# ABUNDANCE, BEHAVIOR, AND HABITAT UTILIZATION BY COHO SALMON AND STEELHEAD TROUT IN FISH CREEK, OREGON, AS INFLUENCED BY HABITAT ENHANCEMENT

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## INTRODUCTION

Construction and evaluation of salmonid habitat improvements on Fish Creek, a tributary of the upper Clackamas River, was continued in fiscal year 1985 by the Estacada Ranger District, Mt. Hood National Forest, and the Anadromous Fish Habitat Research Unit of the Pacific Northwest Forest and Range Experiment Station (PNW), USDA Forest Service. The study began in 1982 when PNW entered into an agreement with the Mt. Hood NatIonal Forest to evaluate fish habitat improvements in the Fish Creek basin on the Estacada Ranger District. The project was initially conceived as a 5-year effort (19824986) to be financed by Forest Service funds. Several factors limiting production of salmonids in the basin were identified during the first year of the study, and the scope of the habitat improvement effort was subsequently enlarged.

The habitat improvement program and the evaluation of improvements were both expanded in mid-1983 when the Bonneville Power Administration entered into an agreement with the Mt. Hood National Forest to provide additional funding for work on Fish Creek.

Habitat improvement work in the basin is designed to increase the annual number of chinook and coho salmon, and steelhead trout smolt outmigrants.

The primary objectives of the evaluation include the:

1) 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) Evaluation of the cost-effectiveness of habitat improvements developed with BPA and Forest Service funds on Fish Creek.

Several prototype enhancement projects were constructed and tested during the first three years of the study. The Intention was to identify successful techniques that could then be broadly applied within the bash. This stepwise procedure has been largely successful in identifying the most promising enhancement techniques for the Fish Creek basin. To date, 7-10 percent of the habitat area in the basin has been treated. When work on Fish Creek is completed, it is estimated that 50-60 percent of the total habitat area used by anadromous salmonids will have received some form of treatment.

This annual progress report will focus on the projects completed in the basin In 1983, 1984, and 1985, and their evaluation. Winter habitat use and coho salmon and steelhead trout smolt production will also be emphasized.

## 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.

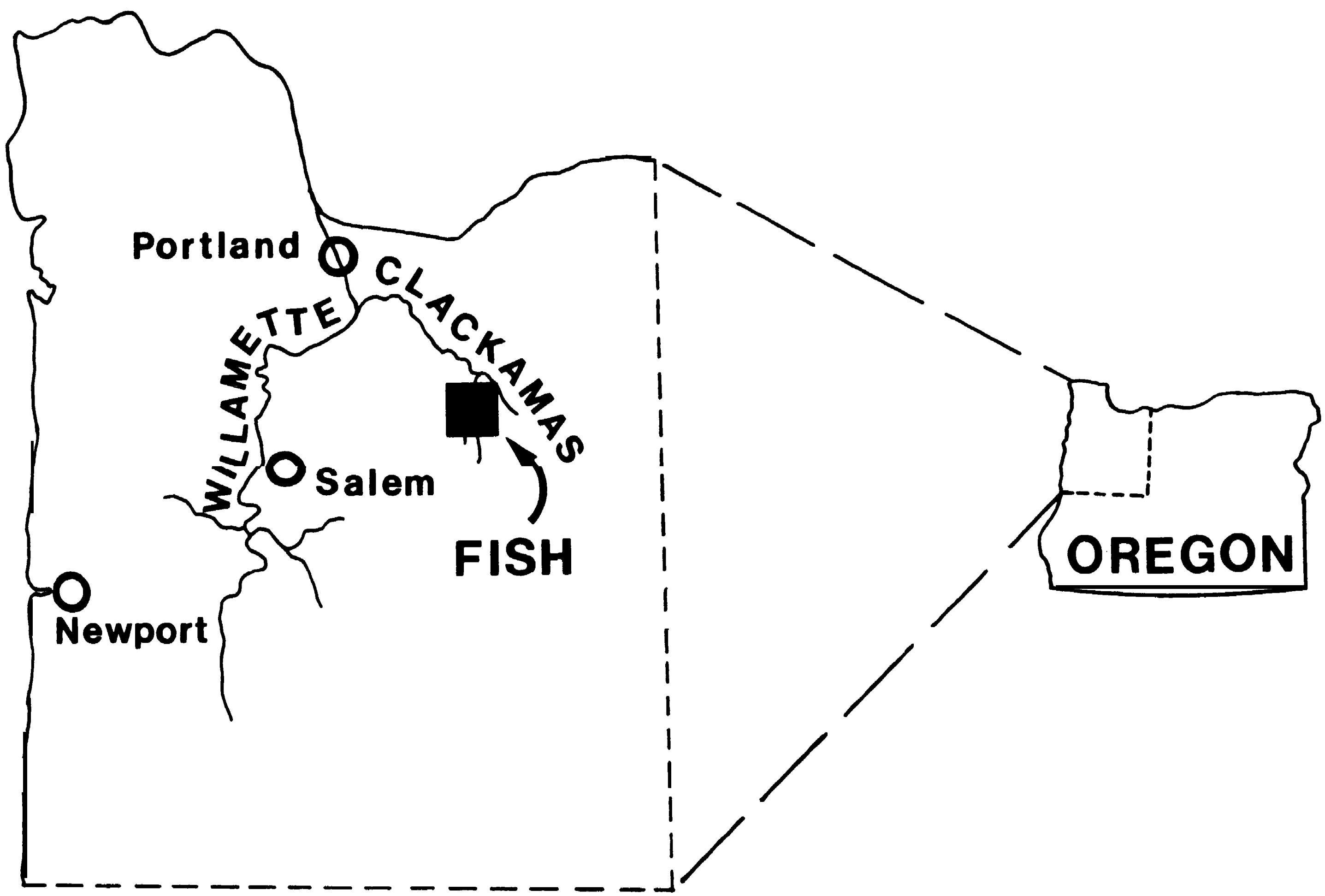



Figure 1. The Fish Creek basin is located in northwest Oregon.

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 (0. kisutch). Upper areas of the basin contain resident rainbow trout (S. gairdneri), Few resident salmonids are found within the range of anadromous fish and all rainbow trout sampled there were treated as steelhead trout. Approximately 16 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 samll 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. Special emphasis on streamside management in the basin is expected to gradually reduce high summer temperatures and eliminate periodic summer thermal stress for juvenile salmonids.

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 1982-85 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.

## DESCRIPTION OF HABITAT IMPROVEMENTS

Two new prototype habitat improvements were constructed on Fish Creek In fiscal year 1985. A new off-channel pond was completed along the west bank of Fish Creek at river km 3.5. The pond and its outlet stream were desIgned to enhance coho salmon spawning and rearing habitat by creating about 1500 $m^2$ of new habitat In the basin. Two new alcove habitats were constructed along the east bank of Fish Creek, also at river km 3.5, to provide additional winter habitat for coho salmon and steelhead trout, and resting habitat for fish during high fall and spring flows. The alcoves were excavated with a backhoe In a reach where little quiet edge habitat previously exIsted.

A number of modifications to existing projects were made in fiscal 1985. The flood overflow channel that was developed in 1984 at km 1.0 to enhance salmonid spawning and rearing habitat was significantly altered. A new flow control structure was added to the Intake, and large woody debris and boulders were placed within the channel to add habitat complexity and act as energy dissipatiors. The south Inlet stream to the off-channel pond developed in 1983 was also altered by adding gravel to enhance spawning habitat for coho salmon in a short reach between the pond and the outfall of the inlet pipe.

Evaluation of habitat improvements completed on Fish and Wash Creek In the summers of 1983 and 1984 were continued in 1985. Each type of Improvement completed during the past three years (Fig. 2) is described In the following pages.

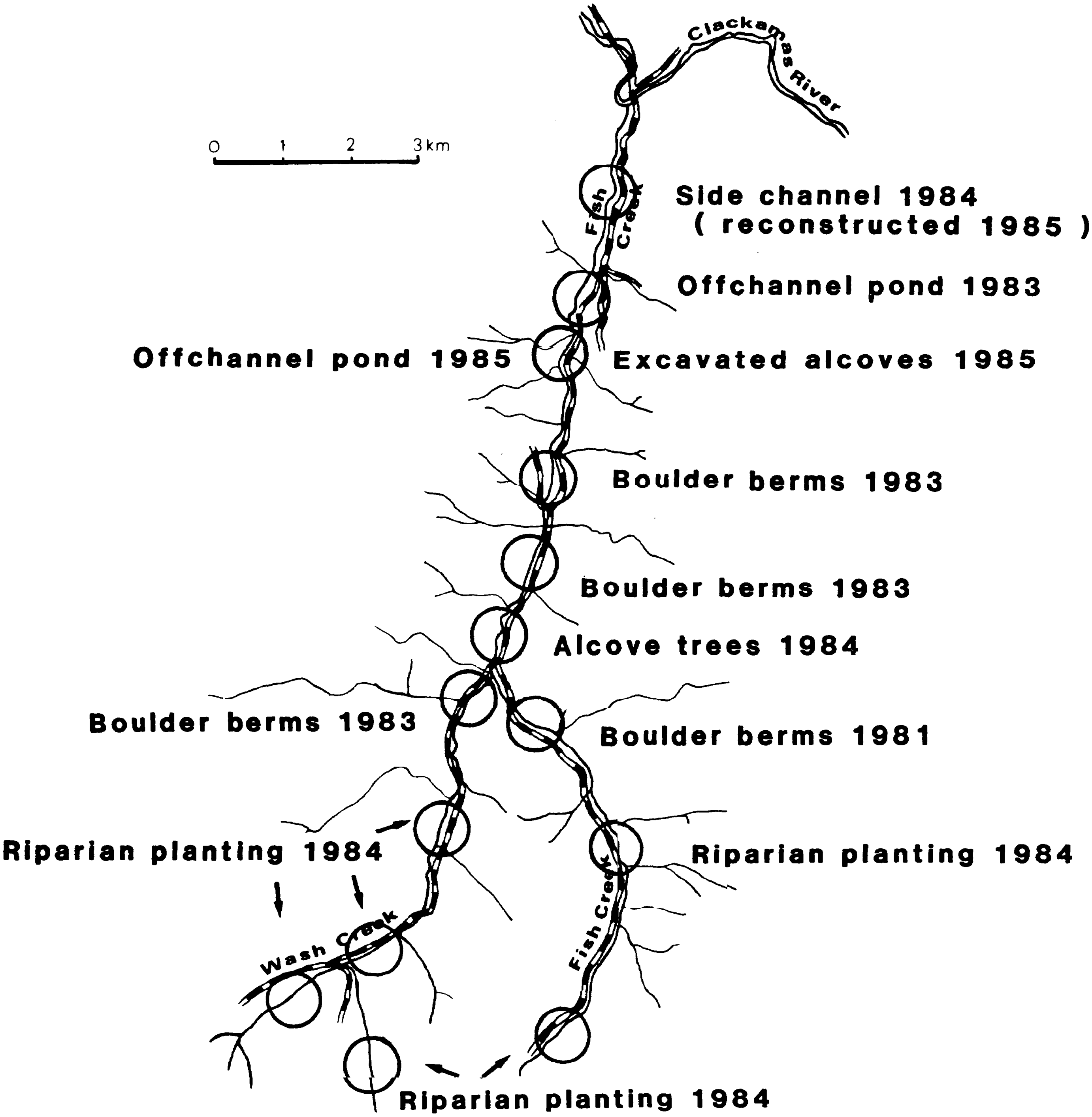



Figure 2. Habitat enhancement projects completed in Fish Creek-basin in 1983, 1984, and 1985.

## 1983 Habitat Improvements

### Boulder Berms

Twenty-one boulder berms were constructed with heavy equipment by removing the boulder armor layer from the streambed at specific locations and stacking the boulders in a V-shaped curve oriented downstream. There was some question as to whether cross-channel berms constructed with boulders could withstand winter flows on Fish Creek. The berms were designed to withstand a flood with a 5-year recurrence Interval. The berms successfully withstood high flows during the winter of 1983-84, but a 10-15 year event In the winter of 1985-86 substantially changed the physical structure of 16 of the 21 berms (See Effects of February 1986 Flood, p. 69). Finished berms ranged from 1 to 1.5 m In height and up to 30 meters long. The berms were designed to capture and retain spawning gravel for steelhead trout and coho salmon. All but 3 of the berms extended from bank to bank across the stream.

### Eastside Off-channel Rearing Pond

An off-channel coho rearing pond was developed by building a gravity-feed pipeline from Fish Creek to an ancient flood terrace on the east bank of Fish Creek about 200 m below the pipeline intake. The 25 cm diameter pipe Is about 135 m in length and is capable of delivering about 35 1/set to the pond. The pond, which formerly was dry in summer, is approximately 90 m in length and 60 m In width. Depth varies from about 0.2 m to 1.25 m, and the surface area is about 0.5 hectares. Volume of the pond Is about 3,600 $m^3$. Water from the pipeline maintains a near constant water level in the pond throughout the year. A second source of water augmentation for the pond was developed by diverting a small tributary stream at the northeast end of the pond. The stream formerly bypassed the pond but now flows directly into the north end.

## 1984 Habitat Improvements

### Perennial Side Channel

A flood overflow channel about 200 m in length located at km 1.0 on Fish Creek was developed by excavating an inlet from Fish Creek to provide perennial flow, and by downcutting the outlet to provide easy upstream access for adult and juvenile salmonids. Water velocity and turbulence in the channel were controlled by installation of several rock weir structures. The channel inlet was armored with logs and cobbles to prevent erosion. The channel was designed to provide off-channel spawning habitat for chinook and coho salmon, and off-channel rearing for juvenile salmonids with special emphasis on improved winter rearing habitat. The 1985 flood event caused substantial changes in the channel (See Effects of The February 1986 Flood, p. 69).

### Alcove Enhancement

A prototype project was undertaken by the Estacada Ranger District and Oregon National Guard in late summer of 1984 to increase the complexity of alcove edge habitats along mains-tern Fish Creek in the vicinity of km 8.5. Several Western Red Cedar (Thuja plicata), Douglas-fir (Pseudotsuga menziesii), and Western Hemlock (Tsuga heterophylla) trees were felled into Fish Creek with explosives. An attempt was made to direct each tree to a preselected point to increase the carrying capacity of edge alcoves for juvenile salmonids. In September of 1984, 12 trees were blasted into the stream. No attempt was made to secure the trees in place. An evaluation of physical and biological changes caused by the trees was initiated at six sites in August 1984.

### Riparian Revegetation

As a result of logging, stream surface shading has been reduced on numerous perennial tributaries in the upper Fish Creek basin. A portion of the riparian zone, totalling 4 acres in six clearcuts, was planted with 2-year old cottonwood in the spring of 1984. The purpose of plantings in the clearcuts was to accelerate regrowth of shading, vegetation and reduce solar heating of upper Wash Creek.

## 1985 Habitat Improvements

### Eastside Off-channel Pond

Fifteen $m^2$ (surface area) of spawning gravel were created by placing 10 $m^2$ of drain rock in the inlet channel. Five to ten pairs of spawning adult coho salmon can be accommodated per year on these sites. Juveniles produced at these sites will provide recruitment for the pond, assuming there is adequate adult escapement.

Westside Off-channel Pond

The methods used to develop a new off-channel pond on the west bank of Fish Creek were similar to those used on the previous pond (Everest et al. 1985). Approximately 90 m of 30 cm diameter pipe was laid on a minus 0.5 percent grade from a pool in Fish Creek through the streambank to the upper end of an abandoned channel complex (Fig. 3). The pipe was fitted with a control valve. A log weir was constructed to act as a control structure at the outlet of the pipe. The inlet of the pipe was protected with a treated timber crib filled with rock. The crib also acts to diffuse the surface area of water entering the pipe, and might prevent the strong suction that sometimes plugs the eastside pond inlet pipe with debris following storm events.

A fish ladder and upstream-downstream migrant trapping facility were constructed at the pond outlet. The design was similar to that used on the eastside facility (Everest et al. 1985).

Alcove Ponds

Two alcove ponds were excavated with a backhoe on the east bank of Fish Creek at stream km 3.5 (Fig. 3, 4). The floodplain was broad and streambanks were low In this area. Excavation followed along the routes of existing overflow channels on the elevated floodplain in an attempt to reduce the amount of excavated material.

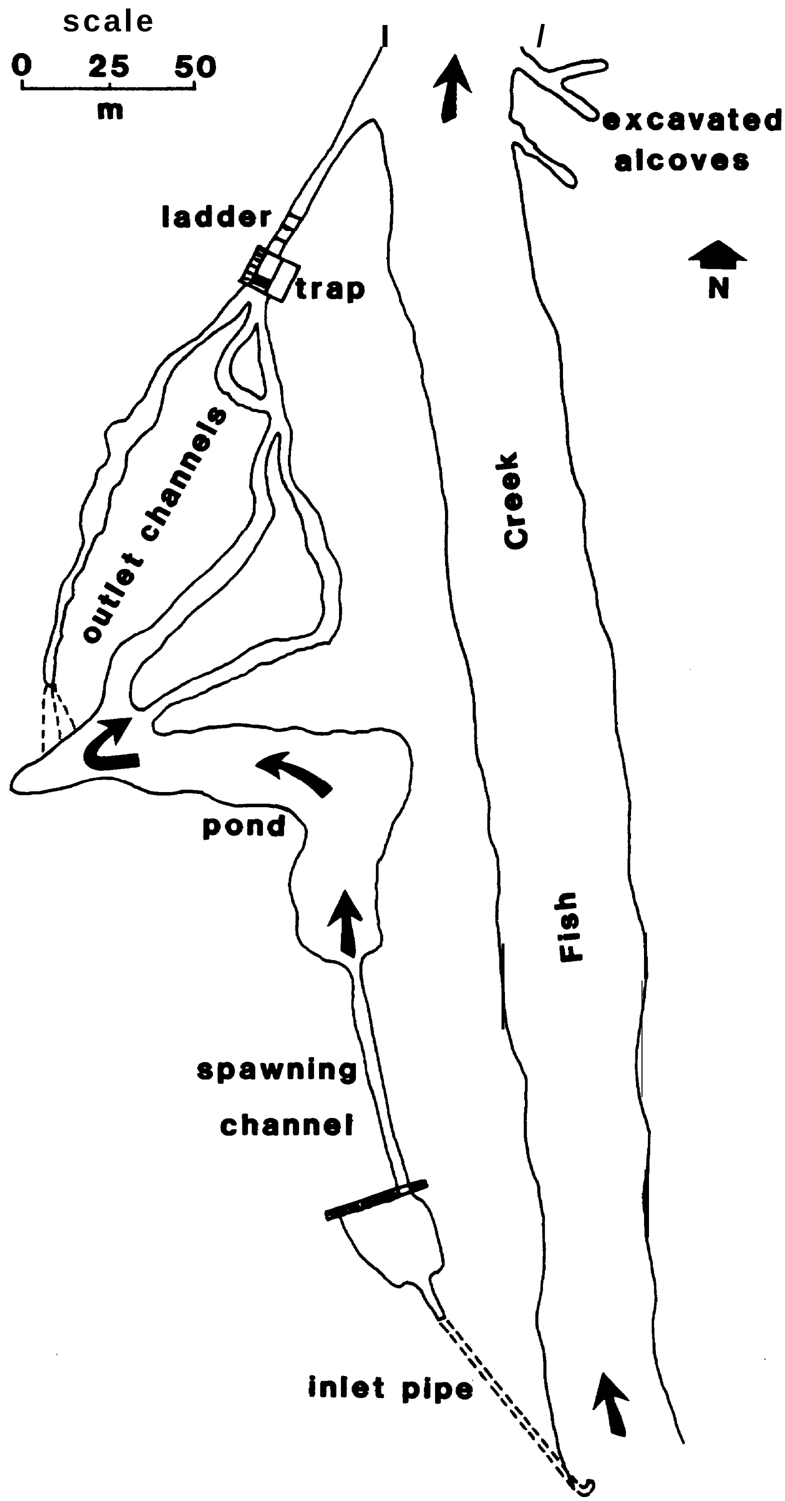



Figure 3. Diagrammatic sketch of westside offchannel pond and constructed alcoves at km 3.5 on Fish Creek.

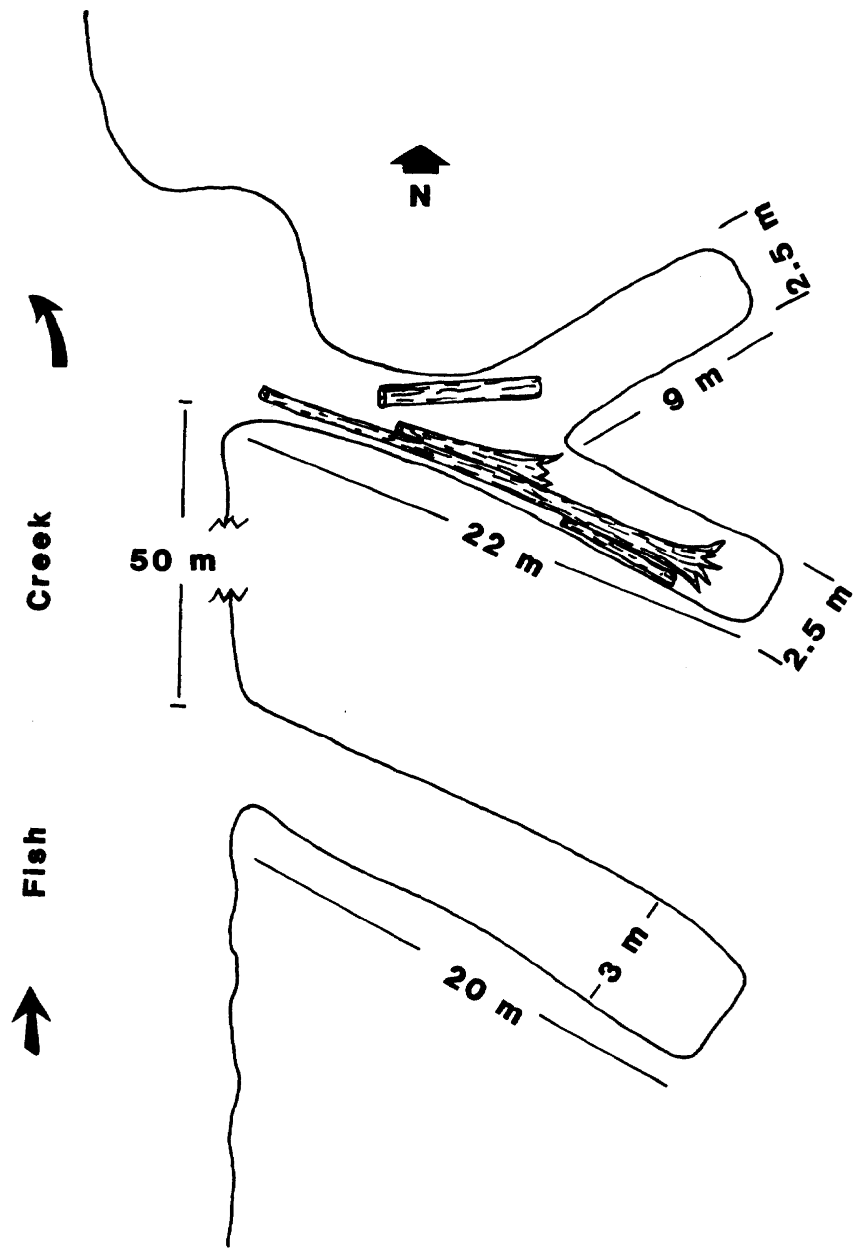



Figure 4. Configuration and dimensions of constructed alcoves at km 3.5 on Fish Creek,

Perennial Side Channel

The perennial side channel constructed in 1984 was modified in 1985 to improve its function. In order to reduce winter flows into the side channel, an inlet control structure was built with rocks and logs. Primary construction was completed with a backhoe. Additional work with organic debris was accomplished by hand labor. Lower flows during winter are expected to improve overwIntering habitat In the channel. The physical structure in the channel was also increased. One log sill, one large root wad, four loose logs, five boulder berms, three group boulder clusters, three flow deflectors and four rubble overwinterIng areas were built. These structures provide additional complexity to the channel and elevation controls to prevent channel downcutting.

## METHODS AND MATERIALS

An important part of the habitat enhancement evaluation on Fish Creek was 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 were also 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 (Fig. 5). 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 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 some 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

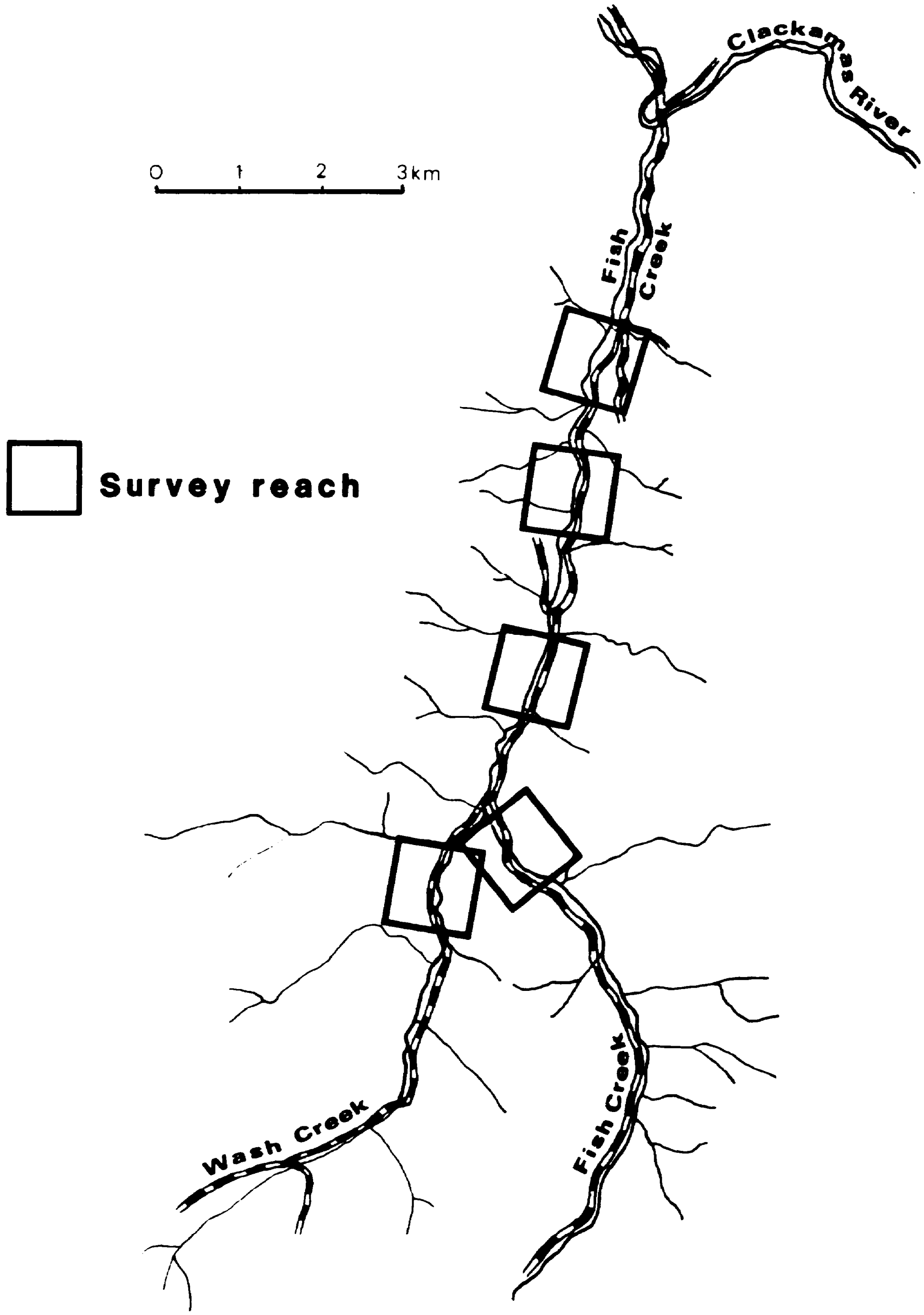



Figure 5. Physical habitat was surveyed at five 0.5 km reaches in Fish Creek basin.

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 preferentially occupied by the three anadromous fish species present in Fish Creek.

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

The habItat survey conducted in August 1985 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 survey done in 1985 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 16.1 km of anadromous habitat was classified according to the five habitat types and its length, width, and mean depth was estimated. In addition, on every 20th unit of each habitat type, 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.

When comparing the 1982-1984 methods of estimating habitat with the methods used in 1985, an error of expansion to total habitat area in the basin was found in the 1982-84 data. The error stemmed from: (1) overestimation of the total stream length available to anadromous salmonids, (2) overestimation of the mean wetted channel width in 1982, and (3) an understatement of the total length of survey reaches where surface area and volume of habitat types were measured. These combined errors resulted in a significant overstatement of the total habitat area in 1982-84. These errors have been corrected in this report.

The overestimation of habitat area in 1982-84 resulted in an overestimation of the total fish populations in the basin and in the report. The previous estimates of fish density and conclusions regarding limiting factors in the basin remain essentially unchanged.

## 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 (Fig. 6). 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 (3/16") block-nets at the upstream and downstream boundries of each site and either electro-fishing 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.

Diver counts of fish were made In some 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, then moved simultaneously upstream recording the number of fish by species and age-class. After

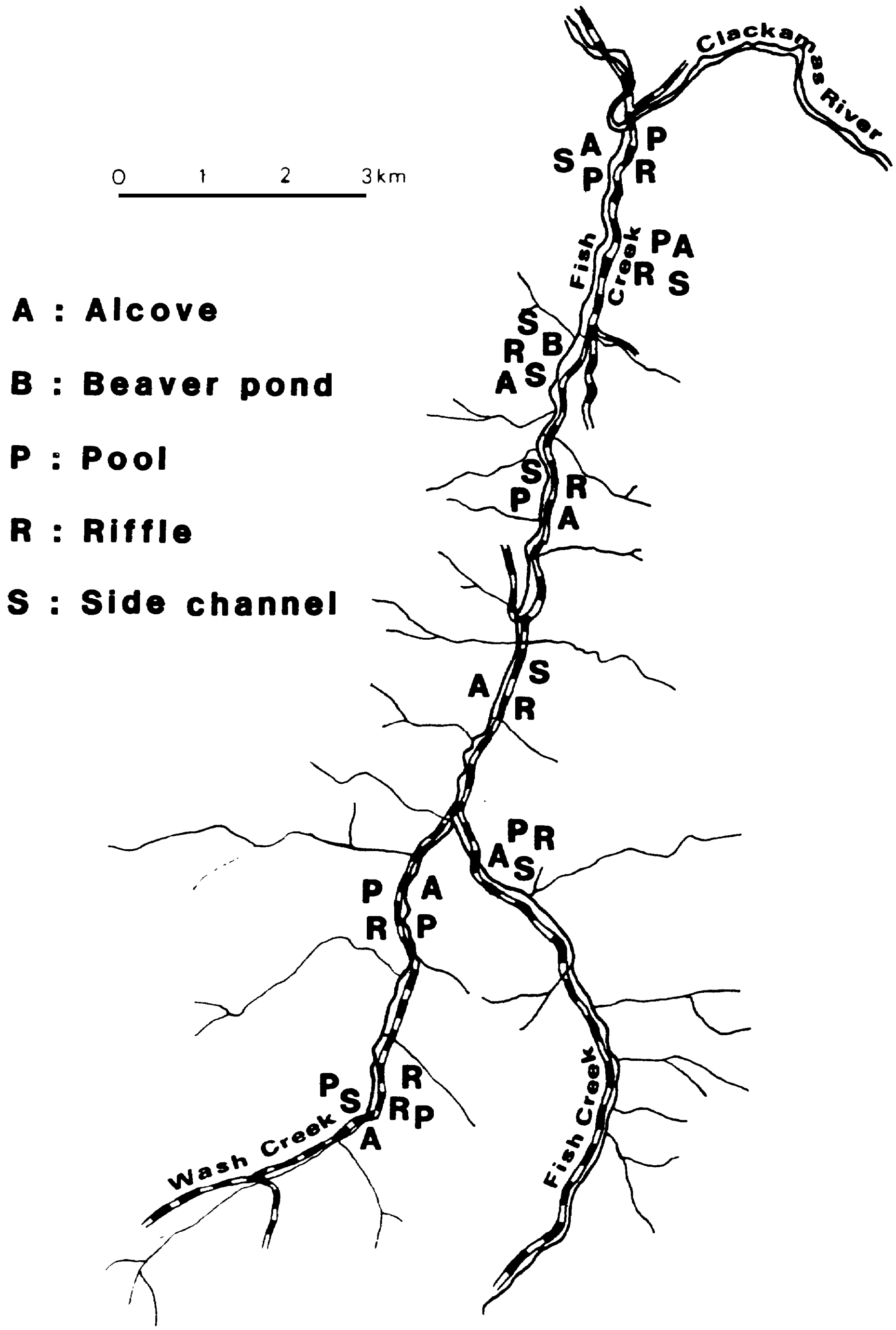



Figure 6. Fish populations were sampled at 8 locations in Fish Creek basin. Thirty-five individual habitat units were sampled, 1982-1984.

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.

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 for additional numbers that were measured only were determined by using length/weight frequency calculations 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.

## Fish Population Estimates 1985

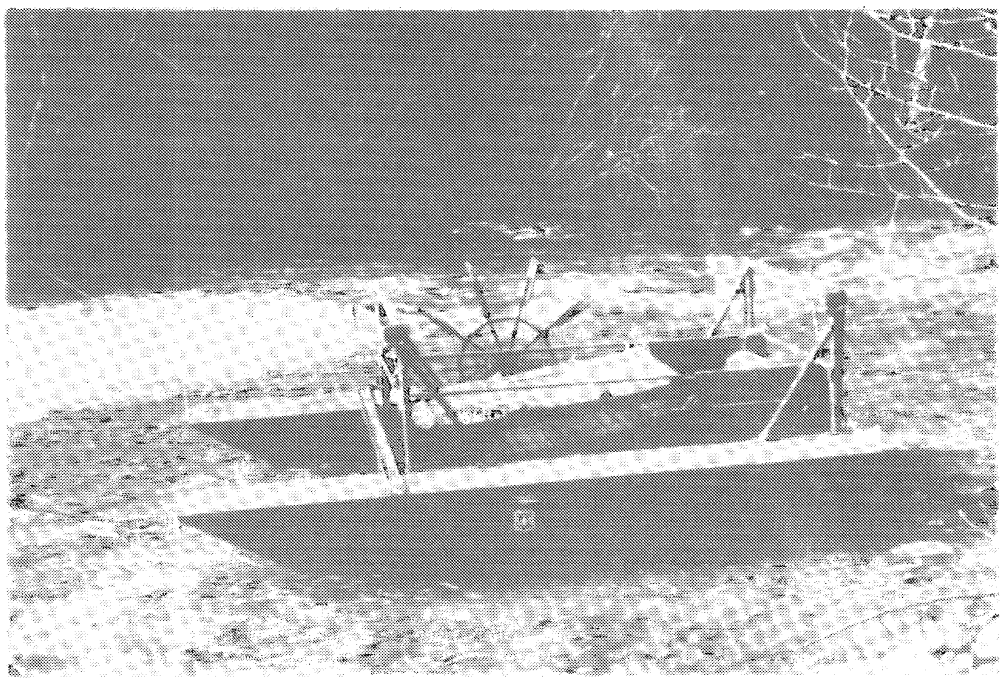
Fish numbers in 1985 were estimated by direct observation with a mask and snorkel and by electrofishing. Direct observations were made by a team of two divers in ten percent of the units of each habitat type. The units in which observations were made were determined by systematic sampling (Hankin in press). Counts were made on a total of 20 riffles, 15 pools, 12 glides, and 1 side channel. 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 was conducted at reference sites established in previous years (Everest and Sedell 1984). 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 $cm^2$ (3/16") block-nets at the upstream and downstream boundries 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). The number of fish weighed varied with the sample size. All individuals were weighed when there was less than 20 fish captured. To avoid bias, every other fish was weighed when there were between 21 and 40 individuals and every third fish weighed when there were more than 41. Weight measures were made to the nearest 0.1 g with an Ohaus Dial-O-Gram 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 was quantified by use of a floating smolt trap. The trap (Fig. 7) 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



gure 7 Humphrey trap used to sample downstream migrant coho salmon and steelhead trout smolts on Fish Creek.

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/set.

The trap was fished 0.3 km above the mouth of Fish Creek by positioning it with cables in high velocity water at the stream thalweg (Fig. 8). 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 the upper axle, the fish drop by gravity into a holding box that can maintain more than 100 fish for several days. Debris that accumulates in the holding box is removed automatically by a rotating self-cleaning drum screen.

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 continously 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

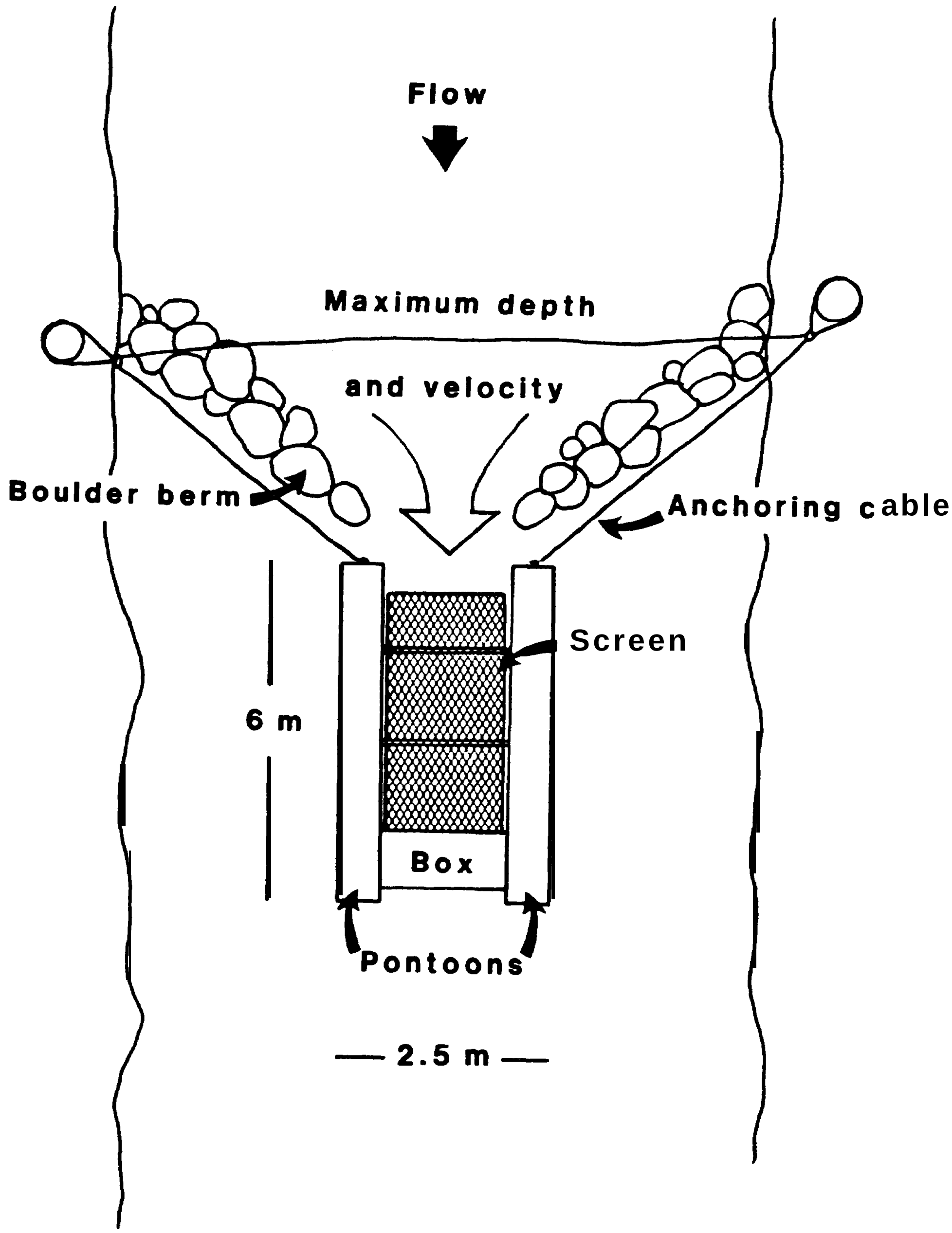



Figure 8. Schematic diagram of Humphrey trap in operating position.

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.

## Winter Observations

The distribution and density of juvenile salmonids in lower and middle Fish Creek, and Wash Creek to the first bridge upstream, were sampled monthly from September to November, 1985. High flows and high turbidity levels precluded sampling in December. Twenty percent of the pools and 10 percent of the riffles and glides were systematically sampled each time. In total, 30 pools, 10 riffles, and 7 glides were sampled. A single diver began at the downstream end of the habitat unit and proceeded upstream, counting all visible fish. Cobbles and boulders of various sizes were also turned by the divers to determine to what extent fish were hiding in interstitial spaces in the substrate.

Physical features of each habitat unit in which observations were made were also recorded. The length, width, and depth were estimated. A correction factor (see section on summer work for explanation) was used to adjust for any estimator bias. The following estimates were also made: (a) size of the dominant substrate particle in the unit; (b) size of the subdominant particle in contact with the dominant particle; (c) percent of the dominant particle imbedded by the subdominant; (d) percent of area occupied by the dominant particle; (e) depth around the dominant particle; and (f) number of clusters formed by the dominant particle. We attempted to relate these features to the number of fish of a given species or age-class per linear meter of habitat.

Observations on the response of 0+ and l+ steelhead trout were also made In laboratory streams (Reeves et al. 1983) located at the Pacific Northwest Forest and Range Experiment Station, Corvallis, Oregon. Fish were captured with an electroshocker, bought back to the laboratory and placed in the channel. They were allowed to recover and acclimate to the channel for 10 days before observations began. Water temperature was decreased from 9° to 2°C over 20 days. Daily temperatures varied 2°C between the high and low.

Fish were observed dally during a feeding and a non-feeding period. The numbers of each age-class that were active and inactive were recorded. The location, habitat, and substrate in which the fish were located were also noted.

## RESULTS

### Habitat AvailabIlity 1982-1985

The area of major habitat types for anadromous salmonids in Fish Creek has been estimated in late summer each year from 1982 through 1985. A new method of estimating habitat area was used in 1985, and previous estimates of area were recalculated when an expansion error was found in the 1982-1984 estimates. The differing techniques used in the 1982-84 period, and in 1985, resulted in some changes in estimates of area for the various habitat types (Table 1). The improved method for estimating habitat area used in 1985 is believed to be more accurate than the techniques previously used.

Table 1. Area ($m^2$) of habitat available to anadromous salmonids on Fish Creek, September 1982-1985.

| | 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 |
| Mean | 21,220 | 153,360 | 21,030 | 4,590 | 2,330 | 240 | 185,290 |

1/ Does not include habitat created by enhancement projects.

Fish Creek is a steep gradient, high energy, riffle dominated system with a channel heavily armored with boulders and large rubble. The area of habitat types in summer varied from year to year as minimum streamflow varied between 1982 and 1985. 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. In 1985, when alcoves were eliminated as a habitat type and glides were added, the ratio of habitat types appeared to change because glides had previously been included primarily with riffle habitat. The percentage of each habitat type in 1985 was: riffles, 65 percent; pools, 18 percent; glides, 15 percent; side-channels, 2 percent; and beaver ponds, 0.1 percent.

The total area of summer habitat in the system varied directly and significantly with streamflow (Fig. 9). 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 other common characteristics. Using 1982 as the base year with a flow index of 1, mean flows in August 1983, 1984, and 1985 were, 1.6, 1.2, and 0.9, respectively. Total habitat available to anadromous salmonids on Fish Creek in late summer is directly related to these indices. The higher the minimum streamflow, the greater the available area and volume of available habitat.

The distribution of habitat used by rearing juvenile anadromous salmonids varies by species (Fig. 10). Steelhead trout use the entire area accessible to anadromous salmonids while chinook and coho salmon use only about the lower one-third of the system. The area of each habitat type available to each species is listed in Table 2. An annual summary

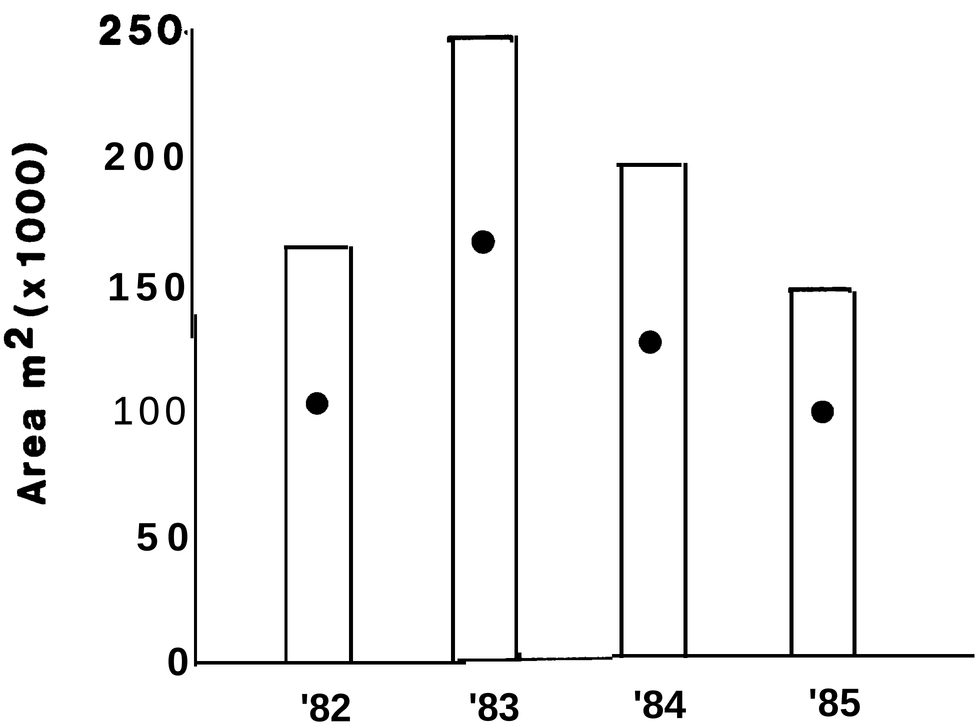



Figure 9. Area of summer rearing habitat available to anadromous salmonids on Fish Creek varies according to low Sumner streamflow. Dots represent index to streamflow.

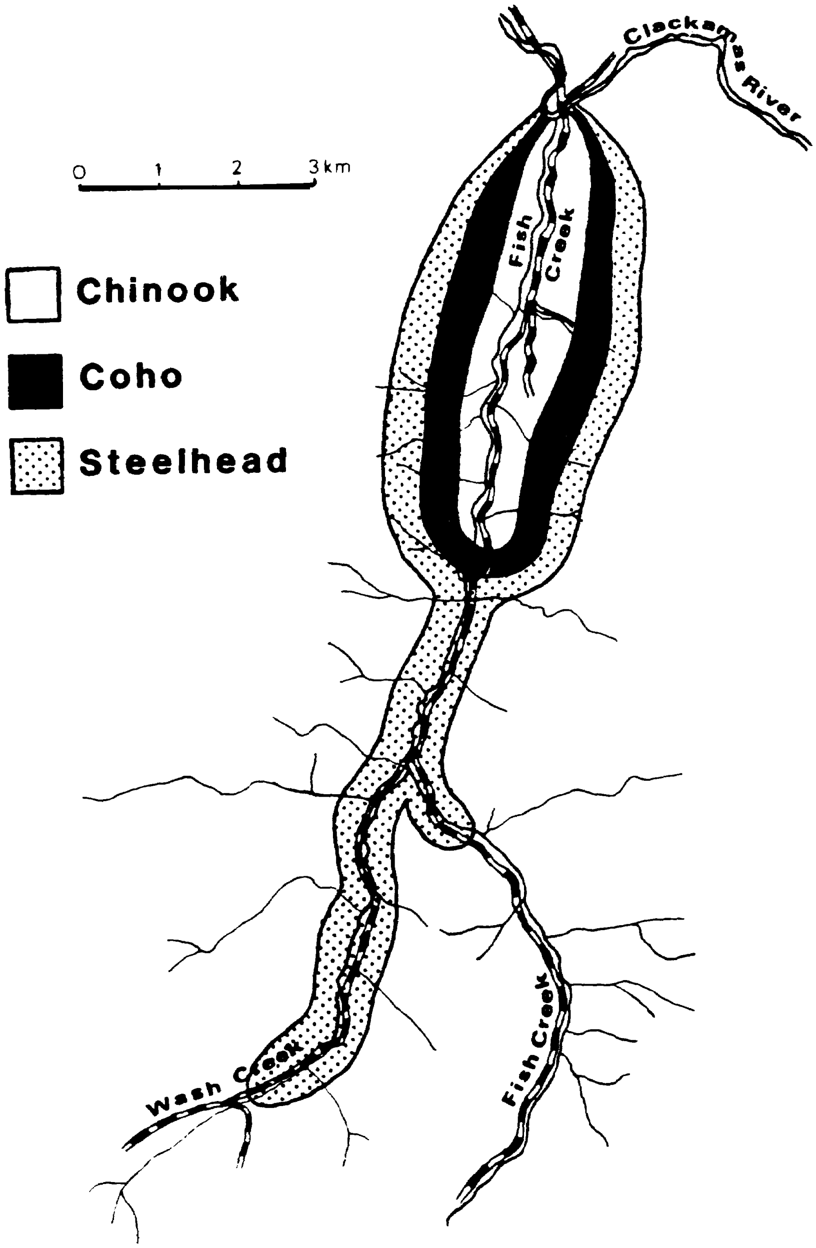



Figure 10 Distribution of juvenile anadromous salmonid in Fish Creek

Table 2. Area ($m^2$) of habitat types utilized by coho and chinook salmon on Fish Creek, 1982-1985.

| | 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 |
| Mean | 9,390 | 78,150 | 13,450 | 2,030 | 1,110 | 240 | 94,000 |

[1/] Does not include habitat created by enhancement projects.

of habitat availability and use by salmonids for the 1982-85 period Is presented in Appendix I.

## Salmonid Populations and Habitat Utilization 1982-1985

Steelhead trout were the dominant species of anadromous salmonid in Fish Creek during the 1982-85 period. Age O+ and l+ juveniles accounted for 90 to 98 percent of the total salmonid population (Table 3). Underyearling (0+) steelhead were the dominate age-class, comprising 66 to 79 percent of the total salmonid population during the same period. Coho salmon contributed 2 to 9 percent, and chInook 0.1 to 3 percent, to the total standing stock of salmonids in the basin (Table 3).

Table 3. Populations of juvenile anadromous salmonids in Fish Creek, September, 1982-1985.

| | 0+ Steelhead | | 1+ Steelhead | | Coho | | Chinook | | |
|---|---|---|---|---|---|---|---|---|---|
| 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 |
| Mean | 87,900 | 74.4 | 21,350 | 18.1 | 7,400 | 6.3 | 1,480 | 1.3 | 118,130 |

Populations of 0+ steelhead trout have been highly variable during the 4 years of the evaluation, averaging about 88,000 fish (± - 30 percent) annually (Table 3). The reasons for the high variability are complex and related both to seeding rates (Fig. 11) and environmental variables (Fig. 12). Numbers of steelhead trout fry show a weak direct correlation (r = 0.36) with the number of adult winter steelhead trout passing North Fork Dam the previous winter and spring, and a strong inverse correlation (r = -0.92) with low summer streamflow. A direct correlation between spawners and fry would be expected when the quantity and quality of spawning habitat is adequate to accomodate increased numbers of adults. The inverse correlation with minimum summer

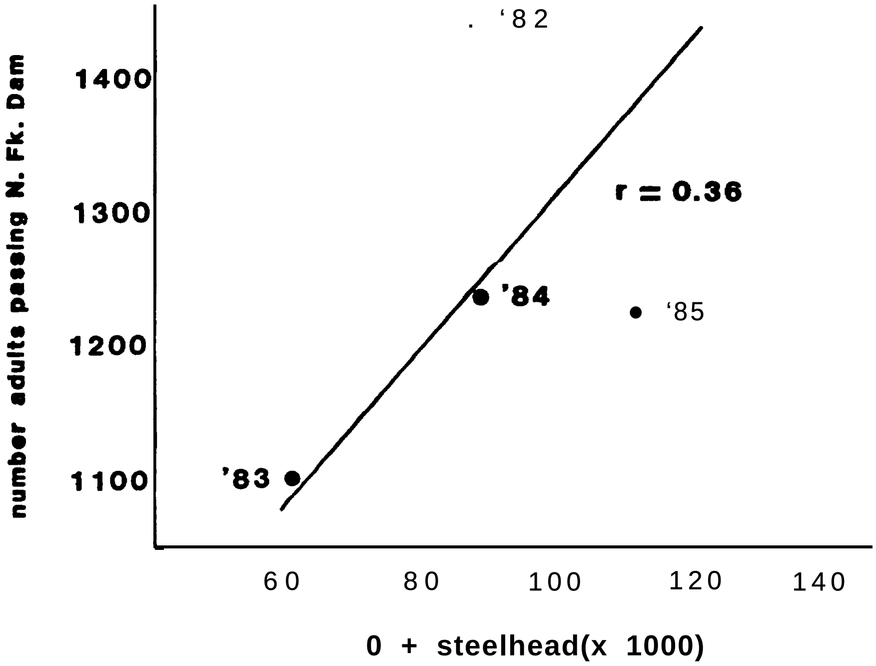



Figure 11. Parent-progeny relationship for winter steelhead in Fish Creek, 1982 through 1985.

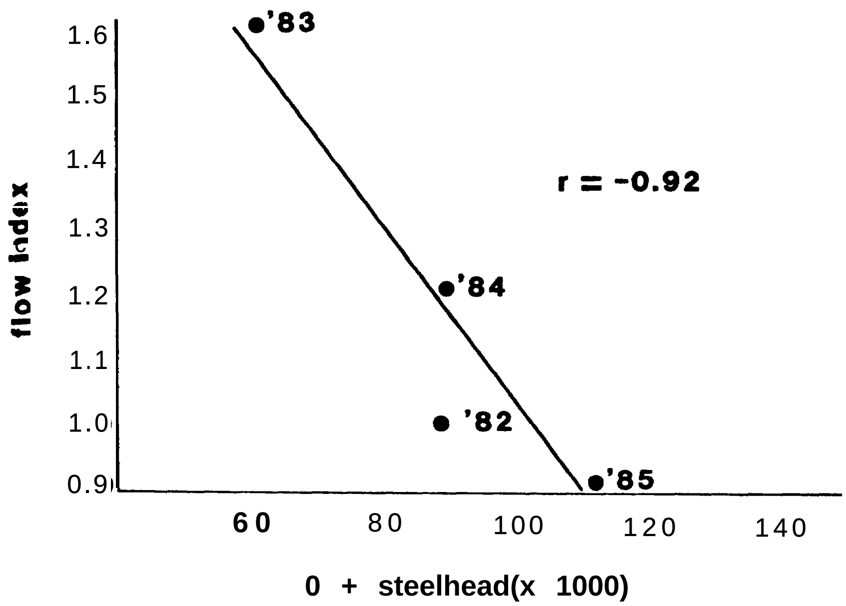



Figure 12. Relationship between index to mean August streamflow and numbers of 0+ steelhead trout in Fish Creek, 1982 through 7985.

streamflow, however, is surprising. One might expect that increases in low summer flow would result in increased survival of 0+ steelhead trout since more habitat area would be available in years with abundant flow, but the opposite was true. Water years with the highest low summer flows also have higher flows in the late winter and spring that might adversely affect survival-to-emergence of fry, or survival of post-emergent fry in their initial weeks of stream life. The effects of flow on fry might be the controlling mechanism since recently-emerged fry seek quiet stream margins that are in short supply in Fish Creek during springs with abundant flow.

Underyearling steelhead trout make significant use of all habitat types in the system, except for beaver ponds (Table 4). Densities (fish/$m^2$) of 0+ steelhead trout are generally highest in quiet shallow habitats such as glides, alcoves, and side-channels, but substantial use of quiet riffle and pool margins also occurred. 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 through 1984 were highest in riffles, followed by decreasing numbers in pools, side-channels and alcoves (Table 5). In 1985 the greatest numbers of 0+ fish also occurred in riffles, followed by lesser but about equal numbers in glides and pools, and substantially lower numbers in alcoves and beaver ponds. Availability and quality of quiet stream margins in late spring and early summer appears to be a key habitat need for post-emergent steelhead fry.

Table 4. Density 0+ steelhead trout (fish/m²) by habitat type, Fish Creek, 1982-1985.

| | Habitat Types | | | | | | |
|---|---|---|---|---|---|---|---|
| Year | Fools | Riffles | Glides | Side-Channels | Alcoves | Beaver 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 |
| Mean | 0.36 | 0.52 | 0.96 | 0.70 | 0.53 | 0.14 | 0.52 |

Table 5. Populations of 0+ steelhead trout by habitat type, Fish Creek, 1982-1985.

| | Habitat Types | | | | | | |
|---|---|---|---|---|---|---|---|
| Year | Pools | Riffles | Glides | Side-Channels | Alcoves | Beaver[1/] Ponds | Mean |
| 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 |
| Mean | 8,250 | 70,770 | 20,270 | 2,870 | 1,210 | 60 | 87,900 |

[1/]Does not include habitat created by enhancement projects.

Age 1+ pre-smolt steelhead trout populations in late summer have been remarkably consistent during the 1982 to 1985 period, averagIng about 21,300 fish (± - 10 percent, Table 3). 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.

Age 1+ steelhead trout show a preference for deep rocky pools but also use riffles, side-channels, alcoves, 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 10-18 percent of total habitat.

Table 6. Density of 1+ steelhead trout (fish/m2) by habitat type, Fish Creek, 1982-1985.

| | Habitat Types | | | | | | |
|---|---|---|---|---|---|---|---|
| Year | Pools | Riffles | Glides | Side-Channels | Alcoves | Beaver Ponds | Mean |
| 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 |
| Mean | 0.18 | 0.12 | 0.09 | 0.08 | 0.05 | 0.02 | 0.13 |

Populations of 1+ steelhead trout are highest in riffles since riffles make-up 80 to 90 percent of the habitat in Fish Creek (Table 7). Pools contain the second highest numbers of 1+ fish in summer followed by glides, side-channels, alcoves, and beaver ponds.

Table 7. Populations of 1+ steelhead trout by habitat type, Fish Creek, 1982-1985.

| | Habitat Types | | | | | | |
|---|---|---|---|---|---|---|---|
| Year | Pools | Riffles | Glides | Side-Channels | Alcoves | Beaver Ponds | Total |
| 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 |
| Mean | 3,770 | 18,080 | 1,800 | 370 | 110 | 0 | 22,730 |

The numbers of juvenile coho salmon in the Fish Creek basin have increased steadily from 1982 to 1985 (Table 3). The reasons for the increase are apparently 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, while the numbers of 0+ fish in Fish Creek increased. It is possible that the numbers of adult coho salmon spawning in Fish Creek have increased, even though the total numbers passing North Fork Dam declined. However, this has not been substantiated by counts of adult fish or redds in Fish Creek because weather and water conditions preclude accurate counts during the spawning period.

Beaver ponds are the preferred habitat of juvenile coho salmon in the Fish Creek Basin in Sumner, 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

Table 8. Counts of adult anadromous salmonids at North Fork dam, 1981-82 to 1984-85,

| Year | Steelhead trout | | | Coho salmon | | Spring chinook salmon | |
|---|---|---|---|---|---|---|---|
| | 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) |
| Mean | 5,674 | 1,252 | 6,901 | 1,631 | (170) | 2,583 | 135 |

Table 9. Density of 0+ coho salmon by habitat type, Fish Creek, 1982-1985.

| Year | Habitat Types | | | | | | Mean |
|---|---|---|---|---|---|---|---|
| | Pools | Riffles | Glides | Side-Channels | Alcoves | Beaver Ponds | |
| 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 |
| Mean | 0.14 | 0.04 | 0.43 | 0.35 | 0.20 | 1.43 | 0.08 |

beaver ponds. Coho prefer moderately deep quiet habitats on the stream margIns or out of the main channel.

The highest populations of coho salmon in the system in summer occurred in riffle habitats from 1982 through 1984 (Table 10) even though the densities in this environment were low. In 1985 when glides were separated

Table 10. Populations of 0+ coho salmon by habitat type, Fish Creek, 1982-1985.

| Year | Habitat Types | | | | | | Total |
|---|---|---|---|---|---|---|---|
| | Pools | Riffles | Glides | Side-Channels | Alcoves | Beaver[1/] Ponds | |
| 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 |
| Mean | 1,300 | 3,390 | 5,720 | 710 | 330 | 340 | 7,400 |

[1/] Does not Include habitat created by enhancement projects.

from riffles, the quieter less turbulent glides were found to be the component of riffle habitat that contained the majority of 0+ coho salmon.

Age 0+ chinook salmon are not abundant in the Fish Creek system 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 generally been highest in pools, although in 1985 near equal numbers occurred in pools, riffles, and glides (Table 12).

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 fall rains and runoff can impede entry of spawners, while early

Table 11. Density of 0+ chinook salmon (fish/m$^2$) by habitat type, Fish Creek, 1982-1985.

| Year | Habitat Types: Pools | Riffles | Glides | Side-Channels | Alcoves | Beaver Ponds | Mean |
|---|---|---|---|---|---|---|---|
| 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 |
| Mean | 0.05 | 0.01 | 0.11 | 0.00 | 0.01 | 0.01 | 0.016 |

Table 12. Populations of 0+ chinook salmon by habitat type, Fish Creek, 1982-1985.

| Year | Habitat Types: Pools | Riffles | Glides | Side-Channels | Alcoves | Beaver Ponds | Total |
|---|---|---|---|---|---|---|---|
| 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 |
| Mean | 570 | 530 | 1,490 | | 10 | | 1,480 |

rains and runoff provide easy access for adult chinook salmon. There is 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.

## Coho Salmon Smolt Production, Fish Creek

The 1985 coho salmon smolt migration from Fish Creek was closely monitored with the floating smolt trap located at km 0.3. The trap was fished from April 15 until August 25 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. 13). A total of 1,095 coho salmon smolts was captured, and the total 1985 smolt migration was estimated at 3,099 fish (Table 13).

The size of coho salmon smolts leaving Fish Creek was apparently slightly larger than average for the entire upper Clackamas River system. Coho salmon smolts captured at N. Fork Dam by PGE in 1976, the last year that migrants were measured, averaged about 110 mm (Cramer, personal communication). Outmigrants from Fish Creek in 1985 averaged about 114 mm 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. 14). It is possible that size differences between 1976 and 1985 are solely due to measurements being made in different years and at different levels of seeding.

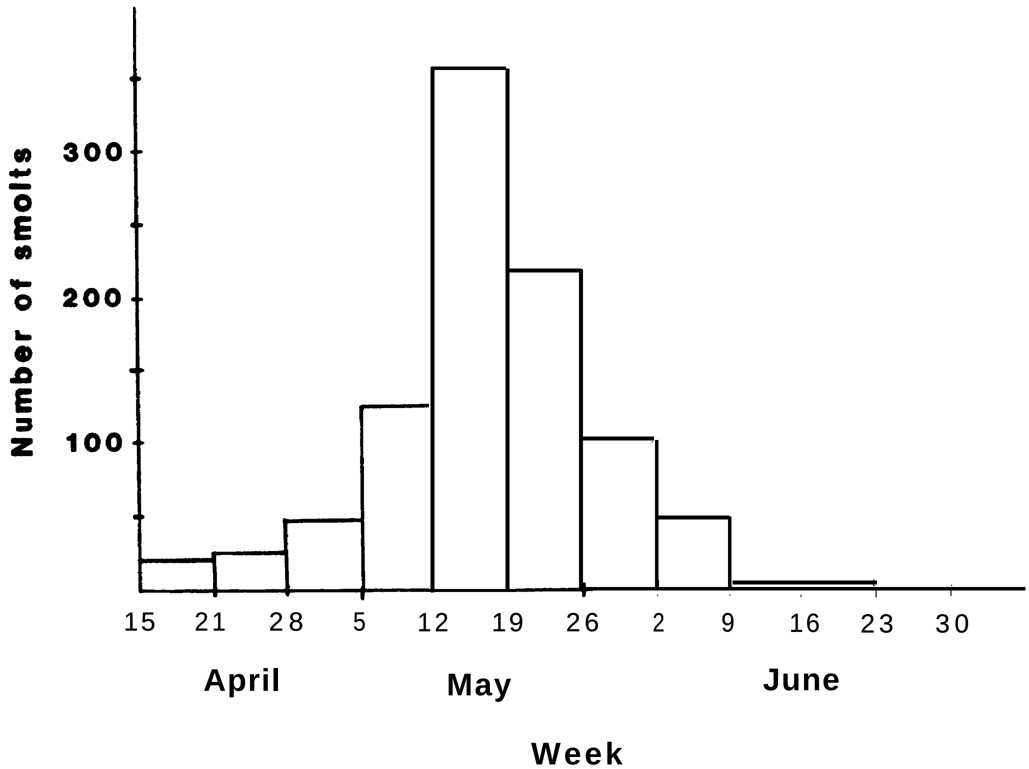



Figure 13. Coho smolts captured at the floating trap at km 0.3 on Fish Creek at weekly Intervals, April 15 through June 30, 1985.

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 % | Estimate[1/] total Smolts |
|---|---|---|---|---|---|
| 4/15-4/28 | 76 | 83 | 38 | 46 | 165 |
| 4/29-5/12 | 217 | 115 | 55 | 48 | 452 |
| 5/13-5/26 | 631 | 497 | 235 | 47 | 1,342 |
| 5/27-6/9 | 171 | 281 | 43 | 15 | 1,140 |
| 6/10-6/23 | 0 | 2 | 0 | -- | -- |
| Totals | 1,095 | 978 | 371 | -- | 3,099 |

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

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 not contributing coho salmon smolts to the Clackamas River in proportion to its basin area. The upper Clackamas River above North Fork Dam covers about 1695 $km^2$ while the Fish Creek basin covers only 171 $km^2$. Thus, Fish Creek represents about 10 percent of the upper Clackamas basin, but produced only about 3 percent of the smolt output in 1985. These statistics are not surprising since Fish Creek contains only a small amount of the types of habitat preferred by coho salmon.

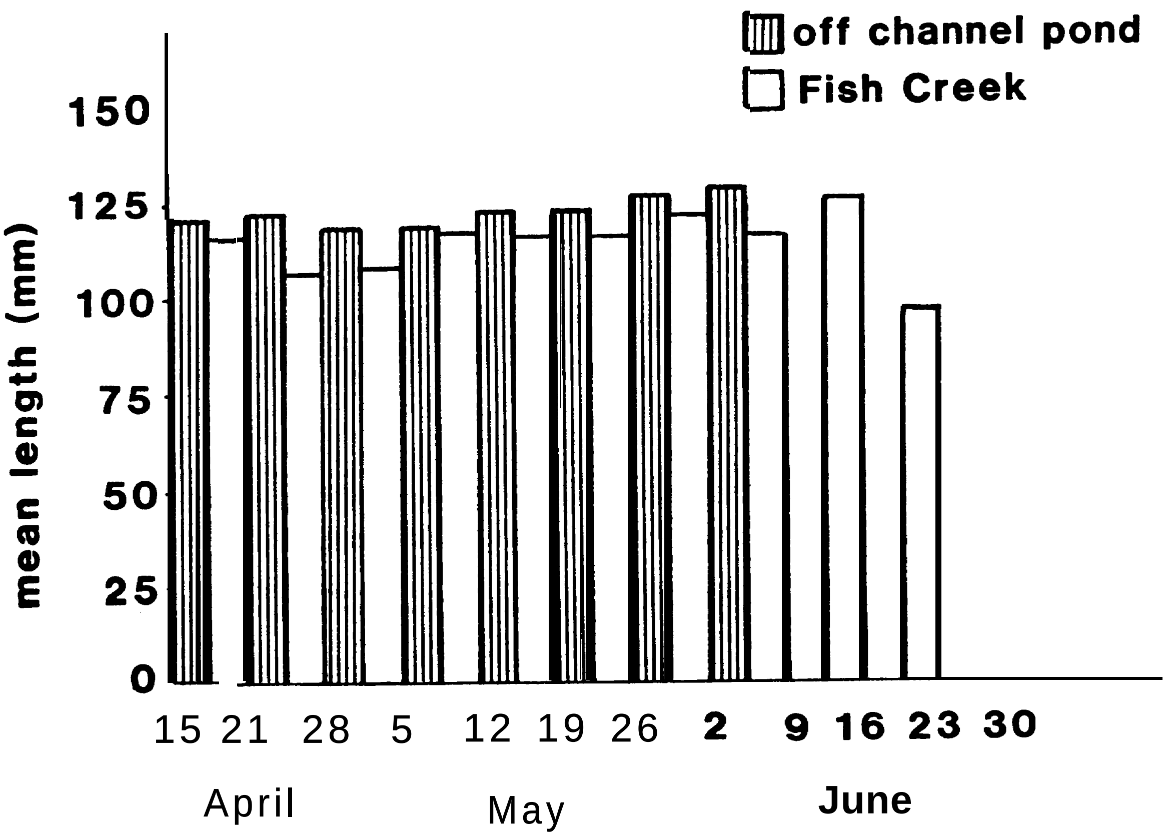



Figure 14. Mean length of coho salmon smolts emigrating from Fish Creek and the off-channel pond at km 3, April 15 through June 23, 1985.

Fish Creek is a very 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 produces about 500 smolts/km and ranks far lower as a coho producer than other comparably sized streams. The reason for this is the present condition of the high-gradient incised channel that provides little of the marginal and off-channel habitat preferred by coho in summer and winter. The 1964 flood, heavy timber cutting in the basin, and intensive debris removal from the channel have over the past 20 years reduced coho habitat in Fish Creek.

## Coho Salmon Smolt Production, Off-Channel Pond

Smolt production from the off-channel pond, constructed on a flood terrace adjacent to Fish Creek at km 3.0 in 1983, was thoroughly evaluated In the spring of 1985. 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 in 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 small population of 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 outmigration 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 124.6 mm, while Fish Creek smolts averaged 113.3 mm. The primarily noctural migration of smolts leaving the pond was also similar to the behavior of coho smolts leaving Fish Creek.

The off-channel pond, even though it has never been fully stocked with fry, has made a significant contribution to coho salmon smolt production from Fish Creek. 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 total run. This contribution is 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 production may be as much as four times greater than that observed in 1985.

## Overwinter Survival Of Coho Salmon On Fish Creek.

The smolt trap has provided a means of estimating overwinter survival of coho parr in Fish Creek. The total number of coho salmon in the system in September 1984 was estimated at 8,290 and the total estimated

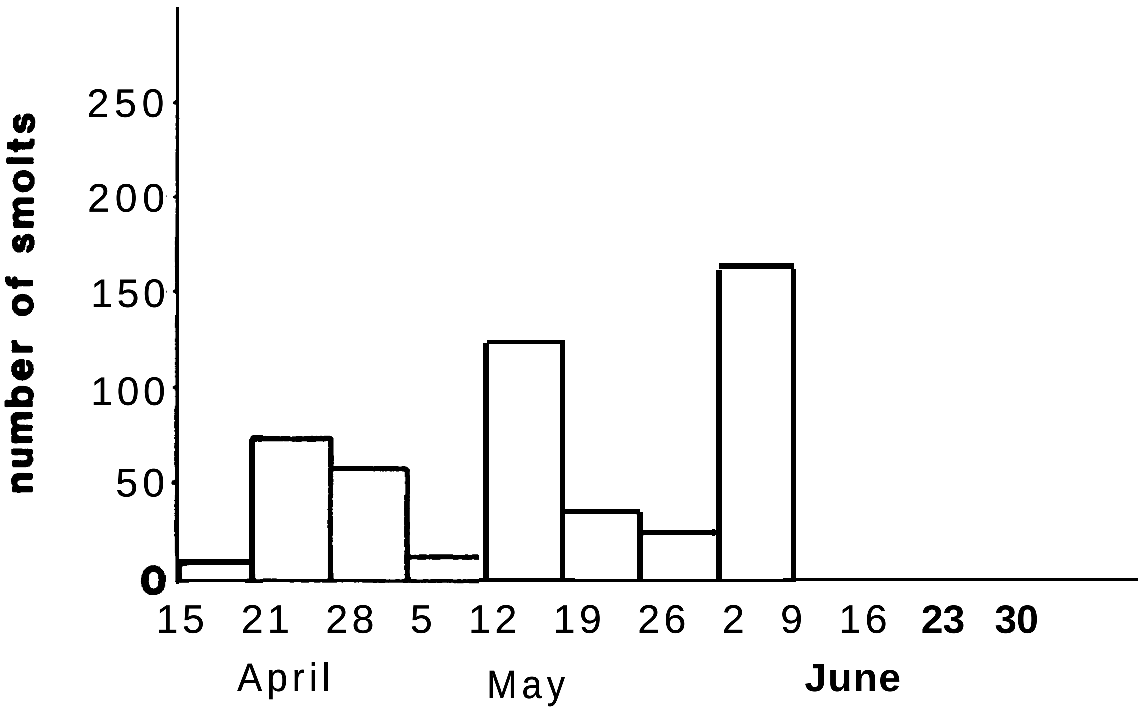



Figure 15. Coho salmon smolts captured at the off-channel pond at km 3 on Fish Creek, April 15 through June 30, 1985.

smolt production from mainstem Fish Creek (excluding smolts from the off-channel pond) was 2,606. From these data overwinter survival is estimated at 31 percent.

The below average winter survival of coho rearing in the mainstem of Fish Creek can be attributed to the general lack of quiet edge habitats and side channels during winter. Diving observations in the winters of 1983-84 and 1984-85 have shown that 0+ coho salmon prefer to winter in quiet backwaters with heavy cover located off the mainstem of Fish Creek. Habitats meeting these criteria are rare within the range of coho in the basin.

The off-channel pond appears to provide nearly ideal overwinter habitat for juvenile coho salmon. While the number of coho parr in the pond in September was not quantified, one could assume at least a 30 percent oversummer mortality of the original 1,326 fry. If that assumption is true, overwinter survival in the pond exceeds 50 percent and could be more than double that observed in Fish Creek.

## Chinook Salmon Smolt Production

Migration of juvenile chinook salmon smolts from Fish Creek occurred in two distinct intervals (Fig. 16). The first was from mid-April, when the floating trap was put into operation, until late May. It was estimated that 131 chinook salmon smolts (mean length 121.4 mm) left during this period. This is probably a minimum estimate, however, since it appears that the migration was underway prior to the placement of the

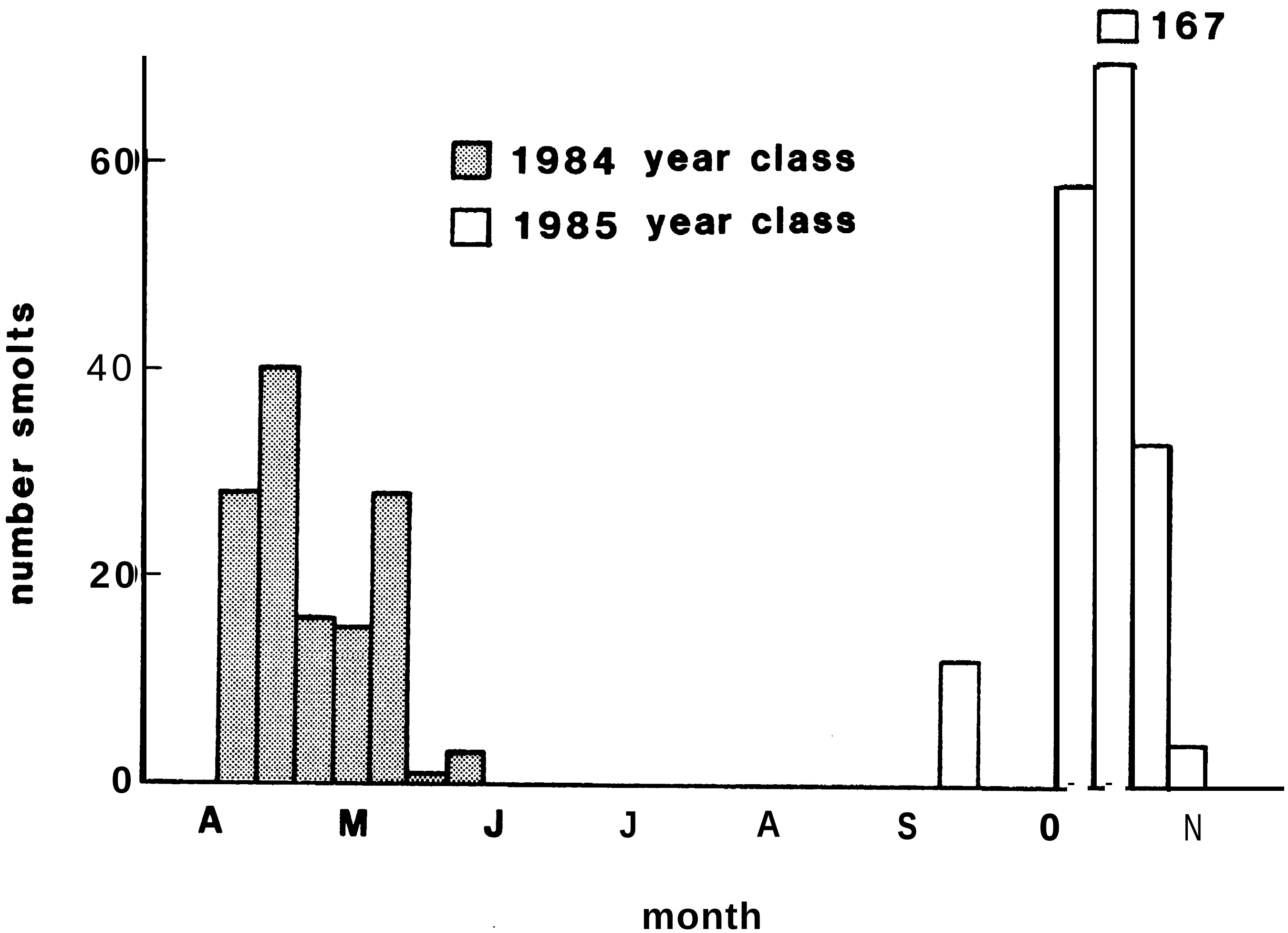



Figure 16. Weekly catch of chInook smolts at the floating fish trap at km 0.3 on Fish Creek, April-November, 1985.

trap. No recently emerged chinook salmon were captured at this, or any other, time. Two possible reasons for this are: (1) any migration of recently emerged fish occurred before the trap was operational; and (2) rearing habitats for chinook salmon in Fish Creek are underseeded and movement was minimal.

The second migration period was from late September to early November (Fig. 14). An estimated 274 juvenile chinook salmon migrated during this time. As during the spring, all chinook salmon captured at this time were smolts. However, these fall migrating fish were smaller (mean length 90.7 mm) than spring migrants.

The pattern of chinook salmon migration from Fish Creek could indicate the presence of genetically distinct subpopulations. (It should be noted, however, that fish represented in Fig. 16 are from two different year classes.) One group rears through the summer and migrates in the late fall or early winter. Examination of Portland General Electric records from the North Fork of the Clackamas passage station show an increase in the number of migrant juvenile chinook salmon at this time. The second group over-winters in Fish Creek and migrates the following spring. We have observed juvenile chinook salmon entering interstices in the substrate in the lower end of Fish Creek in the late fall and early winter (see section on winter habitat for more detail). Carl and Healy (1984) found that on Vancouver Island, British Columbia, differences in timing of migration were due to the presence of genetically distinct subpopulations of chinook salmon. They speculated that the differences are a result of isolated adult spawning populations. The reason for the presence of possible subpopulations in Fish Creek is not clear at present but may be worth investigating in the future. Electrophoretic analysis of the populations might reveal whether genetically difference subpopulations exist in Fish Creek.

## Steelhead Trout Smolt Production

The steelhead trout smolt migration from Fish Creek was monitored from April 15, 1985, until June 28, 1985, when movement of smolts essentially 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. 77). A low steady catch rate averaging IO-12 smolts/day occurred between April 15 and April 27. During the next week (April 28-May 4) the catch increased markedly, averaging about 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 7,470 (Table 14). We assumed that the migration had been in progress for at least 15 days before trapping began, and based on the mid-April catch rate that an average of 10 smolts/day would have been trapped during this period. Using an

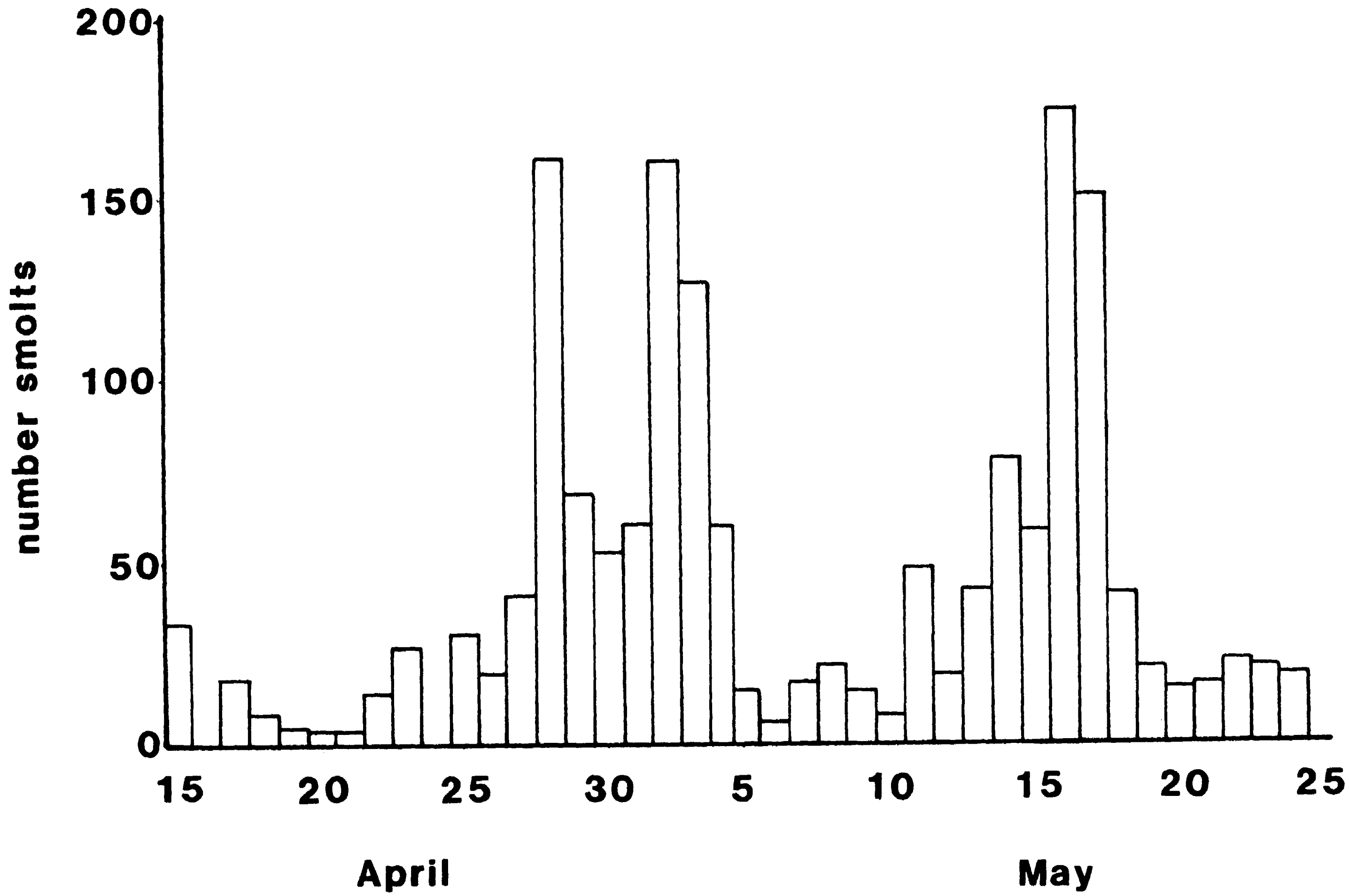



Figure 17. Daily catch of steelhead smolts at the floating fish trap at km 0.3 on Fish Creek, April 15 to May 25, 1985.

Table 14. 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[1/] | Marked smolts recaptured | Trap efficiency x | Estimated[1/] total smolts |
|---|---|---|---|---|---|
| 4/75-4/28 | 382 | 49 | 15 | 31 | 1,232 |
| 4/29-5/l 2 | 708 | 115 | 47 | 41 | 1,727 |
| 5/13-5/26 | 787 | 155 | 57 | 37 | 2,127 |
| 5/27-6/g | 103 | 82 | 10 | 12 | 858 |
| 6/10-6/23 | 166 | 122 | 14 | 11 | 1,509 |
| 6/24-6/30 | 2 | -- | -- | -10 | 20 |
| Totals | 2,148 | 523 | 143 | | 7,473 |

estimated efficiency of about 30 percent for this 15 day period, a total of about 500 smolts probably left the system before trapping commenced. The total smolt migration Is therefore assumed to be about 8,000. The size of smolts ranged from 123 mm to 242 mm, and varied during the trapping season. The average size was about 160 mm, and the approximate minimum threshold size for smolts was 140 nun, although a few smolts were smaller (Fig. 18). The average size of smolts remained fairly constant from mid-April to mid-Hay and then decreased from mid-May to mid-June (Fig. 19). Scale analysis from a small sample of early migrants, both smolts and non-smolts, indicates that this group was composed primary of age 2+ fish, the normal age of most steelhead smolts in western Oregon. The smaller June migrants might have been a mix of smaller 2+ smolts, and socially dominant, fast growing 1+ smolts.

A generalized growth pattern of juvenile steelhead trout Is shown in Fig. 20. This figure was developed from examination of the growth pattern

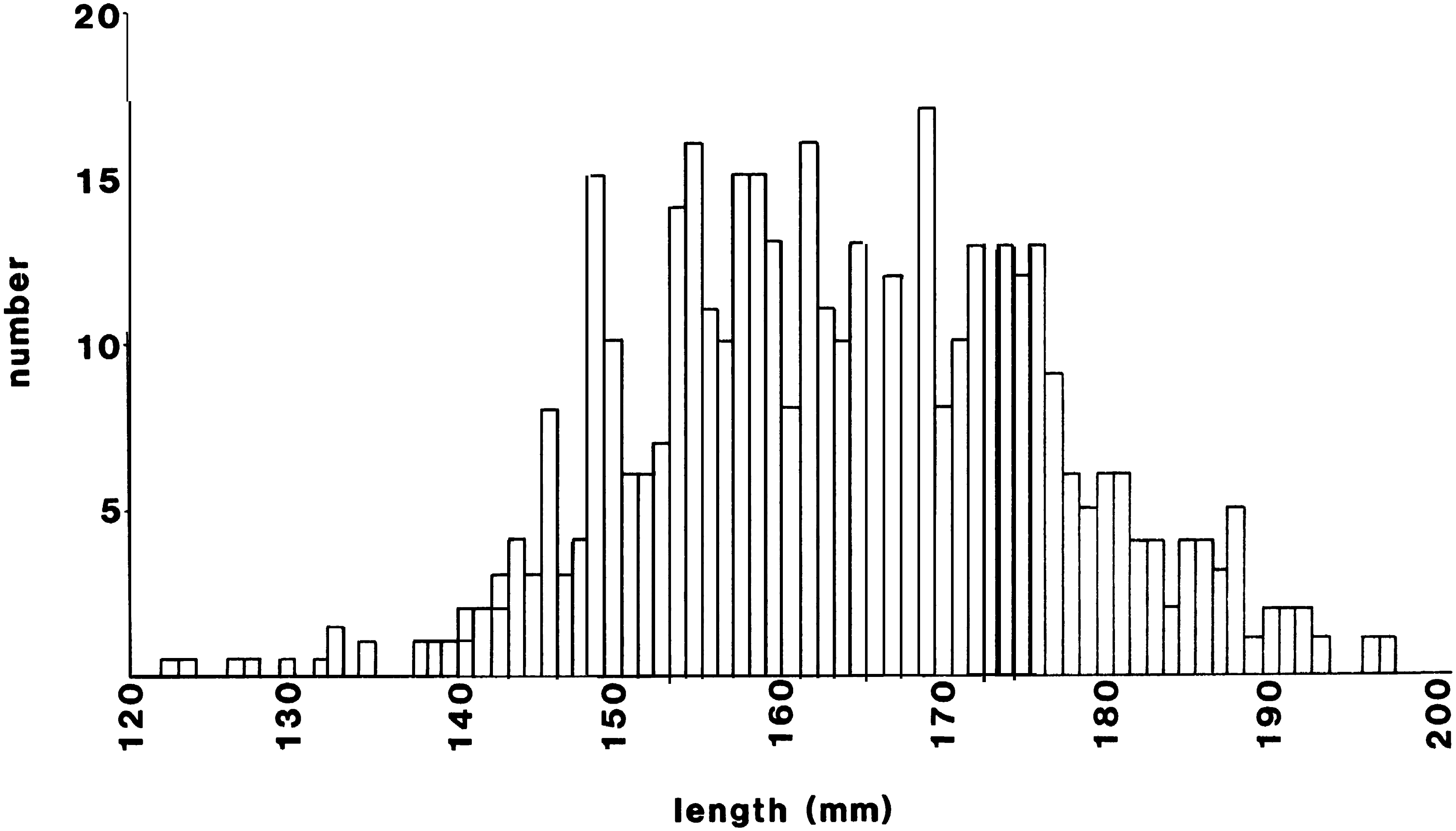



Figure 18  Size frequency of steelhead trout smolts from Fish Creek, 1985

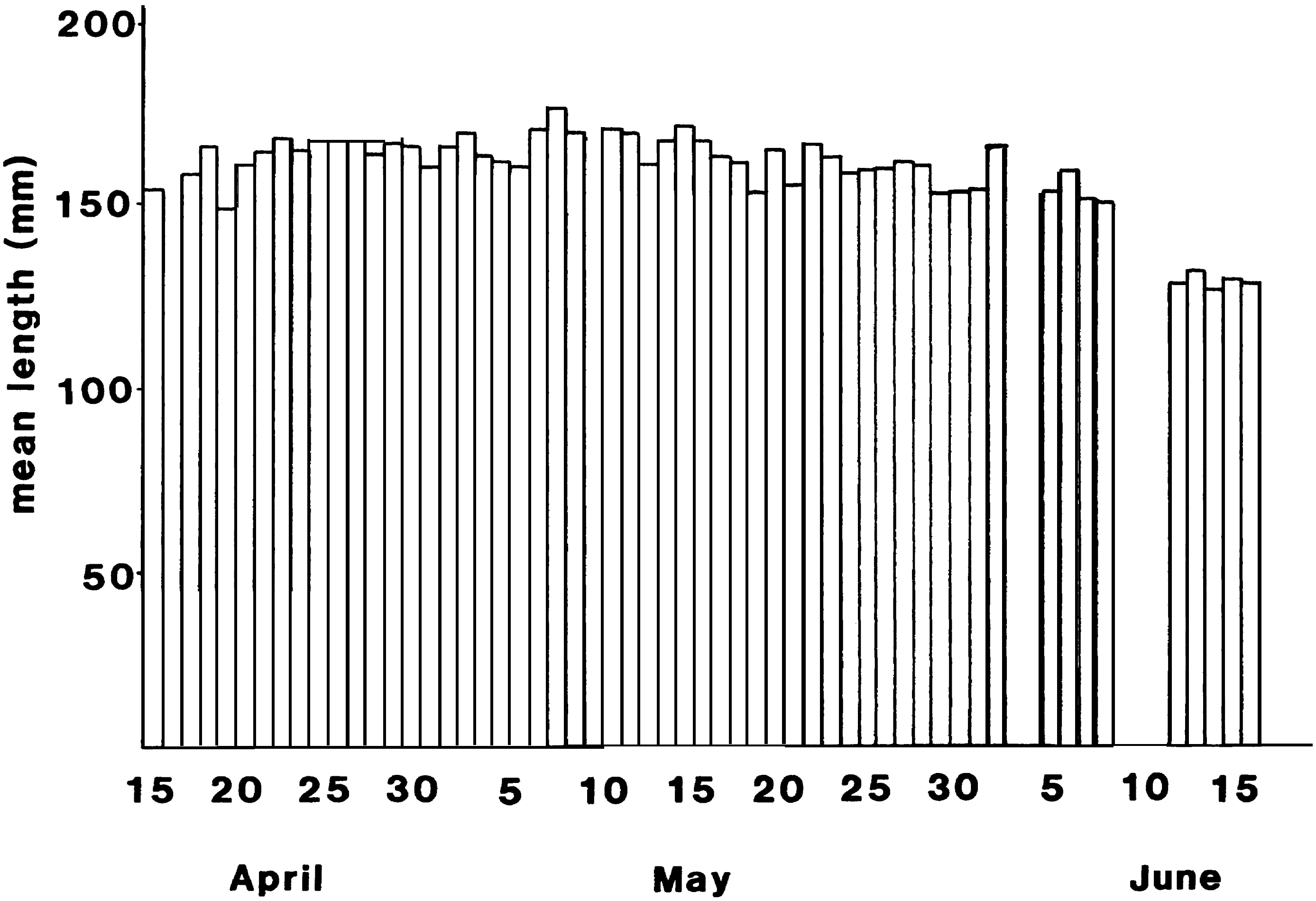



Figure 19. Mean daily lengths of steelhead trout smolts leaving Fish Creek between April 15 and June 15, 1985.

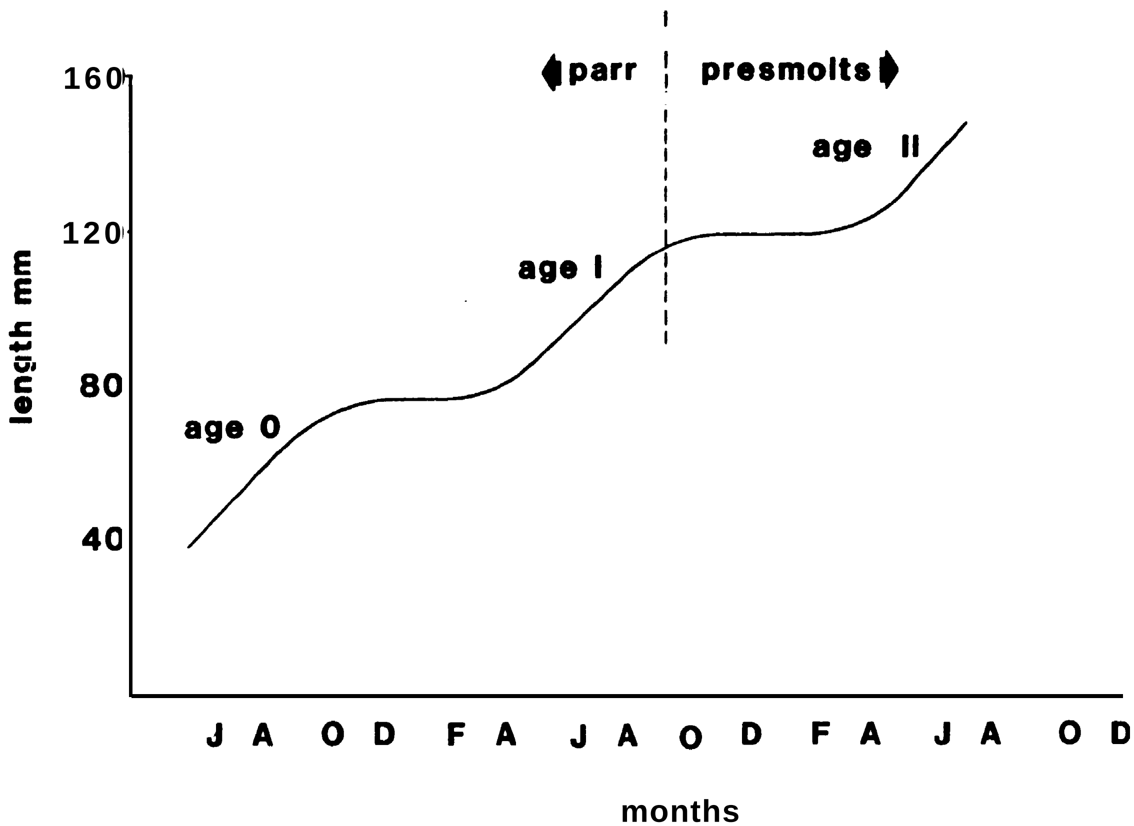



Figure 20. Generalized growth pattern of juvenile steelhead trout in Fish Creek. Emergence occurs primarily in June and smolts leave in May of their second year. Presmolts must be 120 mm fork length by September to smolt the following spring.

observed on scales and by back-calculating the length of fish at the time of annulus formation. The estimated mean length of time of formation of the first and second annulus were 82 mm and 125 mm, respectively. Thus, we speculate that in order for a fish to reach the minimum size to smolt, 14 cm, it must have attained a length of 12 cm the end of the growing season the previous fall. It is probably unlikely that fish less than 12 cm would reach 14 cm threshold the following spring.

Overwinter survival of pre-smolt steelhead trout appears to be favorable on Fish Creek. In the summer of 1984 the Fish Creek basin contained an estimated 23,800 age one year and older steelhead. Approximately 50 percent of these fish, 11,900, were a minimum length of 12 cm by the fall of 1984 (Fig. 21). Since about 8,000 smolts left the basin in 1985, overwinter survival is estimated at 67 percent. An additional contribution could be expected from age 1+ parr that remain in the system for another growing season. Based on off-site data from Washington, overwinter survival of pre-smolt steelhead in Fish Creek was previously estimated at 50 percent. If the 50 percent coeficient had been applied to presmolts in 1984, smolt production would have been estimated at about 5,950 fish rather than the approximately 8,000 smolts that left the basin. The higher than expected winter survival indicates that Fish Creek provides an adequate supply of winter habitat for large juvenile steelhead trout.

The behavior of migrating steelhead trout smolts was typical of other salmonid smolts. Nearly all movement occurred during darkness and migrants apparently moved downstream in the upper portion of the water column near the thalweg.

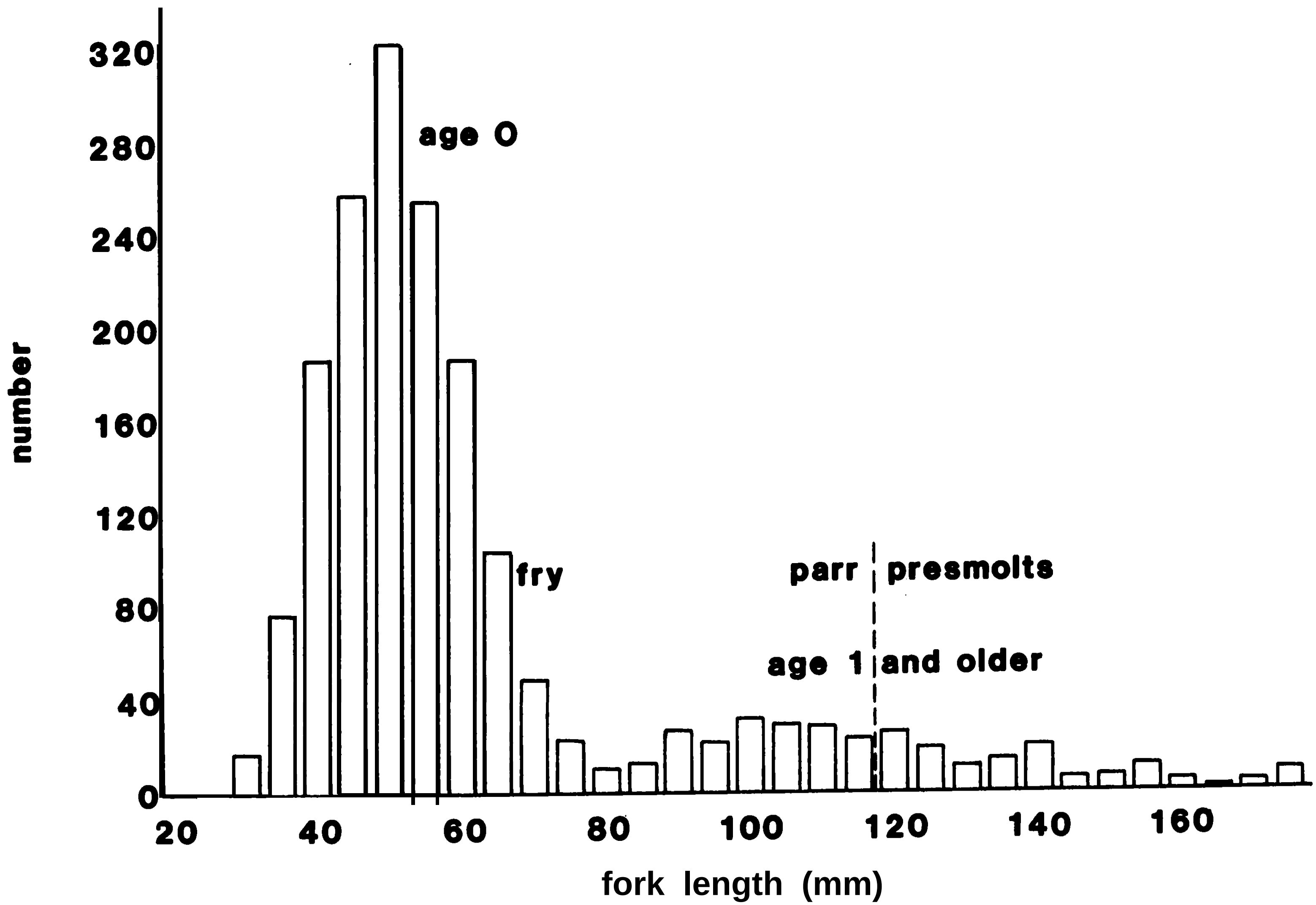



Figure 21. Size frequency of juvenile steelhead trout in Fish Creek, September 1985. Only fish larger than about 120 mm will smolt the following spring.

At this time it is not possible to determine whether prototype projects to improve steelhead trout habitat have had any impact on steelhead smolt production. Projects have only altered about 5 percent of the habitat and natural variability in steelhead populations can be greater than 10 percent per year. Construction of boulder berms was the only project in the basin to significantly impact habitat for 1+ steelhead trout. To date the results of this practice, designed to increase spawning habitat, have not significantly altered the summer standing crop of 1+ steelhead trout.

The Fish Creek basin is a significant contributor to the total steelhead trout smolt out migration from the upper Clackamas in 1985, based on counts made by PGE at North Fork Dam. The total number of wild steelhead smolts was estimated at 35,000 in 1985 (personal communication, O. Cramer, PGE). About 23 percent of that total (8,000 smolts) came from the Fish Creek basin which makes up only about 10 percent of the Clackamas basin above North Fork Dam. Thus, Fish Creek is presently one of the most important subbasins in the upper Clackamas for steelhead trout production.

## Side Channel Development

A flood overflow channel located at km 1 on Fish Creek was improved in 1984. Before development the channel was dry except during large winter freshets. Fish production from the area was essentially nil. Occasionally a few juvenile steelhead trout or coho salmon were swept into the channel on flood flows and trapped in a pool near the downstream end when flows declined. The fish were usually lost to dewatering or predation during the subsequent summer.

Winter habitat conditions in the channel were marginal for juvenile salmonids In the winter of 1984-85, because the channel was deficient in structure and lacked flow control on the inlet. A census of juveniles wintering In the channel in December 1984 indicated that only about 3 juvenile coho salmon and 29 juvenile steelhead trout were utilizing the three remaining pools and accumulations of woody debris and roots for winter habitat (Table 15). The small steelhead trout population was composed of 20 0+ fish and 9 l+ fish. HabItat conditions seemed to favor small fish which were able to find a few suitable niches. Violent flow fluctuations and a general lack of quiet water edge habitats and complex cover limited winter use by juvenile salmonids.

The carryIn capacity of the channel increased in spring and summer 1985 (Table 15) as flows decreased. A substantial number of coho salmon parr reared In the channel through the spring and summer, and a large number of steelhead trout fry were present In August. The channel also provided some habitat for age l+ steelhead trout.

The densities of all species and ages of salmonids were lower in the constructed side channel in the summer of 1985 than in natural side channels on lower Fish Creek (Table 16). Age 0+ coho salmon, 0+ steelhead trout, and l+ steelhead trout had densities about 27 percent, 47 percent, and 78 percent lower, respectively, in the constructed side channel than in two natural side channels (SC 22, 27). The reasons for lower carrying capacity in the constructed channel are apparently related

Table 15. Seasonal estimates of juvenile salmonid populations in a constructed side channel at km 10, Fish Creek, 1984-85.

| Season | 0+ Coho salmon | | | | 0+ Steelhead trout | | | | 1+ Steelhead trout | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Number | Mean length (mm) | Mean weight (g) | Density fish/m$^2$ | Number | Mean length(mm) | Mean weight (g) | Density fish/m$^2$ | Number | Mean length (mm) | Mean weight (g) | Density fish/m$^2$ |
| Winter (December 1984) | 3 | 80.7 | 6.3 | 0.004 | 20 | 73.8 | 5.2 | 0.02 | 9 | 116.0 | 17.9 | 0.01 |
| Spring (May 1985) | 183 | 41.3 | 1.0 | 0.22 | 0 | — | — | — | 64 | 97.0 | 12.31 | 0.08 |
| Summer (August 1985) | 137 | 66.2 | 3.6 | 0.16 | 483 | 52.3 | 1.8 | 0.57 | 19 | 119.1 | 18.86 | 0.02 |

Table 16. Comparison of length, weight, and density of juvenile salmonids in a constructed side channel at Km 1 on Fish Creek and two natural side channels on lower Fish Creek, August 1985.

| Species and Age | Constructed side channel | | | Natural side channels | | |
|---|---|---|---|---|---|---|
| | Mean length (mm) | Mean weight (g) | Densit fish/m$^3$ | Mean length (mm) | Mean weight (g) | Densit fish/m$^3$ |
| 0+ Coho | 66.2 | 3.6 | 0.16 | 67.8 | 4.6 | 0.22 |
| 0+ Steelhead | 52.3 | 1.8 | 0.57 | 51.8 | 1.1 | 1.08 |
| l+ Steelhead | 119.1 | 18.9 | 0.02 | 122.7 | 19.2 | 0.09 |

to Its steep gradient and general lack of structure and complexity. Fish in the constructed channel were not significantly different in length or weight than their counterparts in natural side channels.

Additional habitat complexity is needed to increase the carrying capacity of the constructed channel.

## Winter Observations

The density of 0+ steelhead trout decreased between September and December in all habitats in lower and middle Fish Creek, and in Wash Creek to the first upstream bridge (Fig. 22). In December, observations were made in stream margins at several locations along Fish Creek but no active fish were seen. However, a few 0+ steelhead trout were found in the substrate along the margins in habitats similar to those described by Everest et al. (1985). It Is assumed that since few 0+ steelhead emigrated from the system

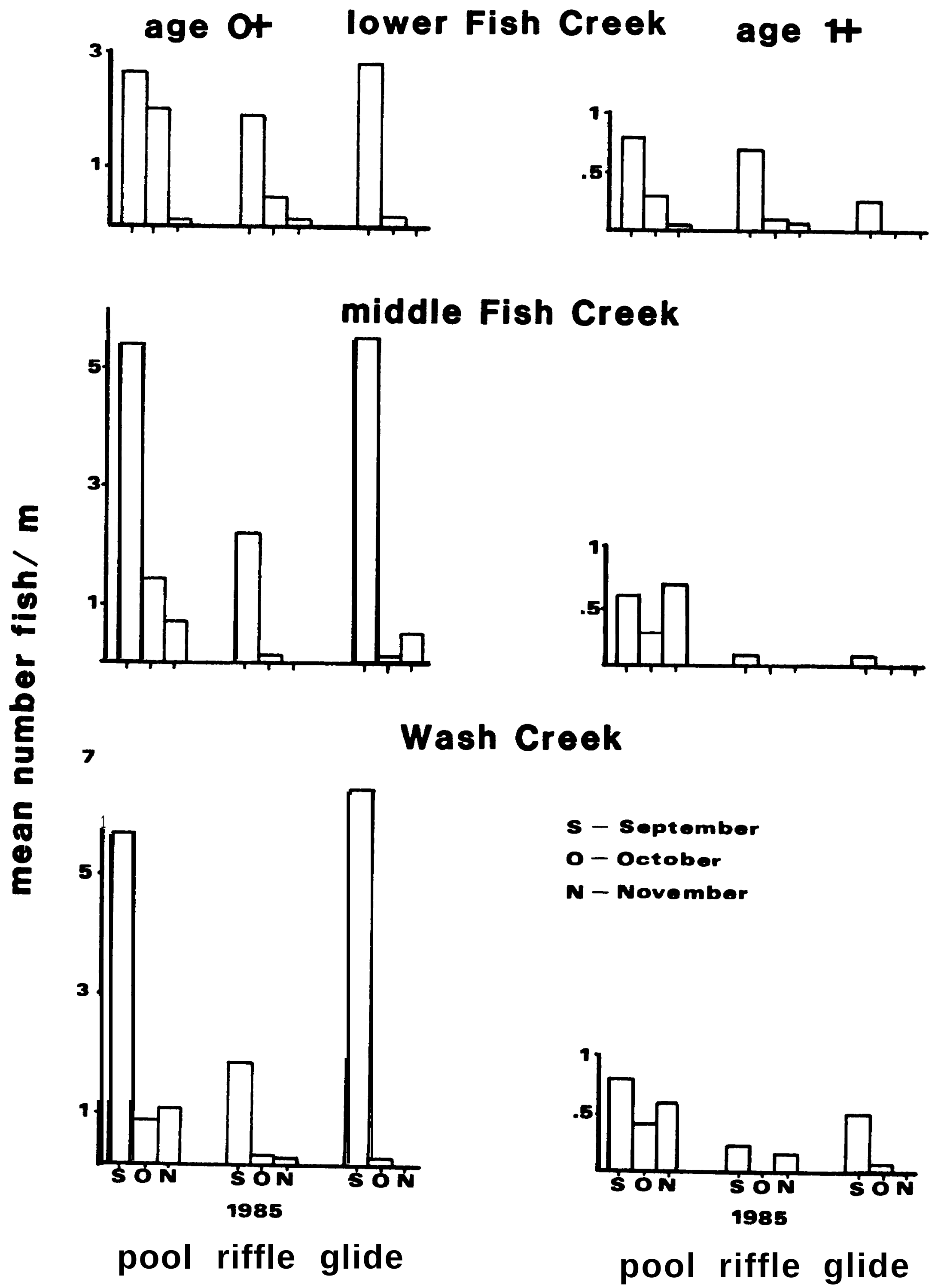



Figure 22. Mean number of juvenile steelhead trout in different habitats In Fish Creek during fall.

during the fall, essentially all 0+ fish had entered the substrate by December.

There were differences in 1+ steelhead trout distributions over time in the different areas. In lower Fish Creek, density in all habitats decreased over time. Age 1+ steelhead trout and juvenile chinook salmon were observed down in the substrate in this area in October. Water temperature at this time was 7°C. The highest densities of fish were found in areas where large angular quarry rock, used as highway rip-rap, had entered the stream margin. In October, large concentrations of juvenile chinook salmon and steelhead trout and what appeared to be rainbow trout of hatchery origin were observed in pools just above the mouth of Fish Creek. These fish may have been moving from the Clackamas River Into Fish Creek for the winter.

Few 1+ steelhead trout were observed in riffles and glides in Wash Creek and middle Fish Creek by November (Fig. 20). In pools, however, densities decreased between September and October but increased to Intermediate levels in November. No active 1+ steelhead trout were seen in the limited observations made in December.

The reason for the difference in the patterns of 1+ steelhead trout densities in the different habitat units between lower Fish Creek and the other areas is not known at present. There are, however, two plausible explanations. Changes in densities of 1+ steelhead trout in middle Fish Creek and lower Wash Creek may indicate a directed movement of fish to pools from other habitat types. Riffles and glides in middle Fish Creek and lower Wash Creek may be less desirable winter habitats than are pools. As a result fish may prefentially move to pools. In lower Fish Creek, fish may utilize riffles and glides, at least to a limited extent, for overwintering because there is a greater diversity of substrate sizes in the upper areas. Also, the sampling program may not have been extensive enough to detect possible directed movements to pools.

Another possible explanation for these differences is a directed upstream movement by l+ steelhead trout. Fish that were unable to find suitable over-winter habitat may move upstream in search of such areas rather than leave Fish Creek. A Humphrey fish trap was operated in lower Fish Creek until November 6, 1985. A few 1+ steelhead trout were captured moving downstream, but the total fall migration was estimated at only 676 fish, or less than 3 percent of the summer standing crop. On a few occasions in November, small groups of 6-10 1+ steelhead trout were observed in pools attempting to swim upstream in lower Wash Creek. The extent of this movement is unknown at present.

No clear relationship was noted between fish densities and the physical features measured. The highest densities of l+ steelhead trout were generally found in pools that contained large boulders (>1 m) that were embedded 25-50 percent by material 0.5-1.0 m in diameter (Fig. 23). Areas with large concentrations of material 0.5-1.0 m also had high densities of fish. These areas were within the low summer flow perimeter (Fig. 24). Age 0+ steelhead trout were generally found along stream margins (Fig. 22). Bustard and Narver (1975) also found 0+ steelhead trout in shallower water, and associated with smaller substrate, than were older age-classes. Pools with bedrock substrate or with smaller sized substrate (<0.25 m) generally had few or no fish (Fig. 23).

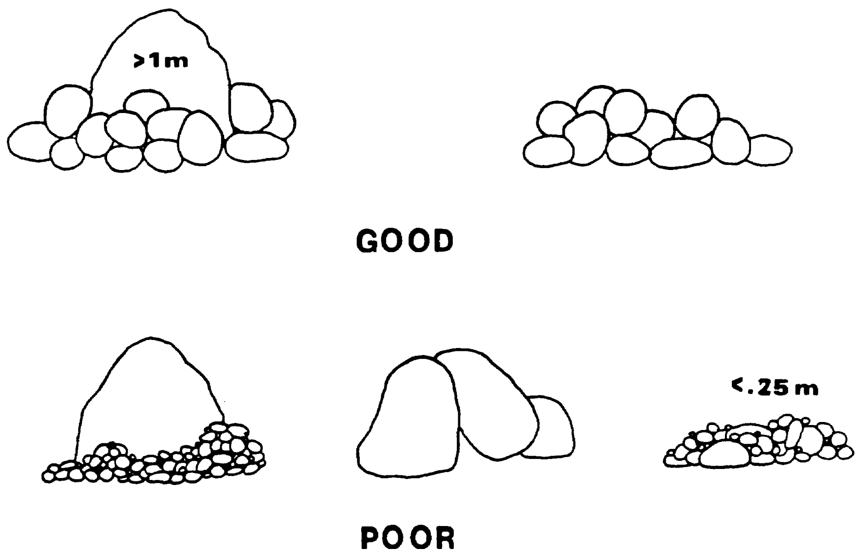



Figure 23. Examples of winter habitat in which 1+ steelhead trout were observed in Fish Creek.

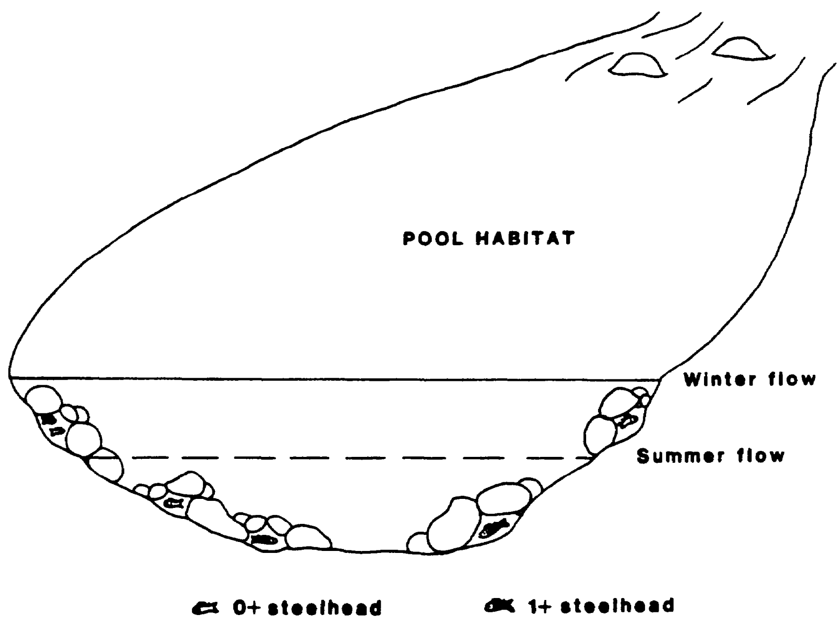



Figure 24. Winter habitat of 0+ and 1+ steelhead trout in Fish Creek (temperature 4°C).

There was a differential response to decreasing water temperature by 0+ and l+ steelhead trout (Fig. 25) in the laboratory stream. Older trout generally moved into winter cover at higher temperatures than did yearlings. Cover consisted of small piles of cobble located at various intervals in the laboratory stream. Once l+ fish moved into the substrate they seldom ventured out, even when food was present. Those l+ fish that did not move to cover either migrated from the channel or became inactive, settling on the substrate near a large rock or piece of wood. Most 0+ trout remained active over the entire temperature range. The reason for this is unclear at the moment.

These observations on differences in winter habitat utilization between 0+ and 1+ steelhead trout require further investigation. If the differences are real, they have important ramifications for future enhancement work. The winter habitat requirements appear to be age-class specific in both type and location. Older trout appear to prefer areas of larger material (>1 m), embedded to some degree by material 0.5-1.0 m, so there is an abundance of interstitial space. This material is generally located within the low summer flow perimeter of the stream. On the other hand 0+ trout, appear to remain active later into the year and utilize stream margins like those described by Everest et al. (1985).

## Effects of February 1986 Flood

The first major flow event to substantially test the design of habitat improvements constructed in the Fish Creek basin occurred on February 23, 7986. The event was estimated to have a recurrence period

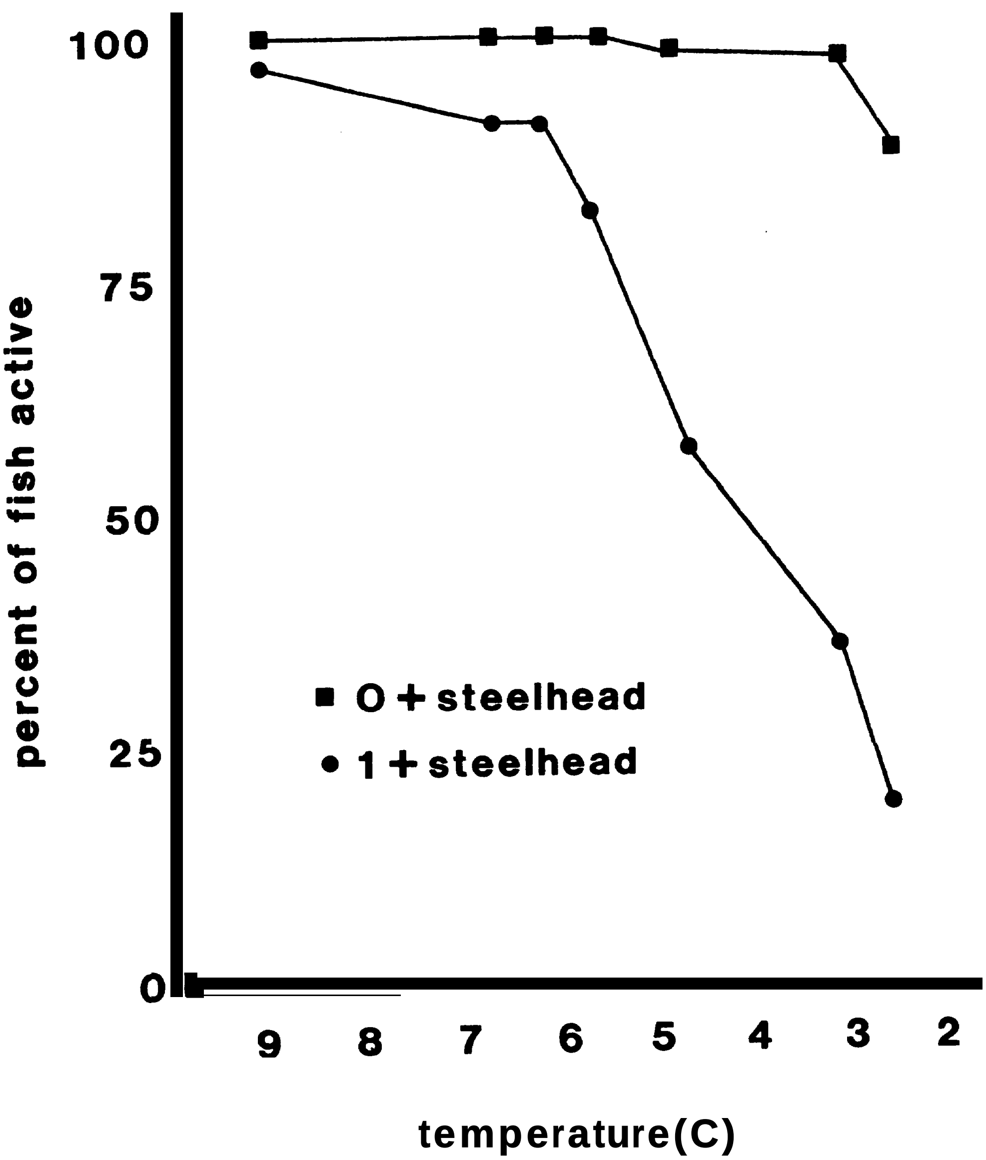



Figure 25. Percent of juvenile steelhead trout observed active in a laboratory stream with decreasing water temperature.

of W-15 years and resulted from intense precipitation on a snowpack that extended to the valley floor. The resulting runoff caused bankfull flows, and in some places overbank flows, throughout the basin. The high flows had some effect on all habitat work previously completed in the basin. A description of the effects, by type of improvement, is listed below.

Boulder Berms

The gravel catchment structures on Fish Creek were built with small (<1 $m^3$) onsite rock after analysing and rejecting use of gabions, trees, and large hauled boulders. The latter options were eliminated primarily because of high cost. Berms designed to withstand a 5-year flow event could be constructed for $250-8200 from small onsite rock, and could be maintained at a cost of $100-$300 per 5-year period.

The effects of the February event on boulder berms were variable and related to the positioning of the berms within the basin, the material , used in berm construction, and the channel width and degree of incision in proximity to the berms. The high flows were the first real test of the 21 berms desIgned and built in 1983 to enhance spawning habitat in middle Fish Creek and lower Wash Creek. Massive bedload movement occurred at bankfull flow when large cobbles could be heard bouncing and clattering downstream.

A survey of the berms was made in May after flows had receded and stabilized. The berms on the mainstem of Fish Creek had been substantially altered by the high flows, but many were still meeting their design objectives (Table 17). All of the berms that spanned the

Table 17. Summary of February 23, 1986 flood effects on Fish Creek and Wash Creek boulder berm.

| Berm Number | Reach | Intact, meeting objectives[1/] | Breached, meeting objectives[1/] | Intact, not meeting objectives | Breached, not meeting objectives | Gravel impoundment ($m^2$) | Steel head redds |
|---|---|---|---|---|---|---|---|
| 1 | | X | | | | 20 | 1 |
| 2 | Upper Fish, | | | X | | -- | -- |
| 3 | 1981 | X | | | | 10 | 1 |
| 4 | | | | X | | -- | -- |
| 5 | | X | | | | 5 | 1 |
| 1 | Wash, | | | X | | -- | -- |
| 2 | 1983 | X | | | | 5 | 1 |
| 3 | | | | X | | -- | -- |
| 4 | | | | | X | -- | -- |
| 5 | Fish, | | | | X | -- | -- |
| 6 | upper | | | | X | -- | -- |
| 7 | Suspender, | | | | X | -- | -- |
| 8 | 1983 | | X | | | 25 | -- |
| 9 | | | | | X | -- | -- |
| 10 | | | | | X | -- | -- |
| 11 | | | X | | | 5 | -- |
| 12 | | | | | X | -- | -- |
| 13 | Fish, | | | | x | -- | -- |
| 14 | lower | | X | | | 10 | -- |
| 15 | Suspender, | | | | X | -- | -- |
| 16 | 1983 | | X | | | 10 | 1 |
| 17 | | | X | | | 40 | 2 |
| 18 | | | X | | | 15 | -- |
| 19 | Fish, | X | | | | 20 | 1 |
| 20 | middle bridge | | | | X | -- | -- |
| 21 | 1983 | X | | | | 6 | 1 |
| | Totals | 6 | 6 | 4 | 10 | 171 | 9 |

1/ All berms were designed to recruit spawning gravels.

channel were breached at the thalweg to a variable degree. Some were largely intact with only a few midstream boulders rolled out of place downstream, while others were largely dispersed with only the wing roots of the berms in contact with the banks remaining in place. The berms that suffered the greatest damage were built with large cobble and small boulders collected from the streambed. The high flows were able to erode berms built with these materials, while berms built with larger boulders were more resistant to erosion.

Even though all 15 cross-channel berms in the middle basin were breached by high flows, six still -Impounded and retained significant amounts of spawning gravel. The six berms impounded 105 $m^2$ of gravel and by May 22 had been used by three pairs of spawning steelhead. In every case impounded gravels were upstream from the berm and located along the stream margin away from the thalweg (Fig. 26). Where the berms occurred in a regular sequence, upstream berms appeared to direct moving gravels so that they were impounded by the next berms downstream. Cross-channel berms that successfully impounded gravels were In areas where the channel cross-sections were wide and shallow. Berms in canyon reaches with narrow incised cross-sections impounded no gravel.

Three berms in the middle Fish Creek series (19, 20, 21) were half-channel structures that were also desIgned to impound spawning gravel. Two of the berms retained their structural integrity during the flood and impounded gravel that was subsequently used by spawning steelhead (Table 17). Gravel was deposited above berm 21 and both above and below berm 19. The offshore end of berm 20 was dispersed by the high flows and no gravel was deposited in proximity to the berm (Fig. 27).

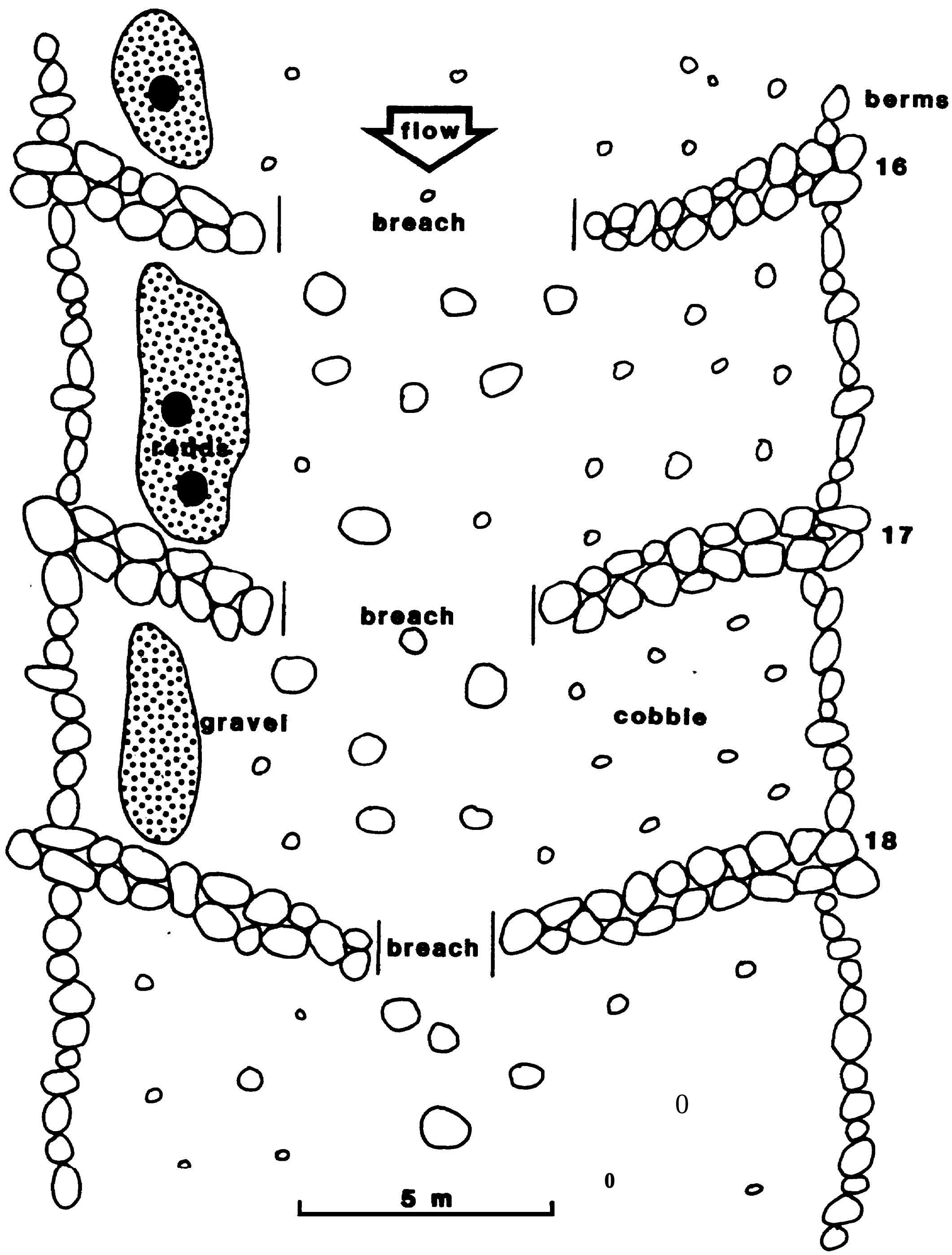



Figure 26. Diagrammatic sketch of berms 16, 17, and 18 in Suspender reach on Fish Creek after the February 23, 1986 flood event.

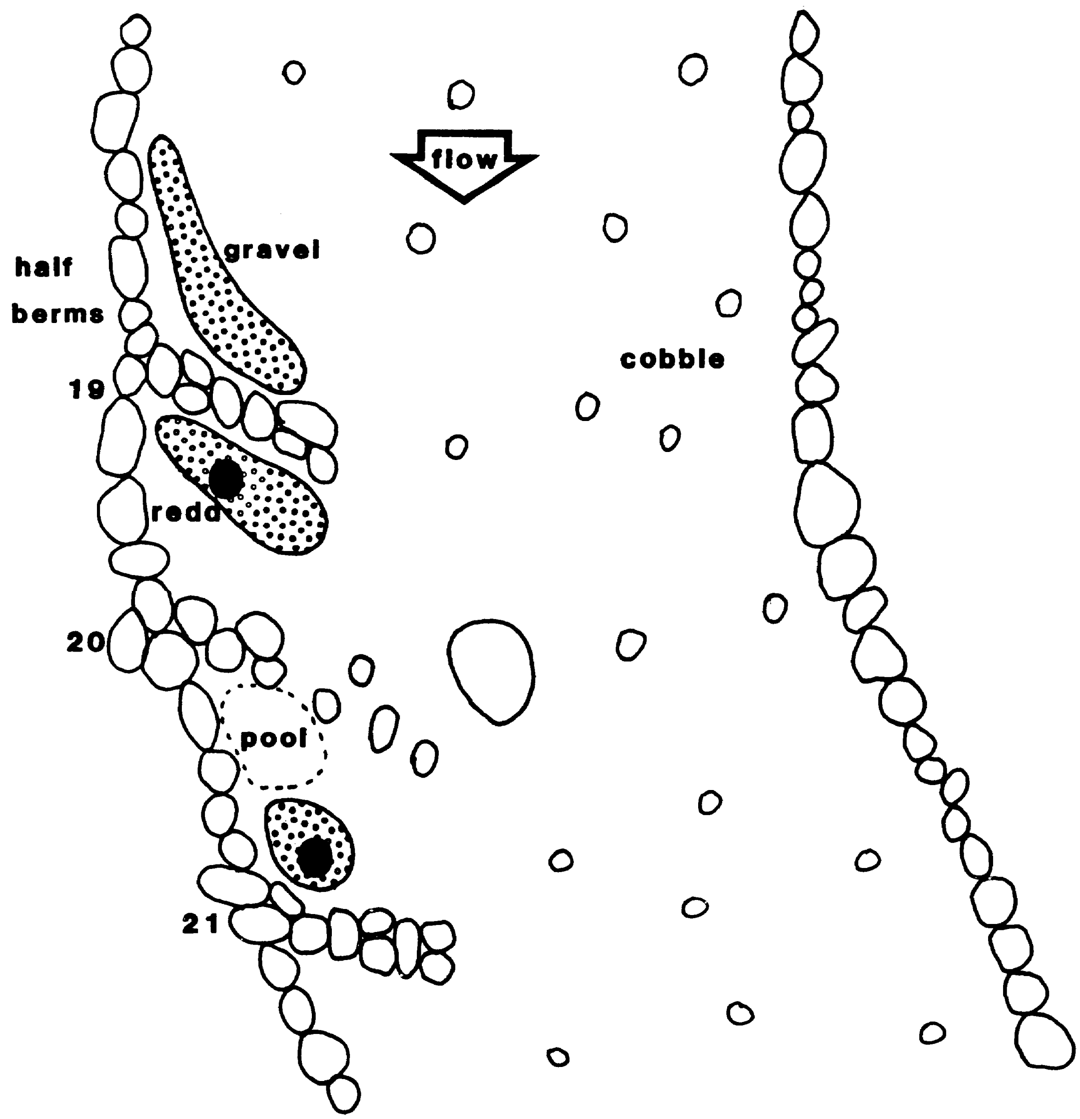



Figure 27. Diagrammatic sketch of half-berms in middle Fish Creek basin after the February 23, 1986, flood.

The three berms on Wash Creek retained their structural integrity during the flood event but only one met its design objectives (Table 17). Berm 2 impounded about 5 $m^2$ of spawning gravel that had been used by one pair of steelhead. The other two berms in the series impounded rubble that was too large in diameter for good spawning habitat.

The five berms built on upper Fish Creek in 1981 all retained their structural integrity during the flood. Three impounded gravel and were used in the spring of 1986 by spawning steelhead (Table 17).

The resistance of the berms to the erosive forces of the flood were directly related to size of material used in construction and their position in the basin. All berms in the forks (Upper Fish and Wash Creeks) retained their structural integrity and half (4) were meeting their design objectives after the flood. All of the cross-channel berms on mainstem Fish Creek were breached by the flood, but even so, six were meeting design objectives after the waters receded, The half-berm structures on mainstem Fish Creek fared better, with two out of three meeting design objectives after the flood. Half-berms might be more viable structures for capturing spawning gravel on high energy streams like Fish Creek than cross-channel berms. Also, half-berms are less vulnerable to erosive forces since they can be kept out of the stream thalweg.

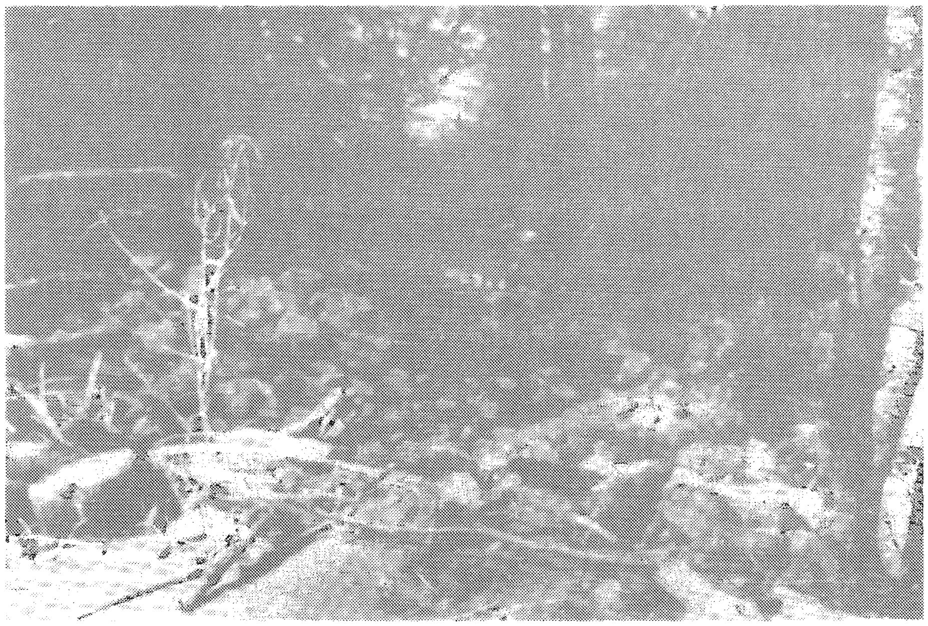
Constructing berms with large angular rock, and locating them near existing hydraulic controls, like pool tailspills, would increase their ability to withstand high flows. Contrary to early predictions, properly designed cross-channel structures can be successfully built on high energy streams like Fish Creek.

Side Channel

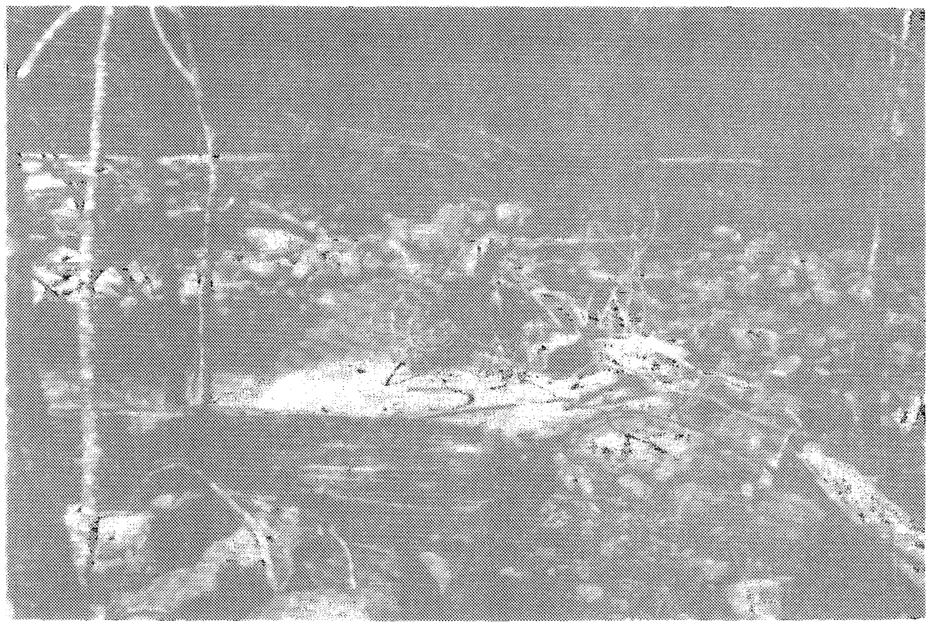
The side channel developed at km 1 on Fish Creek in 1984 was affected in two ways by the 1986 flood. Rising waters swept a number of pieces of large woody debris into the channel and an accumulation of debris formed at the bend near the middle of the channel. The woody material can be rearranged to increase cover and complexity in the channel. As the flood waters began to recede, a berm of sand and woody debris was deposited across the mouth of the channel and eventually flow through the channel ceased (Fig. 28). The berm was small and flow through the channel was quickly restored by handwork. Blockage at the mouth of the channel might be a recurring problem associated with high flow events.

Eastside Rearing Pond

High flows in February 1986 created several minor problems related to the eastside coho rearing pond at km 3 on Fish Creek. The inlet pipe was plugged with two 20-25 cm diamter cobbles that were entrained at high flow and lodged at the valve. The problem was quickly corrected when the valve was disassembled and the cobbles were removed. Bank erosion at one point along the western perimeter of the pond damaged a small levee built to prevent the pond from spilling directly into Fish Creek. The damage was repaired by handwork. The north inlet to the pond transported and deposited about 20 $m^3$ of gravel and rubble in a fan across the pond outlet stream where it enters Fish Creek. About 18 $m^2$ of excellent spawning habitat was lost and 10 $m^2$ created by the deposition fan.



A. View down dry side channel after flood.



B. Sand deposit across mouth of side channel after flood.

Figure 28. A sand berm was deposited across the mouth of the side channel at km 1 on Fish Creek by the flood of February 23, 1986.

Westside Rearing Pond.

The westside rearing pond at km 3.5 was completed in August 7985 but was not scheduled for stocking with coho fry until spring 1986. The high flows in February 1986 might have reduced the potential carrying capacity of the pond as a result of sedimentation. During the flood Fish Creek overflowed its banks in the vicinity of the pipe intake and caused erosion along the pipeline leading to the pond. The problem could have been avoided by raising and rip-rapping the bank In this area. Sediment was deposited in the pond to a depth of a half meter or more, reducing the potential stored water volume and carrying capacity of the pond. High flows also clogged the pipe Intake with small woody debris and buried the valve. Both problems were corrected with handwork. Finally, a log stringer bridge placed across Fish Creek In 1985 to provide access to the westside pond was removed by the flood. Despite the changes, the pond will still function as planned, although additional modifications are planned for the summer of 1986.

Alcove Trees

In 1984, riparian trees were felled into Fish Creek with explosives to provide cover for juvenile salmonids and Improve the complexity of stream edges. An evaluation of trees blasted at six sites was initiated In the summer of 1984. Five of the sIx trees fell Into Fish Creek and fall freshets in 1984 rotated four of the trees downstream parallel to the bank. The fifth tree remained perpendicular to the flow (Fig. 29). Three of the trees that rotated downstream were left above mean high

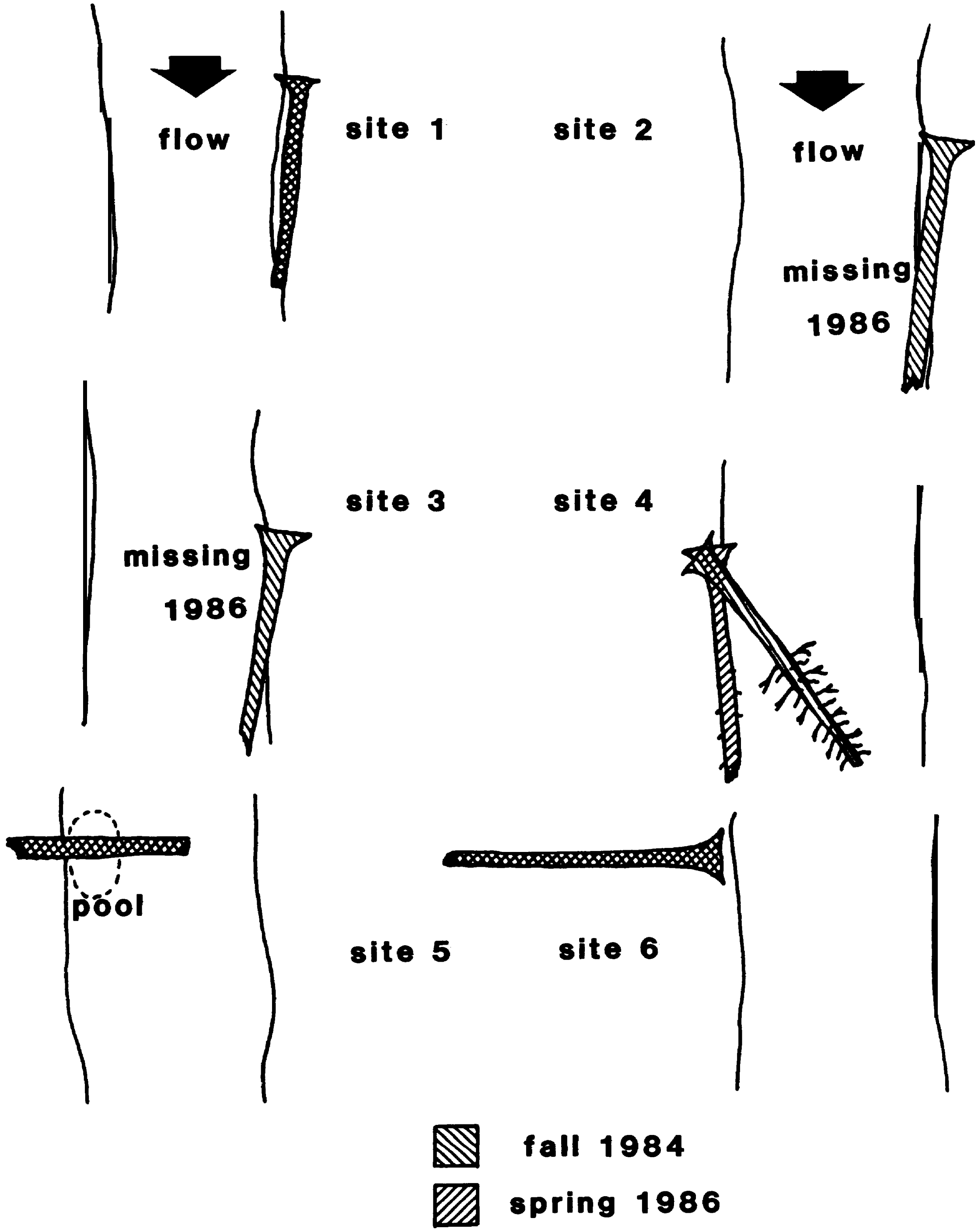



Figure 29. Orientation of alcove trees felled with explosives.

water when the freshets receded and were of no immediate benefit for fish production.

Additional changes in orientation of some of the trees occurred during the February 1986 flood (Fig. 29). The position of trees at sites 1 and 5 were unchanged. Hydraulic forces around the tree at site 5 scoured a small pocket pool next to the east bank of the stream and summer rearing habitat for steelhead might be improved as a result. The tree at site 1 is not presently interacting with the stream or Improving fish habitat. Trees at sites 2 and 3 were removed by the flood and have not been relocated. The tree at site 4 remained in place but lost its limbs and rotated so high against the bank that it is largely ineffective in improving fish habitat. The tree at site 6 fell away from the stream and remains in that position.

This operation has not necessarily been a failure even though most trees are not functioning as originally planned. The trees that remain in the system have the potential to be moved downstream by high flows to other locations where they might lodge and provide improved habitat. Introduction of single trees at separate sites, however, might not be the best technique for adding complexity to stream edges. The simultaneous introduction of several trees at a carefully selected site might be a better alternative. The weight and bulk of several trees, perhaps cabled together, have a greater potential for remaining In the desired position and meeting project objectives.

Any trees introduced in the future should be anchored in some way to prevent their movement out of the system. Trees should also be marked with permanent tags so their movements on flood flows can be monitored.

Alcoves

The alcoves excavated along the east bank of Fish Creek at km 3.5 in August 1985 were no longer functional after the February 1986 flood. Both alcoves were isolated from Fish Creek by deposition of large sand berms during the flood (Fig. 30). The upstream alcove was almost completely filled with sand that ravelled off the raw banks of the excavation. If alcoves of this type are to be tried again in a high gradient canyon stream like Fish Creek, a complete reassessment and redesign will be necessary.

## Limiting Factors.

Four years of data on salmonid populations and habitat utilization in the Fish Creek basin have provided information on factors limiting production in the basin. The observations are summarized below for each species.

Steelhead

An analysis was made in 1982 to determine whether spawning or rearing habitat was limiting steelhead trout populations in the basin. Gravel resources and rearing areas were quantified and compared (Everest and

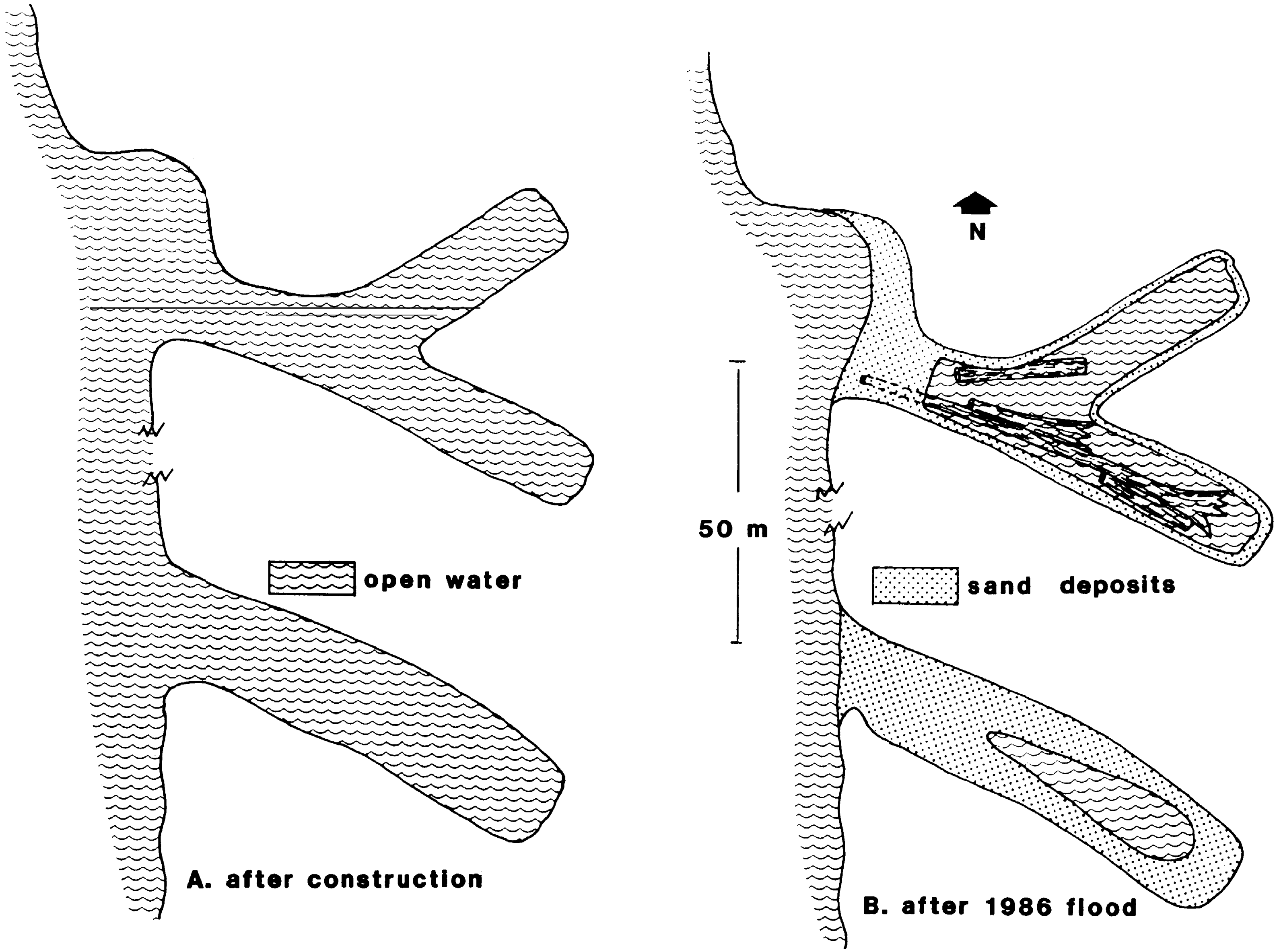



Figure 30. Constructed alcoves before and after the February 1986 flood.

Sedell 1984). The conclusion was that spawning habitat was more than adequate to seed available rearing habitat and that rearing habitat was limiting steelhead trout production. The conclusion remains unchanged, even after the recalculation of rearing area.

Analysis of data collected between 1982 and 1985 has helped identify the components of rearing habitat that limit steelhead trout production In the basin, and which age-class of steelhead trout is most affected. Substantial variations in age-class strength of 0+ steelhead trout are related both to adult spawners and the annual flow regimen in the basin. Despite variation in numbers of 0+ fish, the number of age l+ (age 1 and older) fish has remained remarkably constant over the same time period. If numbers of age 1+ steelhead trout were determined by age-class strength of 0+ steelhead trout, one would expect to see a direct relationship between 0+ numbers in one year and 1+ numbers the following year. Our data, however, show no relationship between 0+ numbers and l+ numbers the following year. These data indicate that either winter habitat for 0+ steelhead trout or summer habitat for age I+ steelhead trout, rather than seeding, limits the number of age l+ steelhead trout rearing in the basin.

The question of whether l+ steelhead trout numbers are limited by the number of 0+ fish surviving the previous winter or by summer habitat conditions available for the l+ age-group cannot be answered with present data. The consistency in numbers of l+ fish in the system in September of 1982-1984 and the apparent abundance of winter habitat for age 0+ steelhead, however, leads us to speculate that it is summer rearing habitat that limits the number of this age-group.

Analysis of habitat area and utilization by 1+ steelhead trout indicates that availability of pool habitat is limiting summer rearing. Pool habitat is the most productive habitat in the system for 7+ steelhead trout, but is in short supply relative to riffle habitat. Further addition of deep (>1.5 m) bouldery pools would be the factor most likely to enhance summer rearing capability for age 1+ steelhead trout.

Overwinter survival does not appear to be a serious factor limiting production of steehead smolts in the basin. Smolt trapping in the winter of 1984-85 yielded an estimate of 67 percent overwinter survival for pre-smolts. Caution must be exercised when using this figure since it is based on only one data point, but nevertheless overwinter survival of pre-smolt steelhead in Fish Creek appears to be favorable.

Coho salmon

Coho production in Fish Creek is believed to be limited by inadequate seeding at the present time. The number of juvenile coho salmon in the system in the summer of a given year appears to be directly related to the number of spawners the previous winter. While our counts of spawning coho in the system are incomplete because of weather and water conditions during winter, we observed increased coho spawning activity in the proximity of the eastside rearing pond in each year from 1981-85. Counts of adult coho at N. Fork Dam did not trend upward during this period of time (refer to Table 8). If the number of adults returning to the basin increased, production of coho salmon would be limited by rearing habitat rather than spawning habitat. Beaver ponds, glides, and side channels are the most productive summer rearing habitats in the system for coho salmon, but combined constitute only about 16 percent of total habitat. To enhance numbers of coho salmon rearing in the basin in summer, escapement of adult coho salmon must first be increased, and then the area and complexity of side channels and off-channel habitats, such as beaver ponds, must continue to be increased. The importance of winter habitat to coho smolt production is presently unknown.

Overwinter survival of coho parr in Fish Creek was estimated at 31 percent in 1985, a below-average figure for western Oregon. The low winter survival of coho can be attributed to the general lack of quiet edge habitats and side channels in winter. It appears, then, that coho smolt production can be Improved by creating additional favorable edge habitat for use in both summer and winter and by increasing seeding in the basin through larger returns of adult coho.

Chinook salmon

The number of chInook salmon produced by Fish Creek appears to be directly related to climatological conditions. Spring chinook salmon spawn In October when Fish Creek is often at minimum base flow. If no significant fall storms have raised the flow level before mid-October, adult chinook salmon have a difficult time negotiating the rocky alluvial fan of boulders at the mouth of Fish Creek. The number of spawners in the Fish Creek system is more related to the timing of the first fall freshets than it is to the escapement of chinook salmon to the upper

Clackamas basin (Everest et al. 1985). Access at the mouth of Fish Creek might be improved by rearranging boulders on the fan to Improve low-flow passage.

Four years of evaluation on Fish Creek have demonstrated how difficult it is to identify factors limiting fish production in a healthy stream system. Any conclusions based on only one or two years of data - can be misleading and lead to erroneous conclusions. Changes In flow, temperature, and other environmental variables can change the primary limiting factors from year to year. Changes in fish community structure and abundance can also alter the factors limiting a given species or age-class in a given year. These multiple variables operating in concert, make identification of limiting factors a complicated process.

## Estimated Smolt Production CapabilIty

The recalculation of habitat area In Fish Creek required a recalculation of smolt production capabilIty for the basin. The capability of the Fish Creek system to produce salmon and steehead smolts is dynamic and dependent on numerous factors. The capability of any system can be altered temporarily or permanently by climatic trends, watershed disturbances, changes In fish community structure, pollution, or manipulation of physical habitat. In its pristine state, the smolt production capabIlIty of Fish Creek probably varied little around an average figure. Harvest of riparian timber and salvage of dead and down timber in the channel of Fish Creek and Wash Creek has probably reduced the historic smolt production capability for some species to the levels presently observed. Present levels for all species could probably be increased by habitat enhancement. Estimates of smolt production capability for the Fish Creek basin under present conditions, present conditions with full seeding, and potential capability with enhancement are presented in Table 18. Current data are insufficient to derive these figures with certainty. The assumptions used in their derivation are listed below for each species.

Table 18.--Estimates of smolt production from the Fish Creek basin.

| Species | Present | Present with full seeding |
|---|---|---|
| Steelhead trout | 8,000 | 8,000 |
| Coho salmon | 1-4,000 | 6,000 |
| Chinook salmon | ? | ? |

Steelhead

Current estimates of the number of steelhead trout smolts produced by Fish Creek are based on the number of steelhead age 1 or older in the system the previous September and the percentage of those that are large enough to achieve smolt-size by the following spring (50 percent). A survival factor is applied to the September population to estimate the number of fish surviving the winter to begin their seaward migration the following spring. Such survival factors are poorly documented. In 1984, we used a factor of 0.5 based on a Washington study, and in 1985, we have local data from Fish Creek that indicate 67 percent survival of presmolts in the winter of 1984-85.

The estimates in Table 18 are based on an observed population of 23,800 steelhead trout age 1 or older in Fish Creek in September of 1984. We believe this is near the maximum summer carrying capacity for this age group because of the consistency of summer standing crops over the past 4 years. Present smolt production and potential production, since the habitat appears to be fully seeded, would be expected to be about 8,000 smolts (23,800 x 0.50 x 0.67 = 7,973).

Coho

Current estimates of the number of coho salmon smolts are based on the number of 0+ fish in the system the previous summer. Since the system appears to be underseeded, the number of 0+ fish has high annual variability. Smolt production, estimated by multiplying 0+ September populations by the winter survival factor estimated at the smolt trap in 1985 (0.31) has ranged from 600 to 3,700 from 1982-1985. We believe that full seeding of present habitat, independent of enhancement, could boost summer populations to 15-20,000 fish, or a maximum smolt production of 6,200 fish. This estimate is based on habitat utilization by coho salmon observed from 1982-84 as populations in the system varied between about 2,000 and 12,000 fish.

Chinook

Fish Creek is, and probably always will be, a minor producer of chinook salmon smolts. Spawning in the system depends on the size and timing of fall freshets and most juvenile chinook leave the basin prior to achieving smolt status. In some years, Fish Creek might contribute significantly to seeding of downstream waters of the Clackamas River with chinook fry. It does not appear that the health of upper Clackamas chinook runs are dependent on Fish Creek, but rather that chinook are opportunistic users of the stream when conditions are favorable.

## SUMMARY AND CONCLUSIONS

1) Monitoring efforts in 1985 focused on estimates of summer habitat availability, summer standing crops of juvenile anadromous salmonids, quantification of outmigrant steelhead trout, coho and chinook salmon smolts, and winter habItat availability and use by juvenile anadromous salmonids.

2) Sumner habitat availability varies directly with the quality of the water year, and available area can vary by more than 50 percent annually.

3) Summer populations of 0+ and l+ steelhead trout, and coho and chinook salmon were estimated at 115,700, 18,520, 11,980, and 4,350, respectively in 1985.

4) Quiet stream margins in late spring and early summer appear to be a key habitat need for post-emergent steelhead fry.

5) Steelhead trout smolt production in 1985 was estimated at 8,000 fish and overwinter survival of presmolts was estimated at 67 percent.

6) Fish Creek is a disproportIonate steelhead trout producer, making up 10 percent of the upper Clackamas basin area, but contributing 23 percent of the upper Clackamas smolt migration in 1985.

7) Coho salmon smolt production was estimated at 3,100 fish, with a presmolt-to-smolt overwinter survival of 31 percent.

8) Juvenile coho salmon prefer to winter in quiet backwaters with heavy cover located off of the mainstem of Fish Creek. Such habitats are rare within the range of coho salmon in the basin.

9) In 1985 Fish Creek produced 3 percent of the coho salmon smolts emigrating from the upper Clackamas basin.

10) The off-channel pond constructed at km 3 on Fish Creek increased coho salmon smolt production from the basin by 18.6 percent. Overwinter survival in the pond exceeds 50 percent.

11) Juvenile salmonids appear to move upstream in the fall before entering winter habitat. Fish also move into lower Fish Creek in the fall from the Clackamas River.

12) Preferred winter habitat for age 1+ steelhead trout consists of large boulders surrounded by small boulders and cobbles positioned within the wetted summer perimeter.

13) Preferred winter habitat for juvenile coho salmon consists of quiet marginal or off-channel habitats with heavy cover.

14) The developed side channel at km 1.5 has provided spawning and rearing habitat for steelhead trout, and coho and chinook salmon, but rearing densities of juvenile salmonids are lower than in comparable natural side channels.

15) The flood of February 1986 substantially altered some enhancement projects in the basin. Some continue to meet their design objectives while other do not. Properly designed projects can be effective, even in this high energy system.

16) Limiting factors analyses are one of the most difficult components of enhancement work. With the present state of knowledge in the fisheries profession several years of intensive investigation might be required to reach reliable conclusions about limiting factors,

17) Intensive evaluations of the type in progress on Fish Creek should help to shorten both the time and intensity required for future limiting factors analyses.

18) Project designers should observe changes in berms and alcoves caused by the February flood to improve future designs of such structures.

19) The fate of introduced trees and natural blowdown should be assessed by tagging trees and monitoring their movements on high flow events.

20) Structures designed for any system need to balance cost and design life. The 1986 flood on Fish Creek exceeded the 5-year flow recurrence the berms were designed to withstand, and consequently, they were substantially altered. The structures could be rebuilt to accomplish their original objectives.

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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 IN SYSTEM | NUMBER FISH ESTIMATE BY HABITAT | BIOMASS (g) FISH ESTIMATE BY HABITAT | #/m² | g/m² |
|---|---|---|---|---|---|---|
| COHO | Alcove | 1,080 | 140 | 870 | 0.13 | 0.80 |
| | Riffle | 70,350 | 1,040 | 3,380 | 0.01 | 0.05 |
| | Sidechannel | 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 | -- | - |
| | Sidechannel | 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+STHD | Alcove | 2,270 | 2,200 | 5,010 | 0.97 | 2.21 |
| | Riffle | 138,590 | 75,240 | 211,660 | OS4 | 1.60 |
| | Sidechannel | 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 |
| | Sidechannel | 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 |
| | Sidechannel | 4,250 | 5,740 | 22,520 | 1.35 | 5.30 |
| | 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 IN SYSTEM | NUMBER FISH ESTIMATE BY HABITAT | BIOMASS(g) FISH ESTIMATE BY HABITAT | #/m² | g/m² |
|---|---|---|---|---|---|---|
| COHO | Alcove | 1,170 | 220 | 1,080 | 0.19 | 0.92 |
| | Riffle | 104,820 | 5,340 | 29,680 | 0.05 | 0.28 |
| | Sidechannel | 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 | 7,438 | 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 |
| | Sidechannel | 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 |
| 0+STHD | Alcove | 2,450 | 610 | 1,710 | 0.25 | 0.70 |
| | Riffle | 219,360 | 53,870 | 150,840 | 0.25 | 0.69 |
| | Sidechannel | 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 |
| 1+STHD | Alcove | 2,450 | 90 | 2,370 | 0.04 | 0.97 |
| | Riffle | 219,360 | 23,760 | 427,140 | 0.11 | 1.95 |
| | Sidechannel | 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 |
| | Sidechannel | 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 |
| | 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 IN SYSTEM | NUMBER FISH ESTIMATE BY HABITAT | BIOMASS(g) FISH ESTIMATE BY HABITAT | #/m² | g/m² |
|---|---|---|---|---|---|---|
| COHO | Alcove | 1,080 | 630 | 2,360 | 0.28 | 2.19 |
| | Riffle | 81,610 | 3,310 | 12,740 | 0.04 | 0.16 |
| | Sidechannel | 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 | — | — | — |
| | Sidechannel | 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 |
| | Sickchannel | 5,320 | 2,370 | 6,110 | 0.45 | 1.15 |
| | Pool | 19,180 | 3,850 | 10,240 | 0.20 | 0.53 |
| | Beaver pond | 270 | 0 | 0 | -- | - |
| | Total | 188,750 | 08,060 | 214,860 | 0.47 | 1.14 |
| 1+STHD | Alcove | 2,280 | 110 | 3,360 | 0.05 | 1.47 |
| | Riffle | 161,700 | 18,420 | 405,240 | 0.12 | 2.51 |
| | Sidechannel | 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 | 1,570 | 7,380 | 0.69 | 3.24 |
| | Riffle | 161,700 | 102,740 | 614,830 | 0.64 | 3.80 |
| | Sidechannel | 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 IN SYSTEM | NUMBER FISH ESTIMATE BY HABITAT | BIOMASS (g) FISH ESTIMATE BY HABITAT | #/m$^2$ | g/m$^2$ |
|---|---|---|---|---|---|---|
| COHO | Glide | 13,450 | 5,720 | 34,320 | 0.43 | 2.55 |
| | Riffle | 55,810 | 3,850 | 15,550 | 0.07 | 0.28 |
| | Sidechannel | 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 | OS8 |
| | Riffle | 55,810 | 1,620 | 6,770 | 0.03 | 0.12 |
| | Sidechannel | 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 |
| 0+STHD | Glide | 21,030 | 20,270 | 46,620 | 0.96 | 2.21 |
| | Riffle | 93,770 | 72,960 | 174,370 | 0.78 | 1.86 |
| | Sidechannel | 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 |
| 1+STHD | Glide | 21,030 | 1,800 | 36,680 | 0.09 | 1.74 |
| | Riffle | 93,770 | 12,880 | 262,490 | 0.14 | 2.80 |
| | Sidechannel | 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 |
| | Sidechannel | 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 |