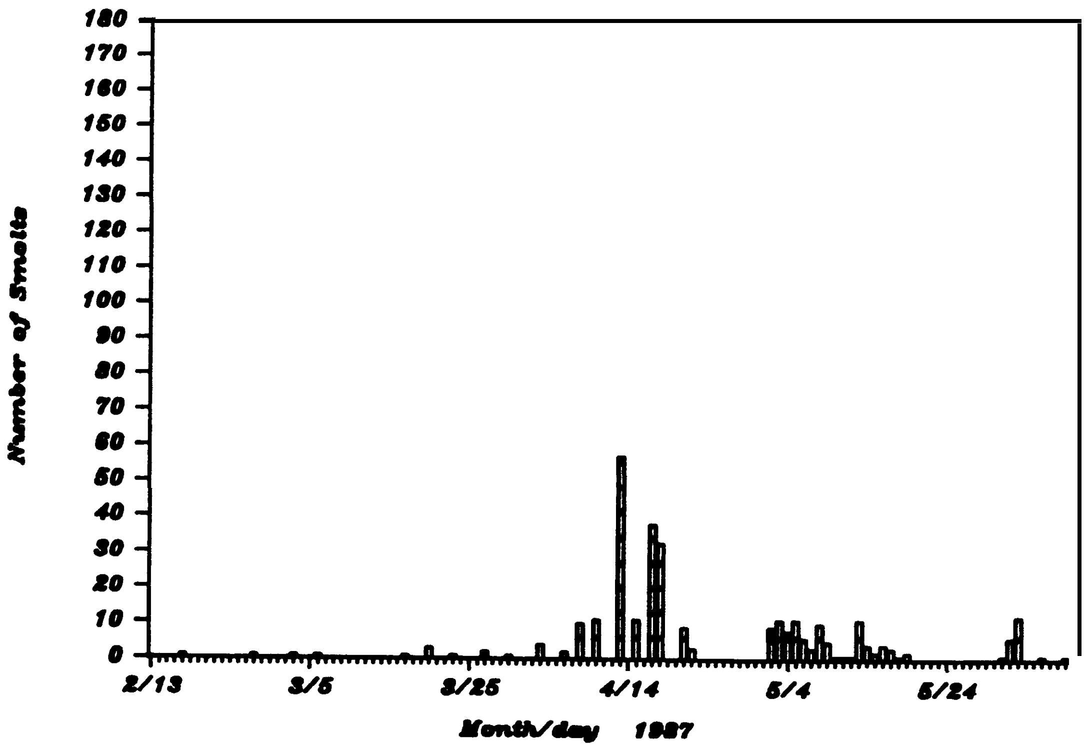


Figure 33. Daily catch of steelhead molts at the floating fish trap at km 0.3 on Fish Creek, February 13 to June 9, 1987.

The total 1987 steelhead trout smolt migration was estimated at about 7,600 fish. Average length of migrants was 151 mm with a length range of 98 to 203 mm (Fig. 34). Smolts averaged 36 g in weight with a range of 6.6 to 79.8 g (Fig. 35). As in previous years, the average size remained constant over the entire migration period (Fig 36).

Overwinter survival of l+ pre-smolt steelhead was estimated at 92 percent for the mild winter of 1986-87. The estimate is based on a summer 1986 population of 20,670 l+ steelhead, of which 40 percent (8,270 fish) were over 120 mm in length. The proportion of l+ fish over 120 mm in length declined from 50 percent of the population in

Table 18. Steelhead smolts captured in a floating trap at km 0.3 on Fish Creek, and estimates of trap efficiency and total smolt numbers by two-week intervals, February - June 1987.

Dates	Smolts captured	Marked smolts released	Marked smolts recaptured	Trap[1/] efficiency percent	Estimated total smolts
02/15-02/28	2	0	0	4	50
03/01-03/14	2	0	0	4	50
03/15-03/28	7	0	0	4	175
03/29-04/11	28	0	0	4	700
04/12-04/25	151	101	1	4	3,775
04/26-05/09	63	112	3	4	1,575
05/10-05/23	30	49	1	4	750
05/24-06/06	20	19	1	4	500
06/07-06/20	1	1	0	4	25
Totals	304	282	6	--	7,600

[1/] Estimated efficiency for the season, including periods when the trap was out of operation.

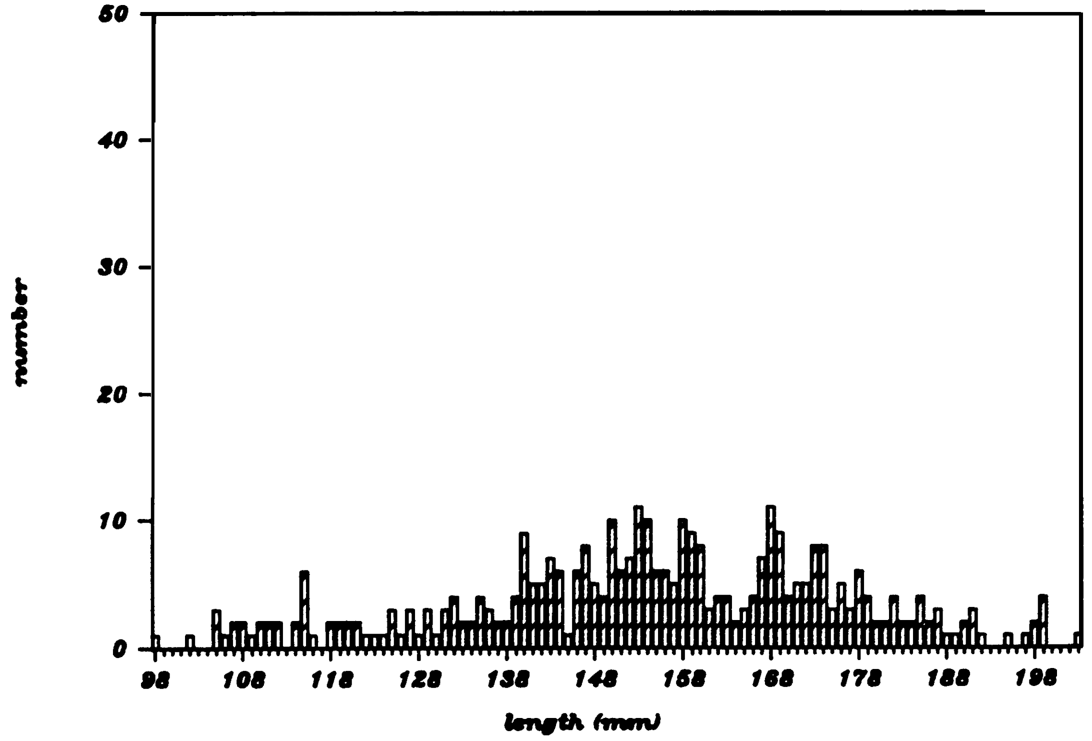


Figure 34. Size frequency of steelhead trout smolts from Fish Creek, 1987.

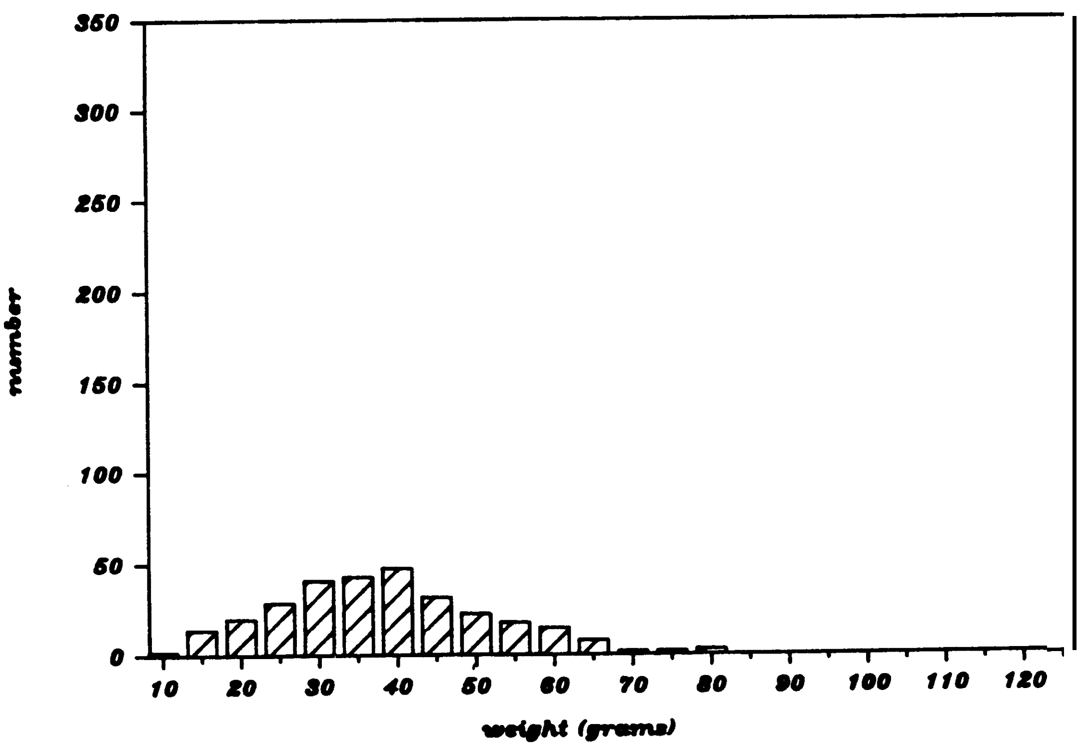


Figure 35. Weight distribution of steelhead smolts captured at the floating trap at km 0.3, 1987.

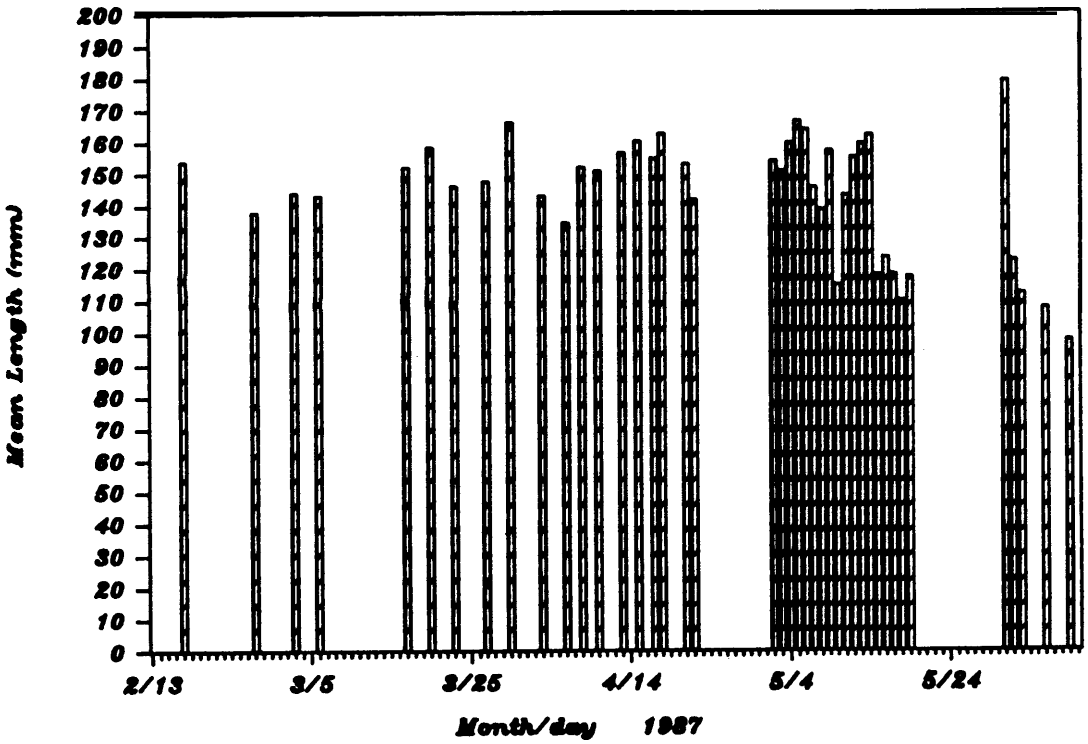


Figure 36. Mean daily lengths of steelhead trout smolts leaving Fish Creek between February 13 and June 9, 1987.

1984 to 40 percent in 1986, due possibly to heavy fishing pressure on juveniles above the legal size limit of 150 mm during the low flow period in the spring and summer of 1986.

The behavior of migrating steelhead trout smolts in Fish Creek appears to be typical of other salmonid smolts. Nearly all movement occurs during darkness and migrants apparently move downstream in the upper portion of the water column near the thalweg.

Habitat Enhancement and Steelhead Trout Smolt Production

At this time it is not possible to determine whether projects designed to improve steelhead trout habitat have had any impact on the production of steelhead trout smolts. By 1985, projects had altered only about 5 percent of the habitat in the basin, and natural variability of steelhead trout populations has been in the range of +/- 10 percent per year. Construction of boulder berms in 1983 was the only project in the basin to significantly impact habitat for age l+ steelhead trout prior to work completed in the summer of 1986. The effect of the boulder berms on steelhead smolt production appeared to be negligible based on summer standing crop of presmolts. Habitat improvements in 1986 and 1987 altered about 35 percent of the steelhead trout habitat in the basin and could significantly affect smolt production in the future. Several years will be required to fully evaluate the effects of this work.

Spawning Gravel Resources

A complete inventory of the spawning gravel resources in the Fish Creek basin was made in the summer of 1987 to assess effects of the February 1986 high flow event on the abundance and distribution of gravels in the system. Previous surveys of spawning habitat were made in 1976 and 1982, and a partial survey (chinook spawning habitat only) was made in the summer of 1984. The results of the 1987 survey and previous surveys are summarized in Table 19.

Spawning habitat for anadromous salmonids in the Fish Creek basin is sparse and scattered. The typically constrained steep gradient channel of the stream results in a substrate composed primarily of boulders and rubble with only isolated patches of gravel suitable for

Table 19. Amount of spawning gravel (m^2) in the Fish Creek basin available to anadromous salmonids, 1976-1987.

Year	chinook salmon	coho salmon	steelhead trout	total
1976		911		911
1982	190	569	1,348	1,348
1984	288			
1987	240	926	1,288	1,288

spawning. Small expanses of gravel suitable for reproduction are found along the stream margins where roughness elements such as boulders and large woody debris have caused deposition. There are a few large expanses of gravel that occur in less constrained areas at the tail of large pools, where the channel is braided, or where the main channel gives rise to side channels. Most gravel resources are concentrated in the mainstem of Fish Creek below the mouth of Wash Creek (Fig. 37).

The amount of spawnfng habitat in the system has been quite stable over the past 6 years. The total spawning habitat in the system shows an apparent change of less than 5 percent since 1982. That change might be due to a change in methods. In 1982 all usable gravel areas >l m^2 were counted, while in 1987 all gravel areas >2 m^2 were counted. The apparent increase in spawning habitat for coho salmon is related to an expansion of the spawning distribution of adults. In

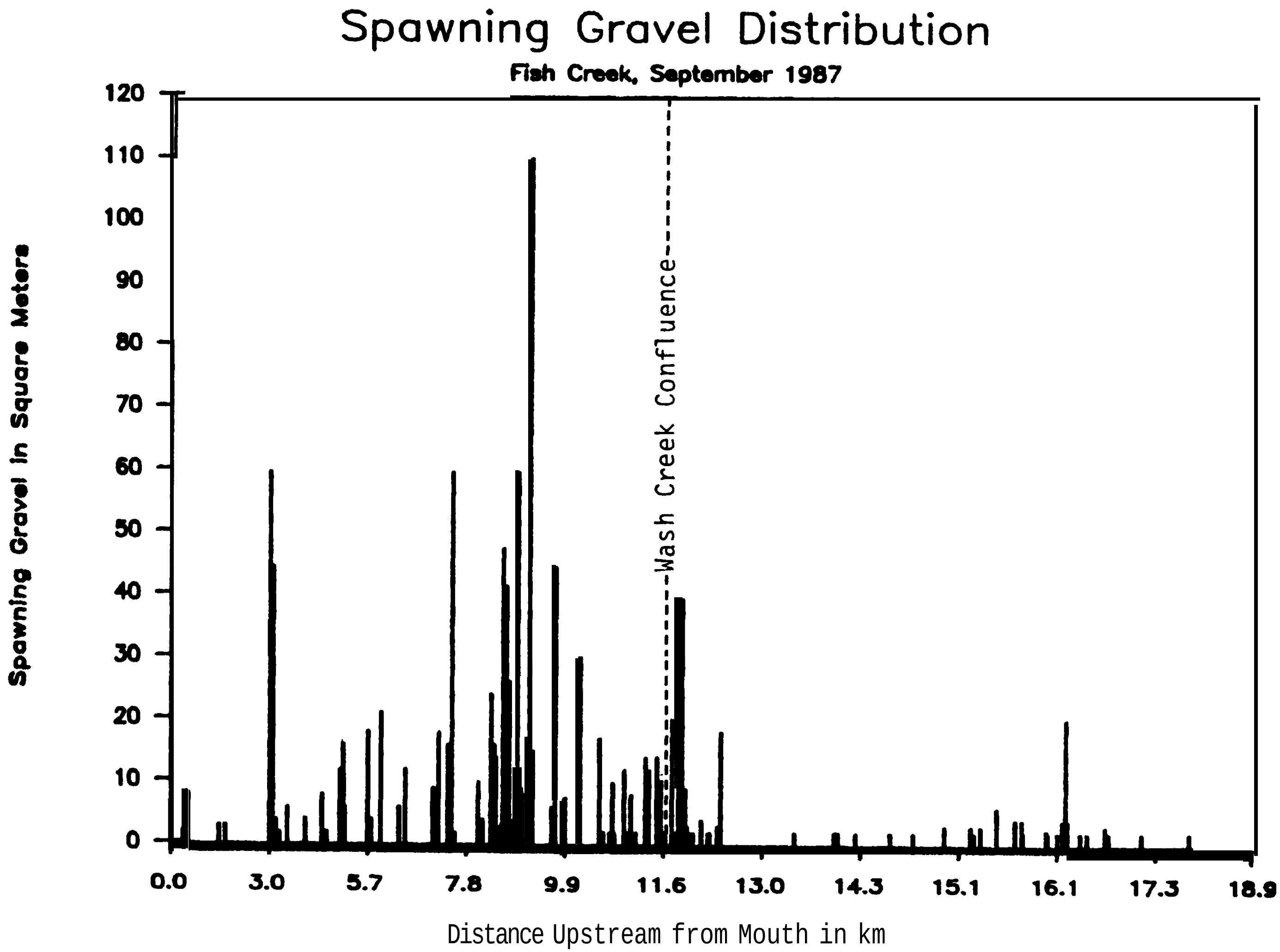


Figure 37* Distribution of spawning gravel in the Fish Creek basin, September 1987.

1982 coho salmon spawning was confined to the lower 5 km of the mainstem of Fish Creek, but by 1987 coho had expanded their spawning distribution by another 5 km and were using the entire mainstem from the mouth of Fish Creek to the mouth of Wash Creek. The reason for the change in spawning distribution is unclear at present.

Even though spawning habitat in the Fish Creek system is sparse and unevenly distributed, the quantity is more than adequate to seed existing rearing habitats of coho salmon and steelhead trout.

* * *

The Characterization and Role of Large Wood in Fish Creek Following Tree Felling

Everest et al. (1985) reported that there was less wood in Fish Creek than one would expect to find if no prior salvage logging had occurred. The average of 4-5 pieces per 100 m of stream found in Fish Creek in 1984 was considered to be about one-fifth of what would be expected in streams flowing through natural old-growth forests. They observed that a serious reduction in favorable salmonid rearing habitat had occurred as well as a loss of spawning gravels that were often deposited around pieces of large wood along the stream margins. They concluded that coho salmon smolt output could be substantially enhanced with a significant increase in large woody debris in the lower reach of the Fish Creek basin. In response to those observations and conclusions, 94 trees were felled into parts of the middle and lower reaches of Fish Creek in 1986, and 280 trees were felled along lower Fish Creek in 1987. These trees ranged in size from 0.6 m to 1.8 m in diameter. Bankside trees were avoided in order to protect the integrity and stability of the banks and maintain stream shading. Most trees that were felled were > 8 m away from the bank and were dropped between standing trees. Probability of displacement of felled trees during flood events was reduced by, (a) having a large portion of the bole on the bank wedged between large living trees, and (b) anchoring them to live trees and to boulders in the channel by cable and epoxy.

The majority of the trees were left whole with limbs attached. As habitat structures, they were used as sediment and slash-size wood collectors, cover in pools, and flow deflectors to scour depth and sort gravels in riffles.

Fish Creek has been arbitrarily divided into four sectors for an inventory of woody debris in the channel: (1) a lower reach from the mouth to the first bridge, a distance of 7.3 km; (2) a middle reach of 3.1 km extending from the first concrete bridge to the confluence with Wash Creek; (3) upper Fish Creek from the confluence of Wash Creek, 1.6 km to a lO+ meter bedrock falls, which marks the end of the anadromous fish utilization in Fish Creek; and (4) Wash Creek from its mouth for 4.7 km to a 5+ meter waterfall which ends the anadromous fish section of Wash Creek. The total length of stream surveyed is 16.7 km. The basin was divided to determine if more pieces of large wood in smaller size dimensions persisted in those sections of streams with less discharge. The middle reach is predominately a bedrock, boulder-veneered, canyon stream that might have larger than average pieces of wood persisting there.

Large wood debris in Fish Creek is defined as being > 5 m in length and > 0.3 m in diameter. These dimensions are greater than the literature values of > 3 m in length and 0.1 m in diameter. The main reasons for increasing the size class for large wood was the large size and high gradient nature of Fish Creek and the amount of time required to measure debris. Unless a piece of woody debris was at least 5 m long, it was that it was not playing a key role in the stream system as stream widths are greater than 10 m. The larger diameter was needed, in addition to the length, to withstand the high-stream power in Fish Creek. The dimensions selected represented a compromise between the lowest end of the key-piece range and the investigators ability to accurately tally and record the significant wood debris in Fish Creek in a timely manner. Each piece of large wood was not measured directly. Its length and diameter was estimated and recorded. In calibration checks, the visual estimates were within 10 percent of measured values. Wood clumps were defined as two to five pieces of large wood that the stream had aggregated. A debris jam is defined as an aggregation of five or more pieces of large wood, often formed on the outside of bends in the stream or at debris torrent deposits.

There are differences in tabulating wood data for single pieces and clumps between 1984 and 1986. In 1984, the method of tabulating wood data called for recording each piece of large wood > 5 m length and 0.3 m diameter. The volume of a clump was estimated by mentally reducing the wood in the clump to a solid cube and recording the dimensions necessary to calculate volume. For clumps that contained large pieces of debris one or more key pieces were tallied for length and diameter. In 1986, all pieces of wood found in a clump that were > 5 m long and 0.3 m diameter were recorded. Then the remainder of the clump was estimated by visually reducing the clump to a solid cube and recording the dimensions.

The methods used between 1984 and 1986 are not radically different, but they do introduce some bias which needs to be accounted for in interpreting differences between years, particularly estimates of the average length of woody debris in the basin. For pieces of wood occurring singly there is no difference. The method for clumps in 1986 is essentially a two-step version of the 1984 method. The 1984 method would have recorded fewer total pieces of wood for computing length-frequency relationships than the 1986 method because it underestimated pieces in the clumps and jams. The 1984 method was biased toward large key pieces in clumps, so the estimated average lengths of wood was longer than that calculated using the 1986 method. For reaches with few clumps the methods would yield similar results. However, as the frequency of clumps increases (especially large jams) the 1984 method of focusing only on key pieces causes overestimates of the average length of pieces.

Data from 1984 was also recalculated and 500 m^3 representing the amount of wood jammed on an island in the lower section of Fish Creek was added to the total. A few other jams on high banks in 1984 were also added. By doing this, a complete and consistent accounting of all of the large wood within the active channel and banks can be maintained. These additions significantly increased the large wood in the active channels of Fish Creek in 1984 beyond what was reported in the 1985 report (Everest et al. 1985).

Comparison of Total Wood in Fish Creek 1984-1987

The total volume of large wood in Fish Creek has increased 1.5 times from 1984 to 1987 (Table 20) from 4,352 m^3 to over 6,590 m^3. From 1983 to 1987, there has been a 3-fold increase in the total amount of large wood in the basin. A major ice and wind storm in December 1983, brought in over 50 percent of the total large wood measured in the floodable channel in 1984--a dramatic change? In fact, 3 major events account for 80 percent of the total volume found in Fish Creek. The ice-wind storm of 1983 accounts for 2,176 m^3, the 1986 enhancement tree felling added 681 m^3, and the 1987 tree felling added 2,466 m^3. The number of pieces of large wood in Fish Creek

Table 20. Volume (m^3) of downed wood in Fish Creek in 1984, 1986, and 1987.

	Single Pieces			Clumps			Total		
	1984	1986	1987	1984	1986	1987	1984	1986	1987
Lower Fish Creek	1702	1987	1734	297	1516	3046	1999	2314	4780
Middle Fish Creek	609	307	NM[1/]	0	547	NM	609	854	NM
Upper Fish Creek	243	128	NM	152	11	NM	395	139	NM
Wash Creek	481	342	HIM	868	473	NM	1349	815	NM
Total Basin	3035	1575	NM	1317	2547	NM	4352	4122	6590[2/]

[1/] NM - Wood was not measured.

[2/] Total volume estimate was derived from actual measurements of Lower Fish Creek and 1986 estimates for remaining stream sections.

more than doubled from 1984 to 1987 (Table 21). The total number of pieces increased 36 percent from 1986 to 1987 due to tree felling.

The volume of wood in clumps in the basin shifted dramatically because of a major flood in February 1986, and because of 1987 enhancement efforts. In 1984, single pieces of large wood accounted for 70 percent of the total volume as compared to aggregates or clumps of 2 or more pieces (Table 20). The February 1986 flood clumped the wood brought in during the Christmas 1983 ice storm. For both 1986 and

Table 21. Number of pieces of large wood in single pieces and clumps in Fish Creek in 1984, 1986, and 1987.

	Single pieces			Clumps			Totals		
	1984	1986	1987	1984	1986	1987	1984	1986	1987
Lower Fish Cr.	349 1/	219	426	NM 2/	407	708	NM	626	1134
Middle Fish Cr.	247 1/	124	NM	NM	209	NM	NM	333	NM
Upper Fish Cr.	104 1/	102 3/	NM	NM	8 3/	NM	NM	110	NM
Wash Cr.	177 1/	120	NM	NM	241	NM	NM	361	NM
Total Basin	877	565	NM	NM	865	NM	NM	1430	1938 4/

1/ Includes single pieces and l-2 Key pieces per clump.

2/ NM - Wood was not measured.

3/ Only wood in large jams was recorded as clump data. Pieces in small clumps recorded as single pieces.

4/ Total volume estimate was derived from actual measurements of Lower Fish Creek and 1986 estimates for remaining stream sections.

1987, the total basin volume in single pieces dropped to 38 percent of total wood. Wood volume in clumps rose from 30 percent in 1984 to 62 percent in 1986 and 1987. Enhancement efforts in 1987 did not change the proportion of wood in clumps. Twenty-two clumps of wood account for 34 percent of all of the wood volume in Fish Creek and 54 percent of the wood volume in clumps in the basin. In 1987, there are 15 clumps with volumes between 50-100 m^3, 6 clumps with volumes between 100-150 m^3, and one jam that is over 480 m^3 in volume.

The proportion of total basin wood volume in lower Fish Creek has increased from 46 to about 73 percent (Table 20). The lower section of Fish Creek has 40 percent of the pieces of large wood found in the basin in 1984, compared to 61 percent in 1987 (Table 21). Both numbers and volume reflect enhancement tree felling as well as some wood that floated into the lower section from the middle reach during the February 1986 flood.

In 1984, clumps and jams accounted for only 15 percent of the total volume in the lower Fish Creek section. After the February 1986 flood and the 1987 enhancement tree felling, clumps accounted for 66 and 64 percent, respectively. In 1986, 5 jams were greater than 50 m^3 in volume and accounted for 52 percent of the clumped wood volume (3 = 50 - 100 m^3, 1 = 100 - 150 m^3, and 1 = 480 m^3). After enhancement efforts in 1987, over 61 percent of clumped wood was contained in 17 jams greater than 50 m^3 (10 jams = 50 - 100 m^3, 6 jams = 100 - 150 m^3, and 1 jam = 480 m^3). The 17 jams account for 28 percent of the total basin wood.

The middle section of Fish Creek gained both volume and pieces of wood between 1984 and 1986. Wood was not remeasured in 1987 because there had been no significant flood between 1986 and 1987. The proportion of the total basin wood in the middle section increased from 14 percent of the wood volume in 1984 to 21 percent of the wood volume in 1986 (Table 20). The increase was a result of enhancement efforts. In 1984, there were no clumps in the middle section; all of the wood volume was in single pieces. In 1986, clumps accounted for 64 percent of the wood volume. All clumps between 50-100 m^3 in size totaled 221 m3 and accounted for 40 percent of the clump volume and 26 percent of the total wood volume for the section. The enhancement effort accounted for 53 percent of the total wood volumes in middle Fish Creek. Between 1984 and 1986, Upper Fish Creek lost 65 percent of the wood volume in its channel, yet the total number of pieces essentially remained the same. Wood in the upper basin represented 9 percent of the volume in 1984 and declined to 3 percent in 1986. Clumps represented 39 percent of the wood volume in 1984 and only 8 percent of the volume in 1986. Clumps of wood represented 38 percent of the wood volume in 1984 and only 8 percent in 1986. The decline was due to the February 1986 flood that scattered the clumps and washed significant amounts downstream.

The amount of wood in Wash Creek declined 40 percent between 1984 and 1986. Large wood in Wash Creek represented 31 percent of the total basin volume in 1984 and 20 percent in 1986. Wood volume in Wash Creek was not increased by enhancement activities in the interval between

1984 and 1986. The February 1986 flood removed significant amounts of wood from Wash Creek, primarily from a large jam below the first bridge.

The enhancement of wood in the lower section of Fish Creek is dramatically shown in Fig. 38. In 1986, enhancement was confined to the lower 0.7 km of Fish Creek and accounted for 85 percent of the wood in this reach. In 1987, it extended from 1.8 km to the lower bridge at 7.3 km. The largest proportional input from this enhancement effort occurred between 2.8 and 4.0 km where 90 percent of the wood found was due to enhancement efforts. In 1986, 10 percent of the large wood found in lower Fish Creek was a result of enhancement efforts. Large wood from the 1987 enhancement efforts accounted for 52 percent of the wood found in the section. Enhancement efforts to date account for 56 percent of the large wood in lower Fish Creek.

The 1986 enhancement efforts in the middle Fish Creek section were concentrated in a one kilometer reach between 7.3-8.3 km (Fig. 39). The volume of large wood from felling was 454 m^3 and represented 53 percent of the total volume found in the section.

In summary, 17 percent of the total basin wood in 1986 resulted from enhancement efforts. In 1987, 37 percent of the volume of wood was felled. As of 1987, 48 percent of the large wood in the system has been a result of enhancement efforts. Most of the clumps of wood in the lower section from 0.0-0.7 km, 1.8-5.0 km, 5.6-7.0 km are a result of enhancement.

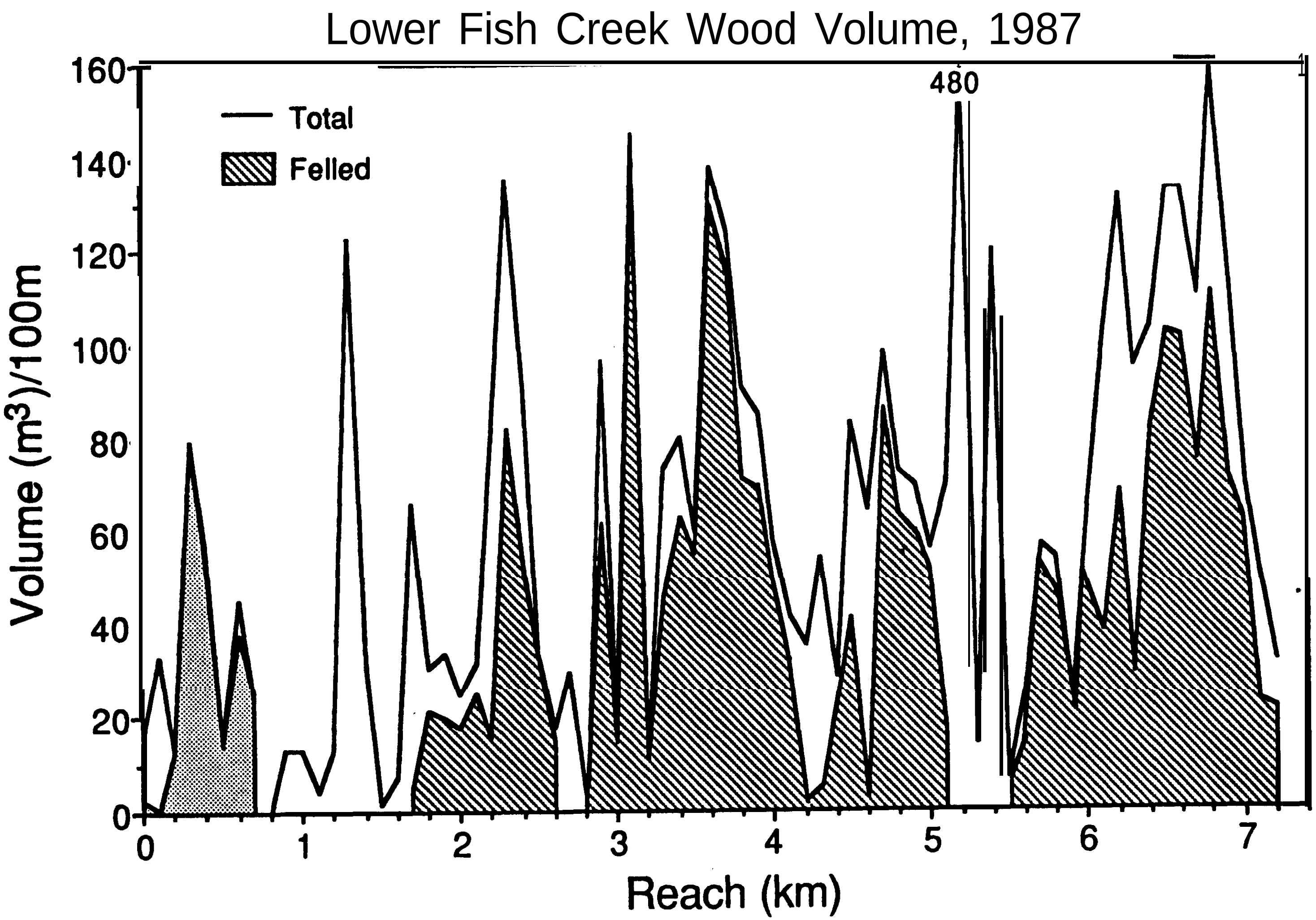


Figure 38. Distribution of wood volumes(m^3/100 m) in lower Fish Creek in 1987. 1986 felled wood is shown in the stippled area. 1987 felled wood is shown in the diagonally shaded area.

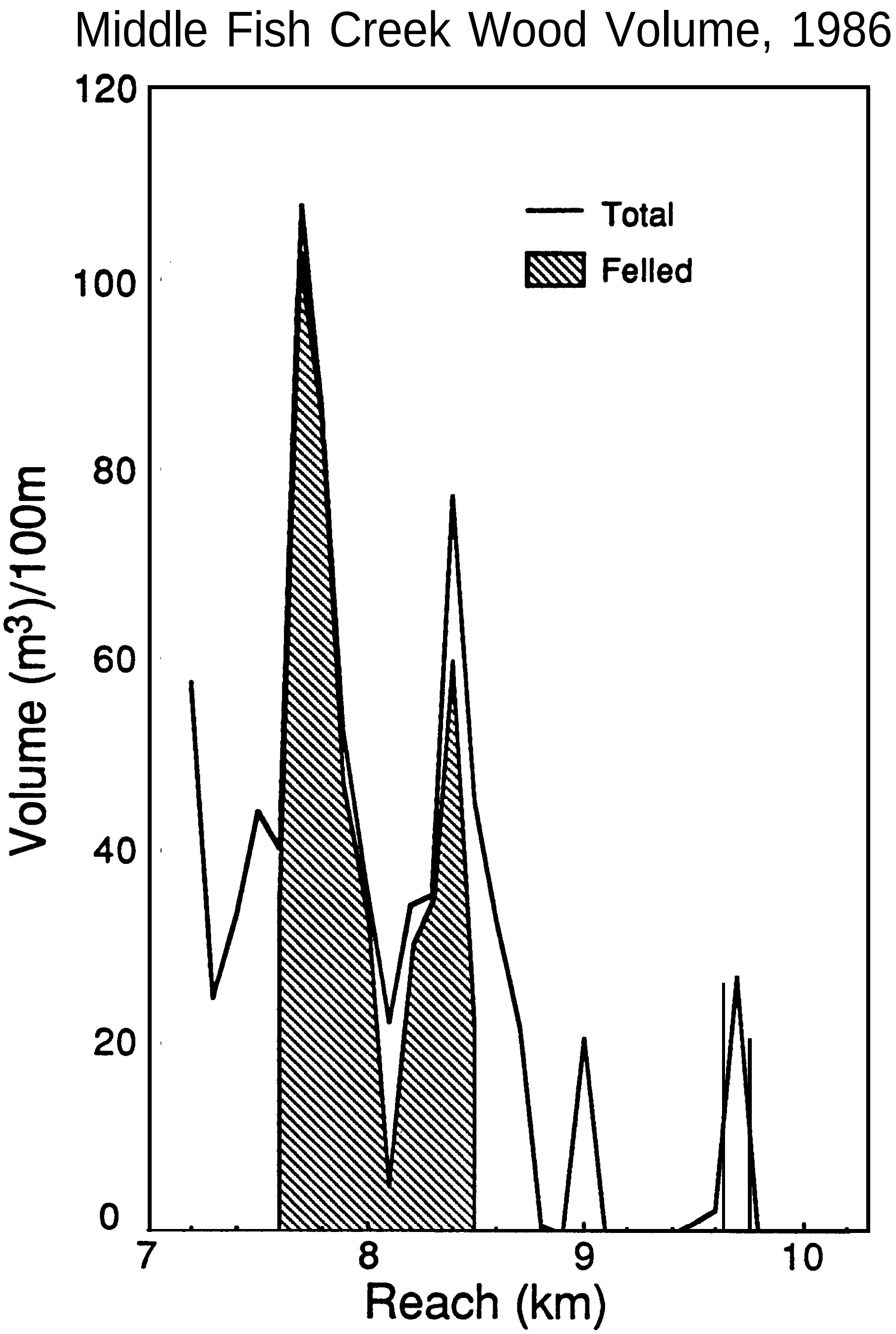


Figure 39. Distribution of wood volumes (m^3/100 m) in the middle section of Fish Creek for 1986. Diagonal shading illustrates wood felled for habitat enhancement.

The issue of how many pieces of large wood are necessary per length of stream to provide good fish habitat is complex. The literature has shown data indicating that 20 or more pieces of large wood per 100 m of stream is what one would find in an undisturbed old-growth forested stream. In 1984, we found between 4-5 pieces of wood per 100 m of stream in Fish Creek excluding clumps. The difficulty in making comparisons between the years, on the basis of wood pieces per length of stream, is apparent from the fact that in 1986 and 1987 almost 2/3 of the wood was in clumps or jams. The reaches of stream discussed

Table 22. Volume m^3 of downed wood per kilometer on Fish Creek, 1984, 1986, and 1987.

	Single Pieces			Clumps			Total		
	1984	1986	1987	1984	1986	1987	1984	1986	1987
Lower Fish Creek	233	109	237	41	208	417	274	317	655
Middle Fish Creek	196	99	NM[1/]	o	176	NM	196	275	NM
Upper Fish Creek	152	80	NM	95	7	NM	247	87	NM
Wash Creek	107	76	NM	193	105	NM	300	181	NM
Total Basin	182	94	NM	79	153	NM	261	247	395[2/]

1/ NM - Wood was not measured.

2/ Total volume estimate was derived from actual measurements of Lower Fish Creek and 1986 estimates for remaining stream sections.

previously have been normalized in Tables 22 and 23 to allow comparison of quantities of wood per kilometer of stream and by 100 m length of stream if the reader divides the numbers in these tables by 10.

What is interesting about the total volumes per km in Table 22 is that all sections had very similar loads of wood, between 200-300 m^3 per kilometer. In Wash Creek and lower Fish Creek, large volumes of wood were located in one jam on each stream. In 1986, after enhancement activities and the February 1986 flood, wood on upper Fish Creek was flushed downstream along with a big jam on Wash Creek. Deposition of this wood resulted in a net gain in large organic debris in the middle and lower sections of Fish Creek. The middle section gained over 40 percent--all of it in clumps. The lower section doubled again in 1987 due to enhancement efforts. From 1984-1987, total wood in the stream increased 50 percent even though the distribution in the sections, and clumps, has changed dramatically. Number of pieces per kilometer was difficult to determine becasue clumped pieces were not measured in 1984, and only the lower section was measured in 1987 (Table 23). However, there has probably been a near doubling of the number of pieces per kilometer in Fish Creek.

Length and Frequency of Large Wood Within the Basin

The length and diameter frequency of individual pieces of wood was highly variable throughout the Fish Creek basin (Fig. 40). There were significant differences between mean lengths and diameters of large woody debris in the four different sections of the basin.

Table 23. Number of pieces of large wood in single pieces and clumps per kilometer in Fish Creek in 1984, 1986, and 1987.

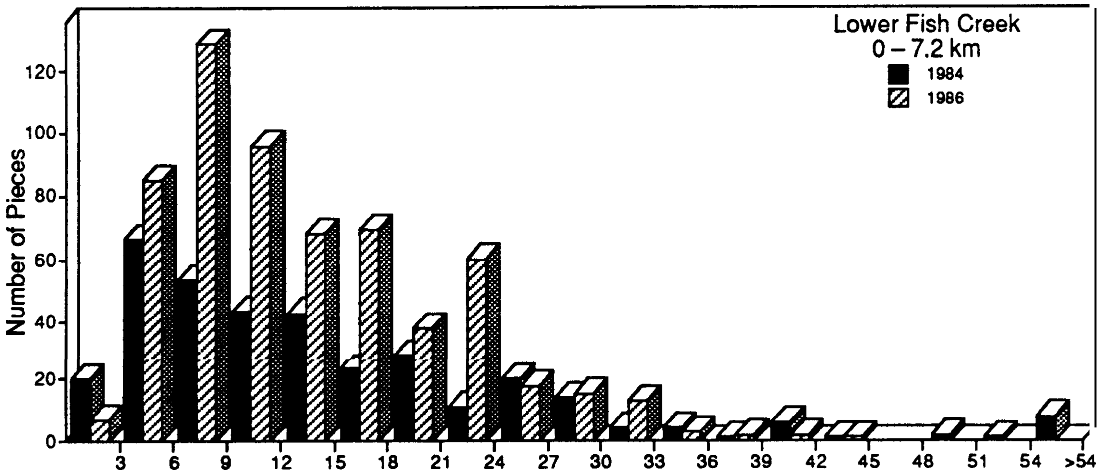
	Single Pieces			Clumps			Total		
	1984	1986	1987	1984	1986	1987	1984	1986	1987
Lower Fish Creek	48	30	58	NM[1/]	56	97	NM	86	155
Middle Fish Creek	80	40	NM	NM	67	NM	NM	107	NM
Upper Fish Creek	65	63	NM	NM	5	NM	NM	68	NM
Wash Creek	38	26	NM	NM	51	NM	NM	77	NM
Total basin	53	34	NM	NM	52	NM	NM	86	116[2/]

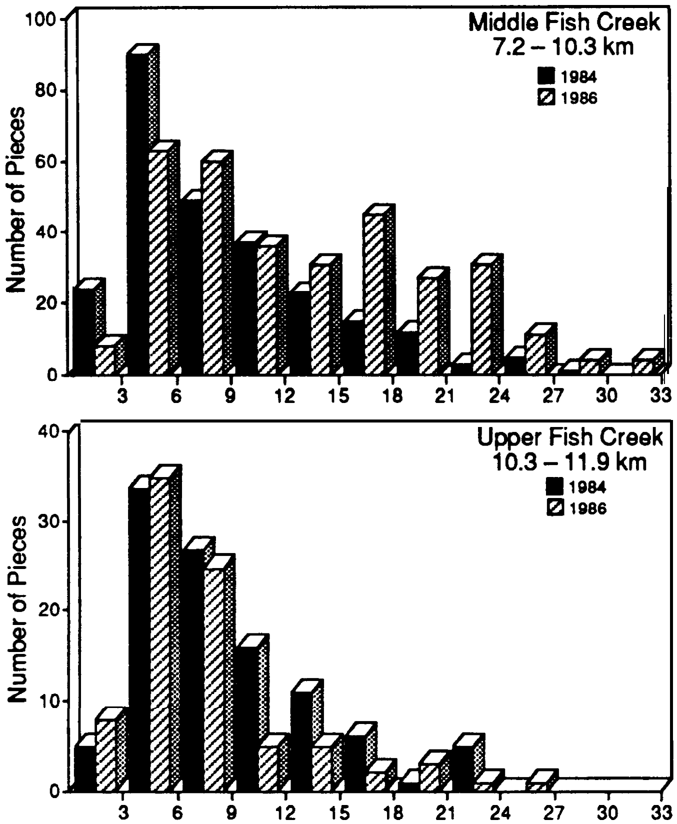
1/ NM - Wood was not measured.

2/ Total volume estimate was derived from actual measurements of Lower Fish Creek and 1986 estimates for remaining stream sections.

In 1984, Wash Creek had the largest mean diameter of pieces at 0.59 m (standard deviation (SD) = 0.24) and these pieces had an average length of 8.1 m (SD = 5.23). The average length was the smallest in the Fish Creek basin and probably reflects both the smaller drainage area and steep side slopes which result in severe breakage when a tree falls. Smaller stream discharges in Wash Creek allow smaller pieces to remain in place longer, or need a larger storm to move them.

A large storm did occur in February 1986 and rearranged large jams near the mouth of Wash Creek. Rearrangement of the jams resulted in more single pieces in Wash Creek and an average length of 9.1 m





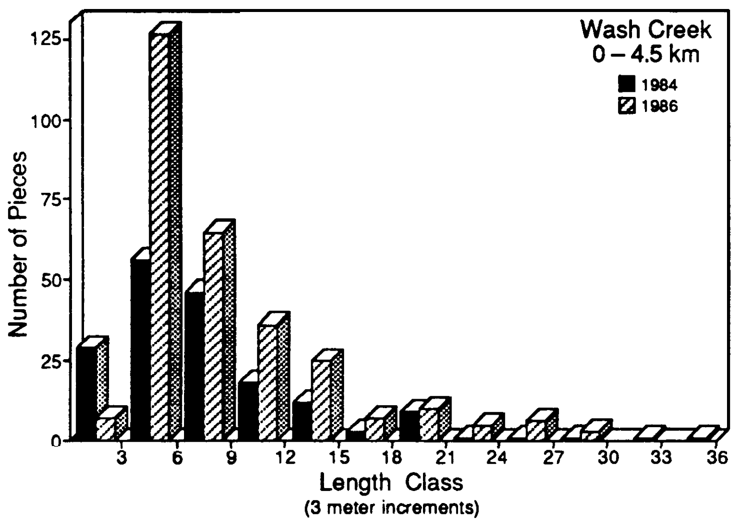


Figure 40. Frequency of large wood lengths (3 m increments) in different sections of Fish Creek measured in 1984 and 1986.

(SD = 5.8) in the 1986 survey. Smaller pieces got washed out or into jams and the average length increased one meter. The large increase in numbers of pieces was a result of the rearrangement of jams and a more inclusive measuring of all pieces (> 5 m), both single and clumped. Overall, Wash Creek lost significant volume between 1984 and 1986.

Individual wood pieces in upper Fish Creek in 1984 averaged 0.52 m (SD = .23) in diameter and 8.9 (SD = 4.6) in length. The average diameter for both 1984 and 1986 is statistically the smallest in the basin yet, in absolute terms it is not much different than the middle and lower parts of the basin. The 1986 survey determined that the 1985-1986 storm washed out 65 percent of the wood in this reach. Both average diameter and length decreased significantly to 0.42 m and 7.7 m, respectively. That the smaller pieces stayed and the larger pieces moved out went counter to our expectations. There is no explanation for this observation at present.

In 1984, the middle reach of Fish Creek had no clumps or jams present. This changed completely after the February 1986 storm and the addition of 454 m3 of old-growth trees into the section in 1986. The mean length of a piece of large wood went from 8.7 m (SD = 5.3) in 1984 to 13.1 m (SD = 7.1) in 1986 (Fig. 40). This was a result of both the storm washing the smaller pieces out of the reach and the felling of 37 trees that averaged 14.4 m in length (SD = 8.7).

The average diameter decreased 10 cm from 0.54 m in 1984 to .44 m in 1986. This was partly due to flushing of large diameter short pieces and the input of felled trees in which the large end of the bole was up on the bank and the upper end of the tree was used in the enhancement structure. The number of long pieces (>12 m) increased 2.5 times due to enhancement felling of trees. Large wood greater than 21 m in length increased more than 3-fold.

The wood in lower Fish Creek was greatly increased by the Christmas 1983 ice and wind storm. The mean length of 1984 wood in this reach was 15.1 m (SD = 9.5) and the mean diameter was 0.56 m (SD = 0.3). The diameters were in the same range as other reaches surveyed in the basin although the mean was statistically greater than the upper and middle Fish Creek reaches in 1984. The mean length of individual pieces was about twice that of any other reaches in the basin. This is related to (1) a wider floodplain in the lower basin and trees that topple without splintering against the opposite side wall as in Wash Creek, and (2) the discharge is highest at the bottom of the basin and tends to float smaller pieces to the edges or downstream to the Clackamas River.

The February 1986 storm broke up many of the large pieces left after the 1983 ice storm. The lower reach also captured many smaller pieces of wood (Fig. 40). In 1986, 57 large pieces of wood were felled into the lower portion of Fish Creek with an average length of 14.4 m (SD = 8.6). The average length of a piece of wood in lower Fish Creek decreased about 2 m to 13.1 m (SD = 7.5). The number of large pieces of wood between 12-24 m in length increased over 2.2 times from 106 to 234 pieces. The number of even longer pieces (>24 m) decreased from 61 to 54 pieces or an 11 percent reduction in 1986.

In 1987, 530 large pieces of wood, averaging 16 m in length, entered the lower section by felling. This raised the average length for the lower reach to 14.4 m (SD = 7.7). a significant increase. The number of pieces in the 12-24 m range doubled to 491 pieces in 1987. Pieces >24 m increased 44 percent (54 pieces in 1986; 78 pieces in 1987) (Fig. 41).

The average length of wood in large streams (20-50 m bankfull width) will probably not exceed 17 m in length, based on our studies of pristine basins in the North Fork Brietenbush River (Oregon Cascades) and Cummins Creek (Oregon Coast Range) where the average length was 16 m and 14.5 m, respectively. A fallen tree breaks into longer pieces when the gradient is not steep and the valley floor is wide. If it hits a steep, opposite-side slope or falls over a side slope, the breakage is greater and the pieces are shorter. This upper limit is directly related to breakage when a falling tree hits the ground.

The proportional number and volume of stumps and root wads in the Fish Creek basin is another important aspect of wood in the basin. Over 55 percent of the basin has been harvested in the last 25 years. Much of the area harvested is located above the anadromous fish zones on upper Wash Creek and upper Fish Creek. The 1986 volume of stumps in Fish Creek (Table 24) represents only 4 percent of the total wood volume of the basin, as shown in Table 21, and 9 percent of the total pieces of large wood in the basin. The frequency of occurrence was low (<l stump/100 m) and the average volume of a stump was low (1.4 m3). Stumps in lower Fish Creek represented 4 percent of the pieces found

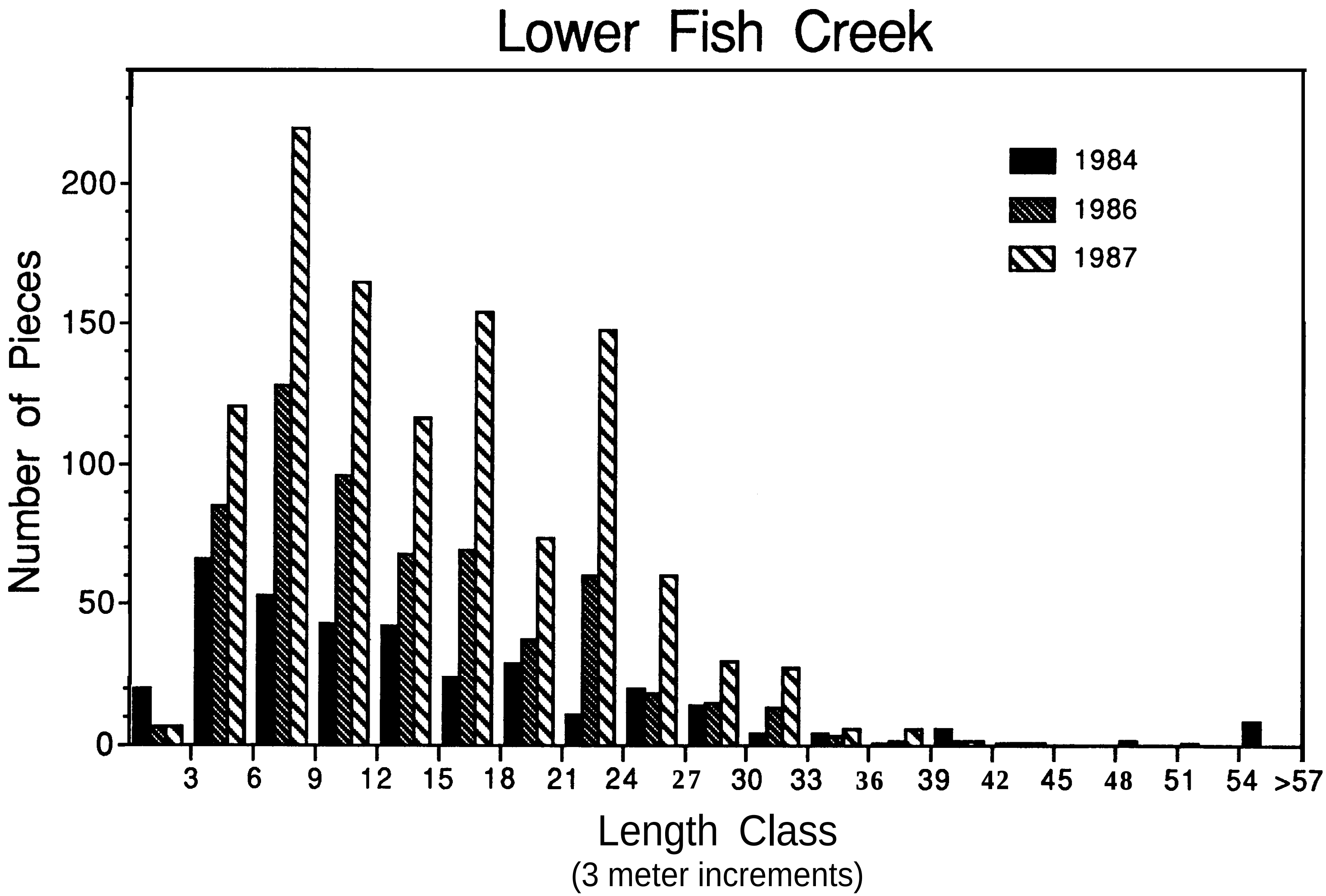


Figure 41. Length class (3 m increments) frequency of large wood in lower Fish Creek for 1984, 1986, and 1987.

Table 24. Habitat units that were influenced by wood.

	Fish Creek, September 1987							
	Without wood				With wood			
	M^2 Area	Percent Area	M^3 Area	Percent Area	M^2 Area	Percent Area	M^3 Volume	Percent Volume
Pools	18425	62	9178	58	11232	38	6601	42
Glides	14392	60	3241	56	9589	40	2581	44
Riffles	41901	53	6723	49	37798	47	7025	51
Side Chan	682	73	62	63	257	27	36	37
Totals	75400	56	19204	54	58875	44	16244	46

and 2 percent of the volume. The average volume of a stump was 60 percent greater in this section of Fish Creek over the basin mean, reflecting the greater stream power in the lower part of the basin. The proportion of stumps in the middle Fish Creek section was also low and represented 3 percent of the pieces and 1.5 percent of the volume. The frequency of stumps in the smaller tributaries, such as Wash Creek and upper Fish Creek, reflects the lower stream power and greater timber harvest activity. Stumps in upper Fish Creek accounted for 23 percent of both pieces and volume in this section. Stumps in Wash Creek represented 18 percent of the pieces and 11 percent of the section wood volumes.

In general, stumps do not play a significant role in the mainstem of Fish Creek. In the smaller forks, 1/5 to 1/4 of the wood pieces are stumps and play a major role in the potential habitat available in the basin.

Stumps tend to be less stable in high gradient streams. Thus, it is hoped that the ratio of stumps to total wood in the basin (numbers and volume) will not increase. Stumps do afford a simplified way of evaluating the effectiveness of hillslope and streamside management practices in a basin.

Wood-Related Fish Habitat

The dramatic input of wood into the Fish Creek basin has substantially increased the amount of habitat created or maintained by wood within the basin, particularly the lower section of Fish Creek. Table 25 illustrates that 44 percent of the total habitat area is influenced by the presence of large pieces of wood from downed trees and 46 percent of the total volume of Fish Creek habitat is influenced by wood. There is no data from other years to quantitatively compare to 1987. However, total volume of wood has increased over 150 percent and the total number of pieces of large wood in the basin has increased

Table 25. 1986 Summary of numbers and volumes of root wads and stumps in Fish Creek.

	Number	Number/km	x volume (m^3)	Total volume
Lower Fish Creek	24	3.3	2.1	50
Middle Fish Creek	11	3.5	1.2	13
Upper Fish Creek	25	15.6	1.3	32
Wash Creek	66	14.0	1.3	87
Total basin	126	7.5	1.4	182

over 200 percent since 1984. The most dramatic increase in wood-related habitat is reflected in the increase of clumps and small debris jams along the stream. The increase in lower Fish Creek went from 0.3 clumps/100 m in 1984 to 0.7/100 m in 1986 and doubled again in 1987 to 1.6/100 m. More clumping should result from major storms in 1987-1988 and yield further increases in edge complexity. The high percentage of riffles with clumped wood reflects the recent entry of wood to lower Fish Creek through enhancement activity. We expect much of the wood in riffles will become associated with pools, if it stays in place following 1987-88 floods, or else will be moved to the edges at bends in the stream and be associated with clumps of wood at those sites.

* * *

SUMMARY AND CONCLUSIONS

1) Evaluation of enhancement efforts in 1987 emphasized estimates of summer habitat availability, summer standing crops of juvenile anadromous salmonids, quantification of outmigrant steelhead trout and coho salmon smolts, and changes in large woody debris abundance in Fish Creek caused by enhancement activities.

2) Availability of summer habitat varies directly with the water year; surface area of summer habitat can vary by 50 percent annually. Drought conditions in the summer of 1987 resulted in the lowest estimates of available habitat since the study began in 1982.

3) Summer populations of 0+ and 1+ steelhead trout, and coho and chinook salmon were estimated at 53,400, 15,970, 37,880, and 6,290, respectively. These are the lowest estimated numbers of steelhead and highest numbers of salmon since the study began in 1982.

4) Low steelhead trout numbers in the summer of 1987 are believed due to habitat losses caused by drought, low streamflow, and heavy fishing pressure, and not related to habitat manipulations in the basin.

5) High numbers of juvenile coho salmon in the basin in 1987 are believed due to increased escapement in the upper Clackamas River, adults returning from increased production at the off-channel pond, and intensive habitat work along the edges of Fish Creek.

6) Steelhead trout smolt production in 1987 was estimated at 7,600 fish and overwinter survival of presmolts was estimated at 92 percent. High winter survival was attributed directly to a very mild winter in 1986-87.

7) Coho salmon smolt production from the mainstem of Fish Creek in 1987 was estimated at 2,600 fish and overwinter survival was estimated at 73 percent, also attributable to the mild winter of 1986-87.

8) The off-channel pond contributed over 1,230 coho salmon smolts to Fish Creek production, a 49 percent addition.

9) Habitat work on the mainstem of Fish Creek has not yet made any significant changes in populations of juvenile steelhead trout rearing in the system. Additional time is needed to evaluate steelhead response to 1986 and 1987 habitat improvements.

10) Benefit/cost analyses indicate that the off-channel pond is a cost-effective project at a production level of 1,200+ coho salmon smolts per year.

11) Habitat work in the summers of 1986 and 1987 have more than doubled the volume of large woody debris in the channel of Fish Creek. Most of the wood is in clumps at the edges where it provides excellent summer and winter habitat for juvenile coho salmon and age 0+ steelhead trout.

12) Project work in 1987 included designs with a higher risk of failure than in previous years, but only nine of the 244 wood structures (3.6 percent) failed to meet physical design objectives after weathering a 10 year flow event in December 1987.

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ACKNOWLEDGEMENTS

We would like to thank Carl McLemore, Tracii Hickman, Tom Mendenhall, Charlie Dewberry, Brad Lovatt, Miranda Raugh, Jack Sleeper, Peggy Mundy , and Paul Boehne for field work and data analysis. Phyllis Taylor-Hill persevered with good humor through the typing and organizing of the tables and text. Kathy Anderson, Dave Heller, and Harv Forsgren provided critical reviews of the manuscript.

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Appendix 1. Recalculated areas of rearing habitats in Fish Creek and associated salmonid densities and biomass.

FISH CREEK, SEPTEMBER 1982

SPECIES	HABITAT	AREA (m^2) IN SYSTEM	ESTIMATED NUMBER OF FISH BY HABITAT	ESTIMATED BIOMASS (g) OF FISH BY HABITAT	$\#/m^2$	g/m^2
COHO	Alcove	1,080	140	870	0.13	0.80
	Riffle	70,666	1,040	3,380	0.01	0.05
	Side channel	1,600	180	1,250	0.11	0.78
	Pool	8,110	290	2,850	0.04	0.35
	Beaver pond	190	260	1,200	1.37	6.34
	Total	81,330	1,910	9.550	0.02	0.12
CHINOOK	Alcove	1,080	10	70	0.01	0.06
	Riffle	70,350	0	0	--	--
	Side channel	1,600	0	0	--	--
	Pool	8,110	110	510	0.01	0.06
	Beaver pond	190	0	0	--	--
	Total	81,330	120	580	0.001	0.01
0+STRD	Alcove	2,270	2,200	5,010	0.97	2.21
	Riffle	138.590	75,240	211,660	0.54	1.60
	Side channel	4,250	5,100	12,870	1.20	3.03
	Pool	18,450	5,170	13,950	0.28	0.76
	Beaver pond	190	0	0	--	--
	Total	159,310	87,710	253,490	0.55	1.59
1+STHD	Alcove	2,270	120	2,240	0.05	0.99
	Riffle	138,590	17,260	317,210	0.12	2.29
	Side channel	4,250	460	8.400	0.11	1.98
	Pool	18,450	3,840	84,930	0.21	4.60
	Beaver pond	190	0	0	--	--
	Total	159,310	21,680	412,780	0.14	2.59
ALL SALMONIDS	Alcove	2,270	2,470	8,190	1.09	3.61
	Riffle	138,590	93.540	542,250	0.67	3.91
	Side channel	4,250	5,740	22,520	1.35	5.03
	Pool	18,450	9,410	102,240	0.51	5.54
	Beaver pond	190	260	1,200	1.37	6.31
	Grand Total	159,310	111,420	676,400	0.70	4.24

Appendix 1. (continued) Recalculated areas of rearing habitats in Fish Creek and associated salmonid densities and biomass.

FISH CREEK, SEPTEMBER 1983

SPECIES	HABITAT	AREA (m^2) IN SYSTEM	ESTIMATED NUMBER OF FISH BY HABITAT	ESTIMATED BIOMASS (g) OF FISH BY HABITAT	#/m^2	g/m^2
COHO	Alcove	1,170	220	1,080	0.19	0.92
	Riffle	104,820	5,340	29,680	0.05	0.28
	Side channel	2,230	130	380	0.06	0.17
	Pool	9,160	1,500	6,900	0.16	0.75
	Beaver pond	300	240	670	0.80	2.-24
	Total	117,680	7,430	38,710	0.06	0.33
CHINOOK	Alcove	1,170	10	30	0.01	0.03
	Riffle	104,820	490	1,960	0.01	0.02
	Side channel	2,230	--	--	--	--
	Pool	9,160	640	2,950	0.07	0.32
	Beaver pond	300	--	--	--	--
	Total	117,680	1,140	4,940	0.01	0.04
o+sTHD	Alcove	2,450	610	1,710	0.25	0.70
	Riffle	219,360	53,870	150,840	0.25	0.69
	Side channel	6,200	1,760	5,610	0.28	0.90
	Pool	20,850	3,780	12,470	0.18	0.60
	Beaver pond	300	10	30	0.03	0.11
	Total	249,169	60,030	170,660	0.24	0.68
l+STHD	Alcove	2,450	90	2,370	0.04	0.97
	Riffle	219,360	23,760	427,140	0.11	1.95
	Side channel	6,200	340	5,780	0.05	0.93
	Pool	20,850	2,800	53,960	0.13	2.59
	Beaver pond	300	0	0	--	--
	Total	249,160	26,990	489,250	0.11	1.96
ALL SALMONIDS	Alcove	2,450	930	5,190	0.38	2.12
	Riffle	219,360	83,460	609,620	0.38	2.78
	Side channel	6,200	2,230	11,770	0.36	1.90
	Pool	20,850	8,720	76,280	0.42	3.66
	Beaver pond	300	250	700	0.83	2.33
	Grand Total	249,160	95,590	703,560	0.38	2.82

Appendix 1. (continued) Recalculated areas of rearing habitats in Fish Creek and associated salmonid densities and biomass.

FISH CREEK, SEPTEMBER 1984

SPECIES	HABITAT	AREA (m^2) IN SYSTEM	ESTIMATED NUMBER OF FISH BY HABITAT	ESTIMATED BIOMASS (g) OF FISH BY HABITAT	$\#/m^2$	g/m^2
COHO	Alcove	1,080	630	2,360	0.28	2.19
	Riffle	81,610	3,310	12,740	0.04	0.16
	Side channel	2,000	1,920	6,240	0.96	3.12
	Pool	8,340	1,840	10,950	0.22	1.31
	Beaver pond	270	590	1,730	2.19	6.42
	Total	93,390	8,290	34,020	0.09	0.36
CHINOOK	Alcove	1,080	0	--	--	--
	Riffle	81,610	0	--	--	--
	Side channel	2,000	0	--	--	--
	Pool	8,340	280	3,140	0.03	0.38
	Beaver pond	270	10	130	0.04	0.48
	Total	93,390	290	3,270	0.003	0.04
0+STHD	Alcove	2,280	830	1,660	0.36	0.73
	Riffle	161,700	81,010	196,850	0.50	1.22
	Side channel	5,320	2,370	6,110	0.45	1.15
	Pool	19,180	3,850	10,240	0.28	0.53
	Beaver pond	270	0	0	--	--
	Total	188,750	88,060	214,860	0.47	1.14
1+STHD	Alcove	2,280	110	3,360	0.05	1.47
	Riffle	161,420	18,420	405,240	0.12	2.51
	Side channel	5,320	440	7,220	0.08	1.36
	Pool	19,180	4,280	112,990	0.25	5.89
	Beaver pond	270	10	330	0.09	1.20
	Total	188,750	23,260	529,140	0.12	2.80
ALL SALMONIDS	Alcove	2,280	1,507	7,380	0.69	3.24
	Riffle	161,700	102,740	614,830	0.64	3.80
	Side channel	5,320	4,730	19,570	0.89	3.68
	Pool	19,180	10,250	137,320	0.53	7.15
	Beaver pond	270	610	2,190	2.26	8.11
	Grand Total	188,750	119,900	781,290	0.64	4.14

Appendix 1. (continued) Area of rearing habitats in Fish Creek and associated salmonid densities and biomass.

FISH CREEK, SEPTEMBER 1985

SPECIES	HABITAT	AREA (m^2) IN SYSTEM	ESTIMATED NUMBER OF FISH BY HABITAT	ESTIMATED BIOMASS (G) OF FISH BY HABITAT	#/m2	g/m2
COHO	Glide	13,450	5,720	34,320	0.43	2.55
	Riffle	55,810	3,850	15,550	0.07	0.28
	Side channel	2,300	600	2,420	0.26	1.05
	Pool	11,840	1,550	9,300	0.13	0.79
	Beaver pond	190	260	1,570	1.37	8.28
	Total	83,590	11,980	63,160	0.14	0.76
CHINOOK	Glide	13,450	1,490	7,750	0.11	0.58
	Riffle	55,810	1,620	6,770	0.03	0.12
	Side channel	2,300	0	0	--	--
	Pool	11,840	1,240	6,450	0.10	0.54
	Beaver pond	190	0	0	--	--
	Total	83,590	4,350	20,970	0.05	0.25
o+sTHD	Glide	21,030	20,270	46,620	0.96	2.21
	Riffle	93,770	72,960	174,370	0.78	1.86
	Side channel	2,580	2,260	4,270	0.70	1.66
	Pool	26:380	20,180	46,410	0.76	1.76
	Beaver pond	190	100	250	0.14	1.32
	Total	143,950	115,770	271,920	0.80	1.89
l+STHD	Glide	21,030	1,800	36,680	0.09	1.74
	Riffle	93,770	12,880	262,490	0.14	2.80
	Side channel	2,580	230	4,310	0.09	1.67
	Pool	26,380	3,610	96,420	0.14	3.66
	Beaver pond	190	0	0	--	--
	Total	143,950	18,520	399,900	0.13	2.78
ALL SALMONIDS	Glide	21,030	29,280	125,370	1.39	5.96
	Riffle	93,770	91,310	459,180	0.97	4.90
	Side channel	2,580	3,090	11,000	1.20	4.26
	Pool	26: 380	26,580	158,580	1.01	6.01
	Beaver pond	190	360	1,820	1.89	9.58
	Grand Total	143,950	150,620	755,950	1.05	5.25

Appendix 1. (continued) Area of rearing habitats in Fish Creek and associated salmonid densities and biomass.

FISH CREEK, SEPTEMBER 1986

SPECIES	HABITAT	AREA (m^2) IN SYSTEM	ESTIMATED NUMBER OF FISH BY HABITAT	ESTIMATED BIOMASS (g) OF FISH BY HABITAT	$\#/m^2$	g/m^2
COHO	Glide	13,750	2,170	9,100	0.16	0.66
	Riffle	62,940	40	160	0.001	0.003
	Side channel 1/	0	0	0	0.0	0.0
	Pool	7,170	1,350	7,130	0.18	0.99
	Beaver pond 2/	190	--	--	--	--
	Total	84,050	3,560	16,390	0.04	0.20
CHINOOK	Glide	13,750	100	420	0.01	0.03
	Riffle	62,940	0	0	0.00	0.00
	Side channel 1/	0	0	0	--	--
	Pool	7,170	100	940	0.01	--
	Beaver pond 2/	190	0	0	--	--
	Total	84,050	200	1,360	0.001	0.02
0+STHD	Glide	27,380	19,490	23,350	0.35	0.85
	Riffle	114,400	94,410	244,870	0.83	2.14
	Side channel 1/	0	0	--	0.00	0.0
	Pool	24,480	13,970	42,050	0.51	1.72
	Beaver pond 2/	190	--	--	--	--
	Total	166,450	117,870	310,270	0.70	1.86
1+STHD	Glide	27,380	3,230	53,040	0.11	1.94
	Riffle	114,400	10,820	182,640	0.09	1.60
	Side channel 1/	0	--	--	0.00	0.0
	Pool	24,480	6,620	120,550	0.24	4.92
	Beaver pond 2/	190	--	--	--	--
	Total	166,450	20,670	356,230	0.12	2.14
ALL SALMONIDS	Glide	27,380	14,990	85,910	0.55	3.14
	Riffle	114,400	105,270	427,670	0.92	3.74
	Side channel 1/	0	0	0	0.00	0.0
	Pool	24,480	22,040	170,670	0.90	6.97
	Beaver pond 2/	190	--	--	--	--
	Grand Total	166,450	123,300	684,250	0.74	4.11

1/ All side channels were dry in 1986.
2/ Beaver pond was not sampled for fish in 1986.

Appendix 1. (continued) Area of rearing habitats in Fish Creek and associated salmonid densities and biomass.

FISH CREEK, SEPTEMBER 1987

SPECIES	HABITAT	AREA (m^2) IN SYSTEM	ESTIMATED NUMBER OF FISH BY HABITAT	ESTIMATED BIOMASS (g) OF FISH BY HABITAT	$\#/m^2$	g/m^2
COHO	Glide	20,370	8,520	25,670	0.34	1.26
	Riffle	58,940	6,160	22,400	0.05	0.38
	Side channel[1]	940	--	--	--	--
	Pool	20,260	22,750	79,010	1.1	3.9
	Beaver pond	190	450	1,150	2.4	6.1
	Total	100,700	37,880	128,230	0.38	1.27
CHINOOK	Glide	20,370	1,450	7,740	0.07	0.38
	Riffle	58,940	1,640	11,200	0.03	0.19
	Side channel[1]	940	--	--	--	--
	Pool	20,260	3,200	18,440	0.16	0.91
	Beaver pond	190	0	0	0.00	0.00
	Total	100,700	6,290	37,380	0.06	0.37
O+STHD	Glide	23,980	15,230	43,400	0.64	1.81
	Riffle	79,700	21,010	69,340	0.26	0.87
	Side channel[1]	940	--	--	--	--
	Pool	29,660	17,150	52,500	0.58	1.77
	Beaver pond	190	10	30	0.04	0.15
	Total	134,470	53,400	165,270	0.40	1.23
1+STHD	Glide	23,980	3,360	59,950	0.13	2.50
	Riffle	79,700	6,760	119,550	0.07	1.50
	Side channel[1]	940	--	--	--	--
	Pool	29,660	5,850	114,700	0.20	3.87
	Beaver pond	190	0[2]	0[2]	--	--
	Total	134,470	15,970	294,280	0.12	2.20
ALL SALMONIDS	Glide	23,980 79,700	28,560	136,760	1.18	5.68
	Riffle	940	35,570	222,490	0.45	2.79
	Side channel[1]		--	--	--	--
	Pool	29,660	48,950	264,730	1.65	8.93
	Beaver pond[2]	190	460	1,180	2.42	6.21
	Grand Total	134,470	113,540	625,160	0.84	4.65

1/ All side channels were nearly dry in 1987 and were not sampled for fish.
2/ One 1+ steelhead trout captured in beaver pond.