THE EFFECTS OF HABITAT ENHANCEMENT ON STEELHEAD TROUT AND COHO SALMON SMOLT PRODUCTION, HABITAT UTILIZATION, AND HABITAT AVAILABILITY IN FISH CREEK, OREGON, 1983-86

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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 1986 by the Estacada Ranger District, Mt. Hood National Forest, and the Anadromous Fish Habitat Research Unit of the Pacific Northwest Research Station (PNW), USDA Forest Service. The 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 (1982-1986) to be financed with Forest Service funds. The habitat improvement program and the evaluation of improvements were both expanded in mid-1983 when the Bonneville Power Administration (BPA) entered into an agreement with the Mt. Hood National Forest to cooperatively fund work on Fish Creek.

Habitat improvement work in the basin is guided by the Fish Creek Habitat Rehabilitation-Enhancement Framework developed cooperatively by the Estacada Ranger District, the Oregon Department of Fish and Wildlife, and the Pacific Northwest Research Station (see Appendix 2). The framework examines potential factors limiting production of salmonids in the basin, and the appropriate habitat improvement measures needed to address the limiting factors.

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

The objectives of the evaluation include :

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

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

3) Benefit-cost analysis of habitat improvements developed with BPA and Forest Service funds on Fish Creek.

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

The projects completed during the first three years of the program were typically prototypes to see which were the most effective given the conditions found in Fish Creek. As a result none of the project areas were intensively treated. Therefore, the emphasis of the 1986 field season was to intensively treat project areas in lower and middle Fish Creek with the objective of increasing habitat complexity. In 1986, about 110 structures were constructed at three work areas in lower and middle Fish Creek and a passage project was completed at the mouth to improve access conditions for spring chinook. The structures built in 1986 were combinations of logs and boulders anchored together and to the stream banks with epoxy resin and cable. The majority of the structures were placed along the stream margin rather than across the channel.

Implementation activities on Fish Creek are scheduled to be completed by 1988. At the end of the habitat improvement program, it is anticipated that at least 80 percent of the habitat available to anadromous fish will have been affected. A total of $133,291 was budgeted for planning, project implementation, and the Fish Creek evaluation in 1986. A total of $124,376 was spent.

This paper will focus on the projects completed in the basin in 1986, and the evaluation of projects constructed during the 1983-85 period. Winter habitat use and coho salmon and steelhead trout smolt production will be emphasized.

A flood event with a 10-15 year recurrence period occurred in the Fish Creek basin in February 1986. This was the first major flow event since habitat work began in the basin in 1981. During the event three debris torrents brought large quantities of woody debris and sediment into the channel of Fish Creek. The combination of high flow, sediment, and wood tested the habitat projects completed in 1983-85. The effects of the flood are described in Everest et al,. 1986 and in the discussions of individual projects in this paper.

* * *

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/sec in late summer to more than 100 m^3/sec 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 km2 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.

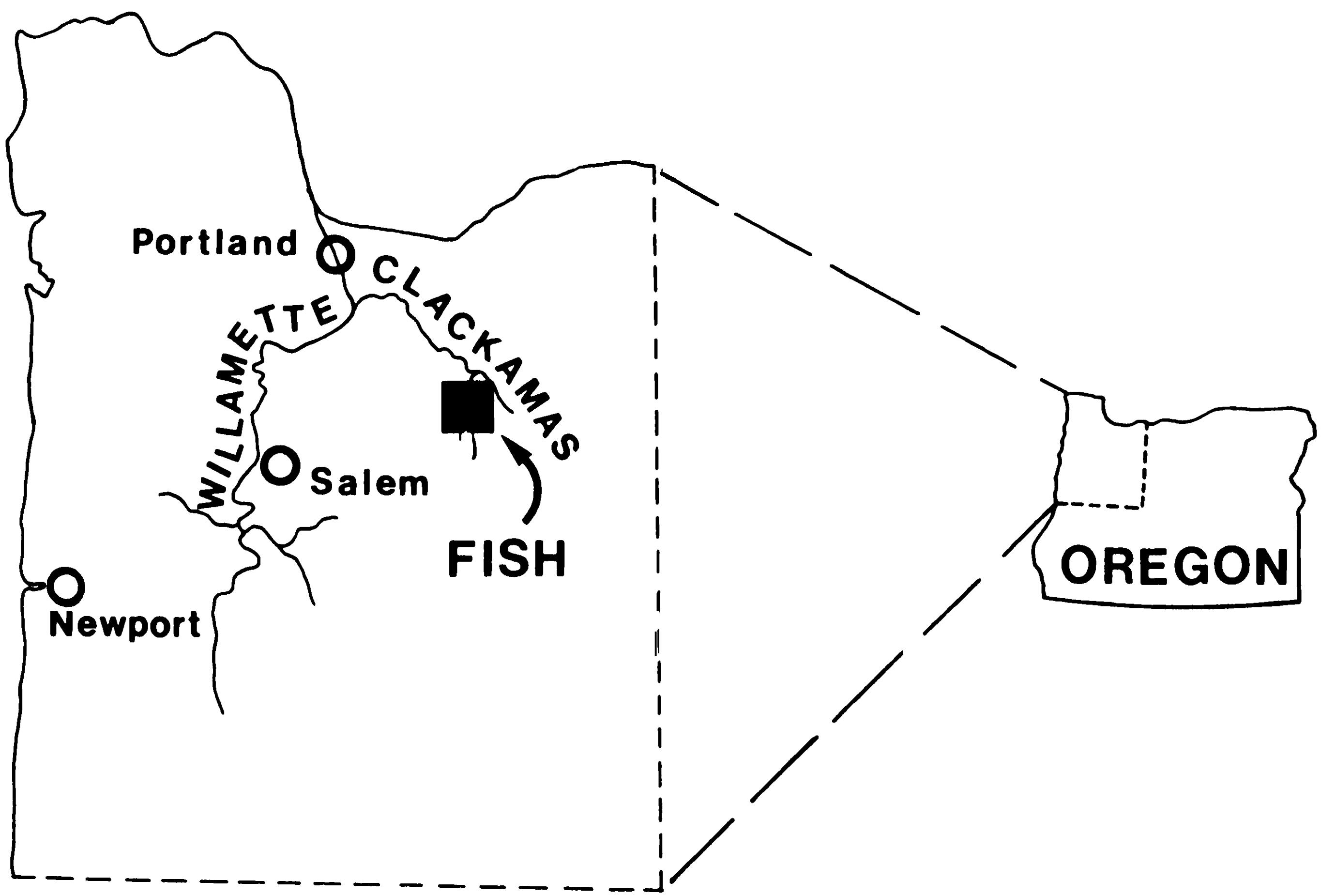

Figure 1. The Fish Creek basin Is located In northwest Oregon.

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. *pairdneri*). Few resident salmonids are found within the range of anadromous fish and all rainbow trout sampled there were treated as steelhead trout. Approximately 16 km of habitat are used by anadromous salmonids, including the lower 4.7 km of Wash Creek. The upper reaches of both Fish and Wash creeks are blocked to anadromous salmonids by major waterfalls. About 20 km on Fish Creek and 8 km of habitat on Wash Creek are unavailable to anadromous salmonids, but provide good resident trout habitat. Culverts have blocked access to a total of 2 km of anadromous habitat on three small tributaries to Fish and Wash Creeks. Water temperatures in habitat used by anadromous fish are generally favorable for fish production, ranging from near 0°C at times in winter to about 20°C in most summers. In years with low summer streamflow and high summer temperatures, however, water temperatures can reach stressful levels for salmonids. For example, in early September 1980, temperatures in lower Fish Creek reached 24° C for several consecutive days. Future streamside management in the basin is expected to gradually reduce high summer temperatures and eliminate periodic summer thermal stress for juvenile salmonids as streamside vegetation recovers where openings were created.

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 1982-86 indicate that pool habitat averaged 11 percent (range 8-18) of total area during those years. The percentage of boulder habitat within the range of anadromous fish increased from 45 to 70 percent in the upper reaches of Fish Creek between 1959 and 1965, and from 25 to 60 percent on Wash Creek. Spawning habitat for anadromous salmonids declined by about one-third during the same time interval. The 1964 flood was followed by a vigorous logjam removal effort that was probably responsible for the observed decline in pool habitat.

* * *

DESCRIPTION OF HABITAT IMPROVEMENTS

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

Evaluation of habitat improvements completed on Fish and Wash Creek in the summer of 1986, as well as those done during the 1983-85 period, continued in 1986. Each type of improvement completed during the past four years (Fig. 2) is described in the following pages.

I986 Habitat Improvements

Approximately 94 trees were felled and more than 300 boulders were used to construct 110 structures designed to add habitat complexity to 2 km of stream at sites located at km 0.0, 0.6, and 7.8. The project was designed to increase the habitat complexity in boulder dominated riffles and increase effective cover in existing pools to improve low flow rearing habitat. The addition of large structural elements to the channel also should improve overwintering conditions and provide additional spawning habitat. Maintenance work was also performed on the off-channel pond constructed in 1985. In addition to increasing mainstem habitat complexity, minor modifications at the mouth are planned to improve upstream passage for anadromous fish.

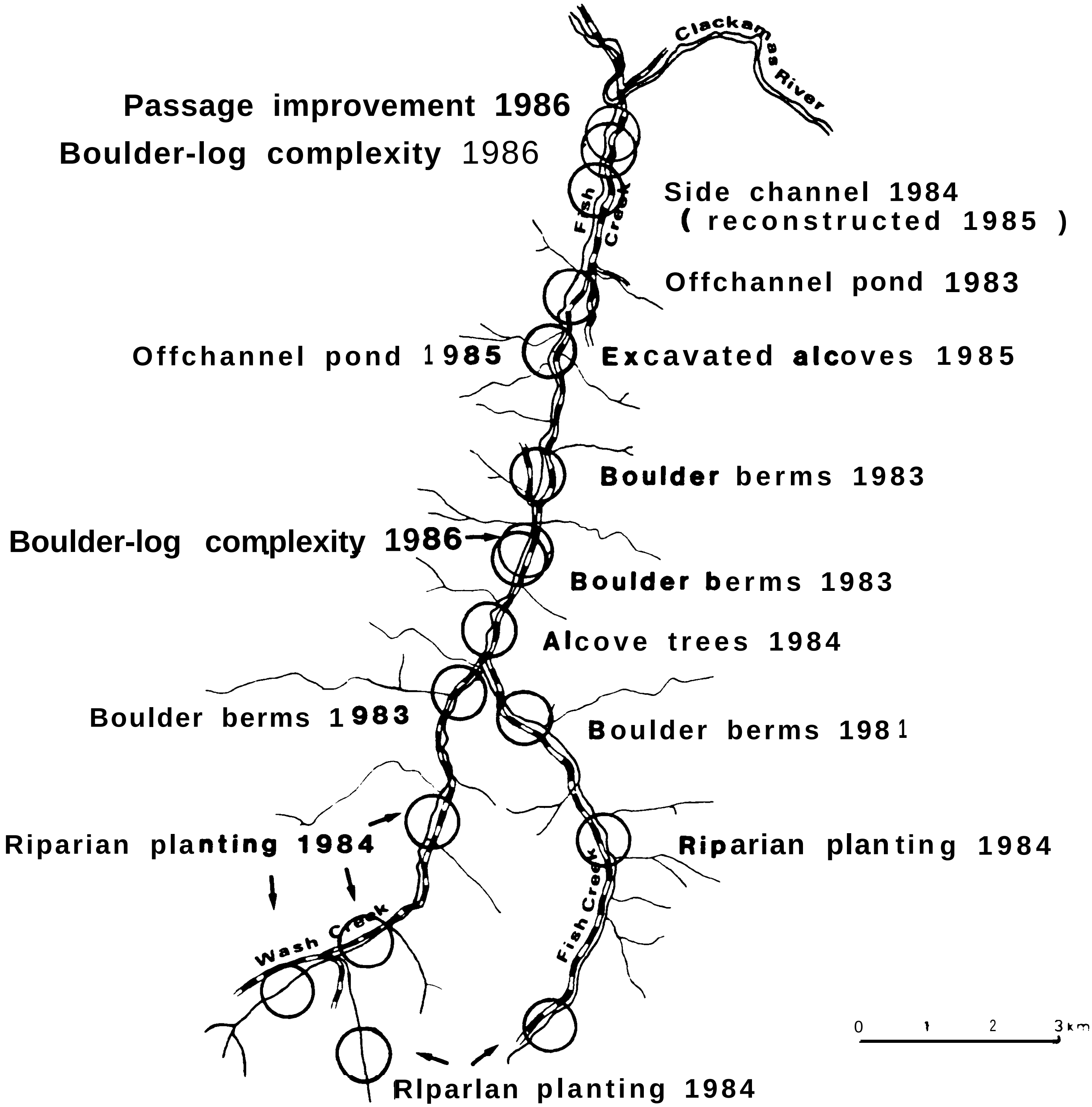

Figure 2. Habitat enhancement projects completed in the Fish Creek basin, 1981-1986.

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

Passage enhancement at the mouth of Fish Creek required placement of large rock to maintain a narrowere channel. The channel broadened at the mouth and did not have sufficient depth to pass chinook. This channel will maintain present flows and allow access for spring chinook salmon over a wider range of flows.

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

Boulder Haul: To minimize the disturbance of boulders already incorporated in the channel approximately 250 boulders were hauled to the project area and stockpiled at eight sites. Transportation of boulders from the stockpile sites to individual work sites was done by the backhoe. About 50 boulders located along the floodplain of the project area were used also. The boulders were placed individually and in groups to act as scouring agents in riffles, to provide cover in pools, and to act as anchoring points for logs.

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

Backhoe Operation: A large excavator/backhoe **was rented to place the** logs and boulders, excavate pools, and reconstruct the west beaver pond. When a boulder was placed it was stabilized by seating it into the substrate. Boulders used as scouring agents were seated low enough to allow flows to pour over the top of the boulder to assist the scouring. Boulders used as anchors were placed on the upstream side of the felled trees to prevent the logs from floating and coming to rest on top of the boulders. Also, the backhoe was used to pull on-site boulders and downed logs along the banks into the channel. As the backhoe left the project area it ripped and placed barrier rock across the spur roads to restrict vehicle access to these areas. Disturbed soil areas were grass seeded upon the completion of the project.

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

1985 Habitat Improvements

Eastside Off-channel Pond

Fifteen m^2 (surface area) of spawning gravel were created by placing 10 m^3 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. 1986). 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 inlet was altered in 1986 to improve flow and reduce maintenance costs.

A fish ladder and upstream-downstream migrant trapping facility was 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 designed to provide quiet water rearing habitat for coho salmon 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

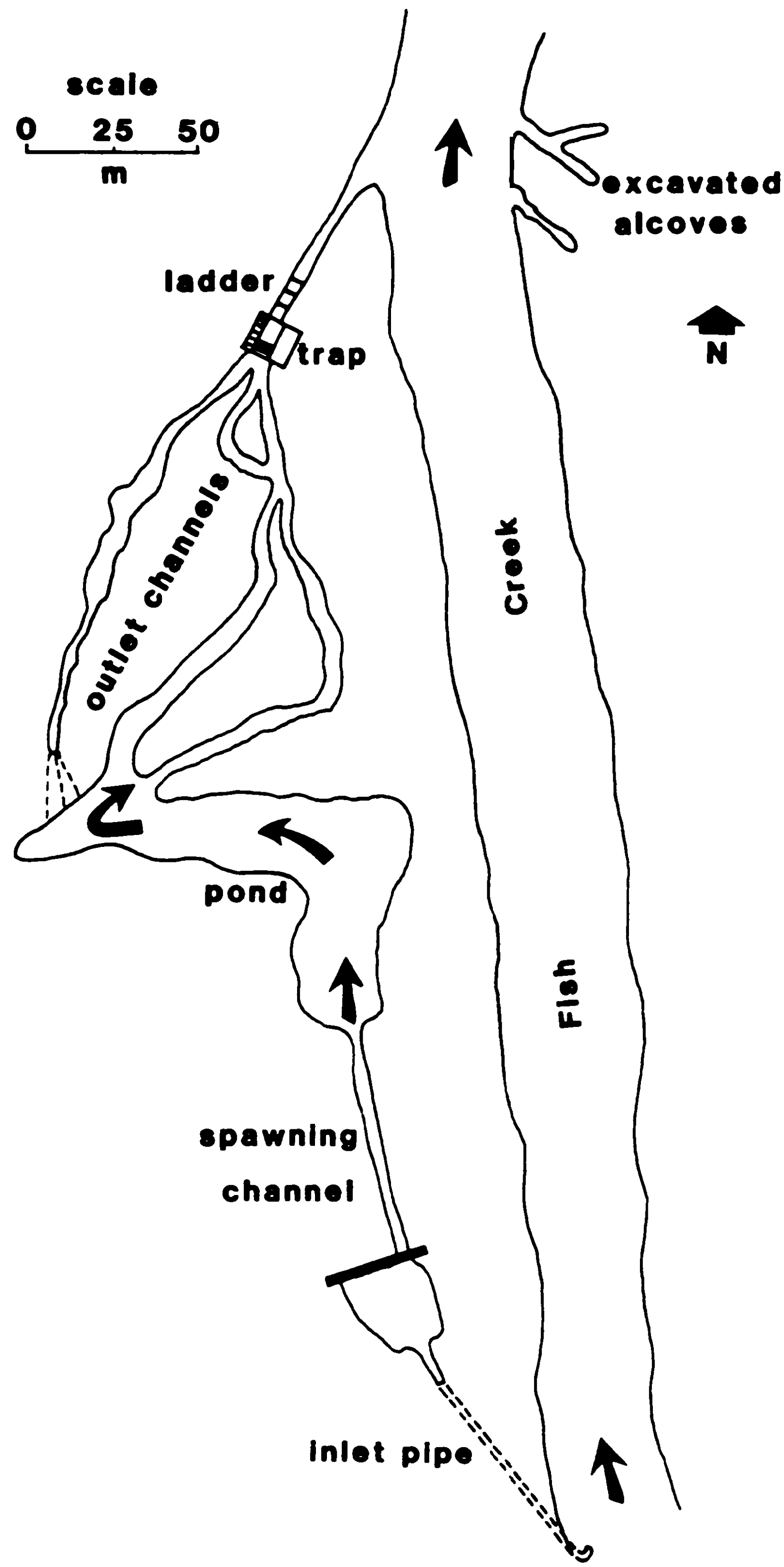

Figure 3. Diagrammatic sketch of westside offchannel pond and constructed alcoves at km 3.5 on Fish Creek.

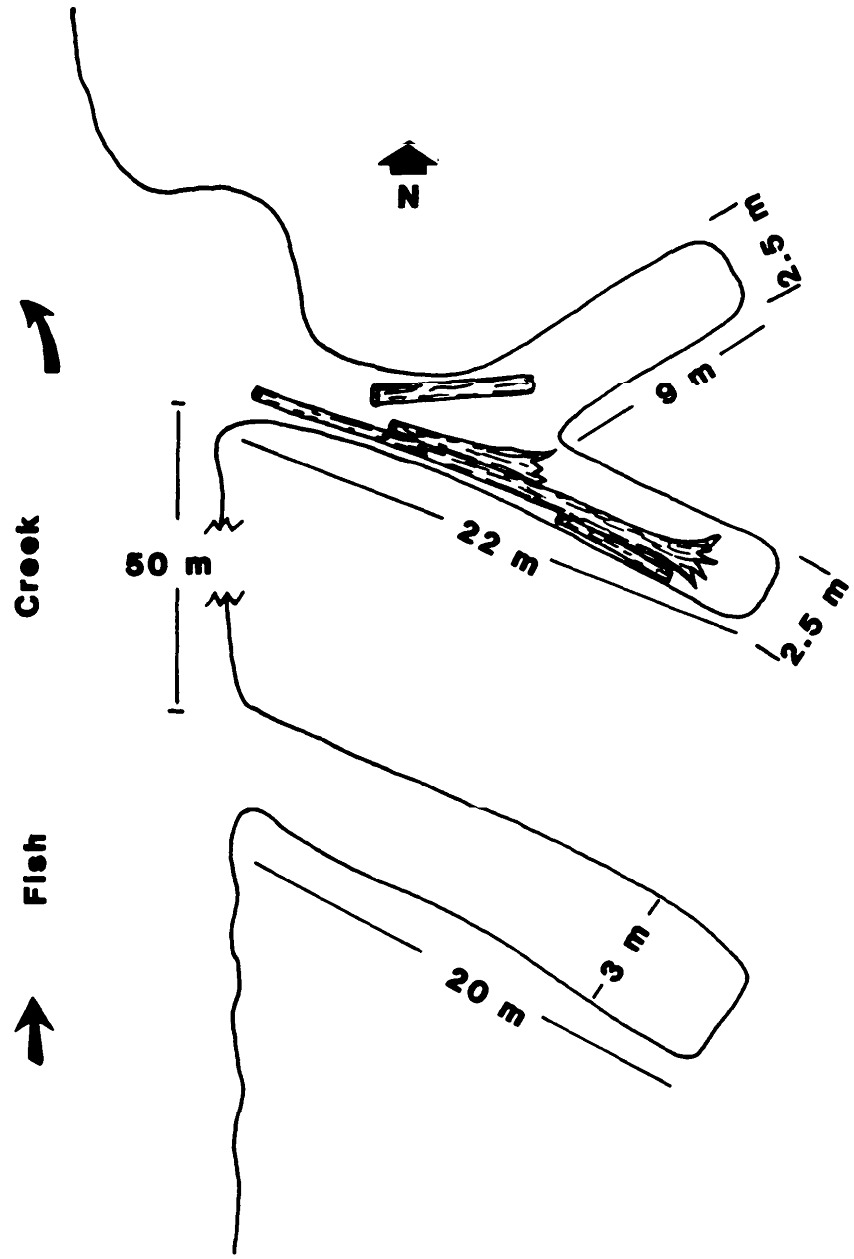

Figure 4. Configuration and dimensions of constructed alcoves at km 3.5 on Fish Creek.

streambanks were low in this area. Excavation followed the routes of existing overflow channels on the elevated floodplain in an attempt to reduce the amount of excavated materials.

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 increased also. 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.

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 1986 flood event caused substantial changes in the channel and influenced the design of future improvements of this type.

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 mainstem 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. Only one of these trees is still in place, indicating that this technique lacks promise for future work.

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.

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 1983-85 period, but a 10-15 year recurrence event in the winter of 1985-86 substantially changed the physical structure of 16 of the 21 berms. 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 l/sec to the pond. The pond, which was formerly 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.

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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 also were made before and after habitat improvements at specific sites.

Habitat Surveys 1982-1984

The composition of physical habitat was measured by compiling the results of habitat surveys in five 0.5 km reaches in the basin (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

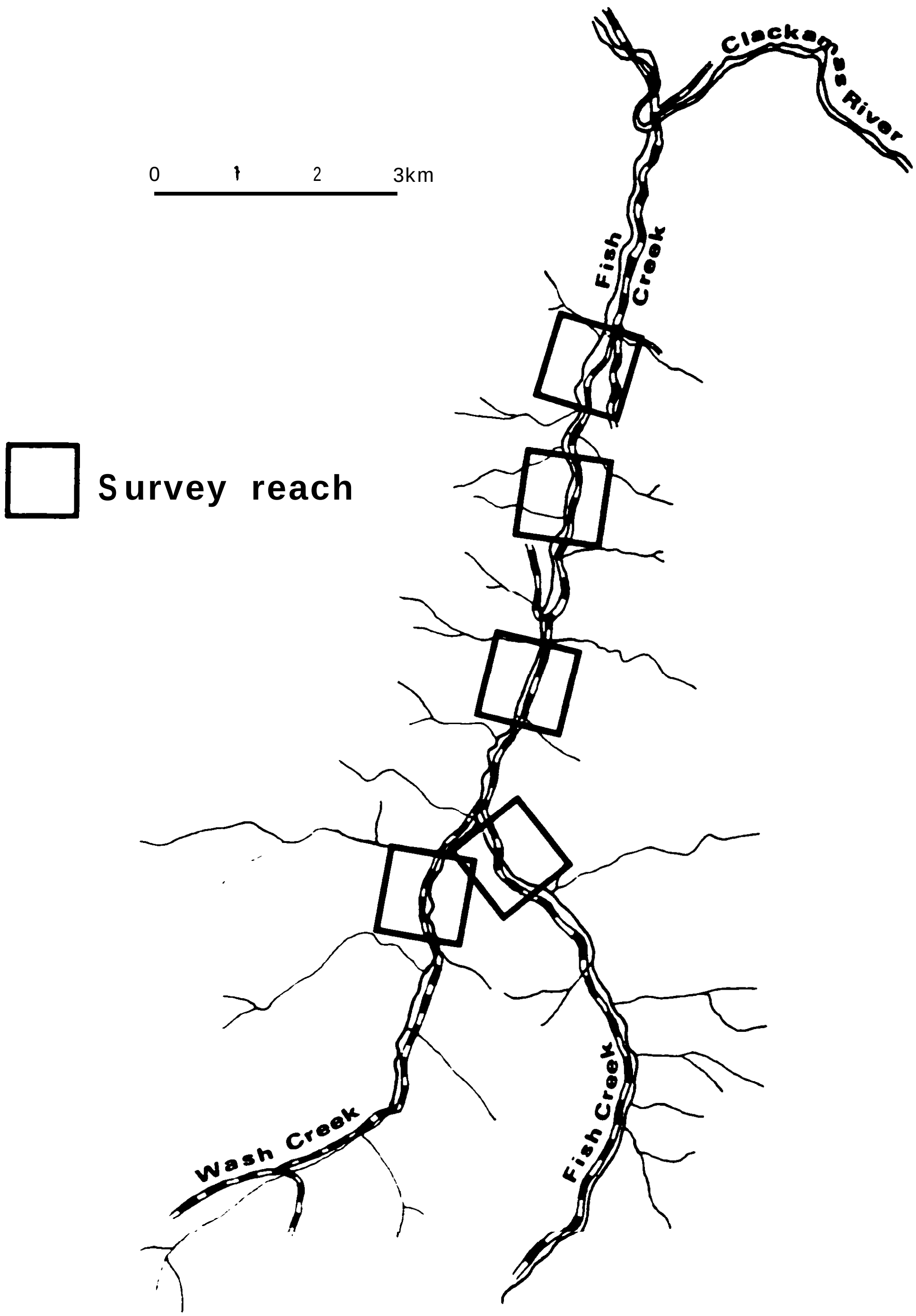


Figure 5. Physical habltat was surveyed at five 0.5 km reaches in Fish Creek basin.

Fish Creek during the summer. Those that remain active in summer have characteristically slow water velocity and low stream flow, but water temperature remains favorable fcr fish production.

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

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, 1986

The habitat surveys conducted in 1985 and 1986 differed from those made from 1982-1984. The edge habitat type previously called "alcove" was dropped from the survey because independent observers showed inconsistency in identifying and quantifying this habitat type. A habitat type called "glide" (Bisson et al. 1982) was added to the survey. Glides are shallow habitats with little turbulence and low velocity. In the 1982-84 surveys glides were included primarily with riffles. The 1985 survey identified five types of habitat: pools, riffles, glides, side-channels, and beaver ponds.

The habitat surveys done in 1985 and 1986 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. The techniques initiated in 1985 are more reliable than those used prior to 1985 because habitat of anadromous fish in the entire basin is sampled, rather than a few selected reaches.

Fish Population Estimates 1982-1984

Fish population estimates for the portion of the basin accessible to anadromous salmonids were made by sampling juvenile salmonids in individual habitat types at 8 locations in the basin (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.

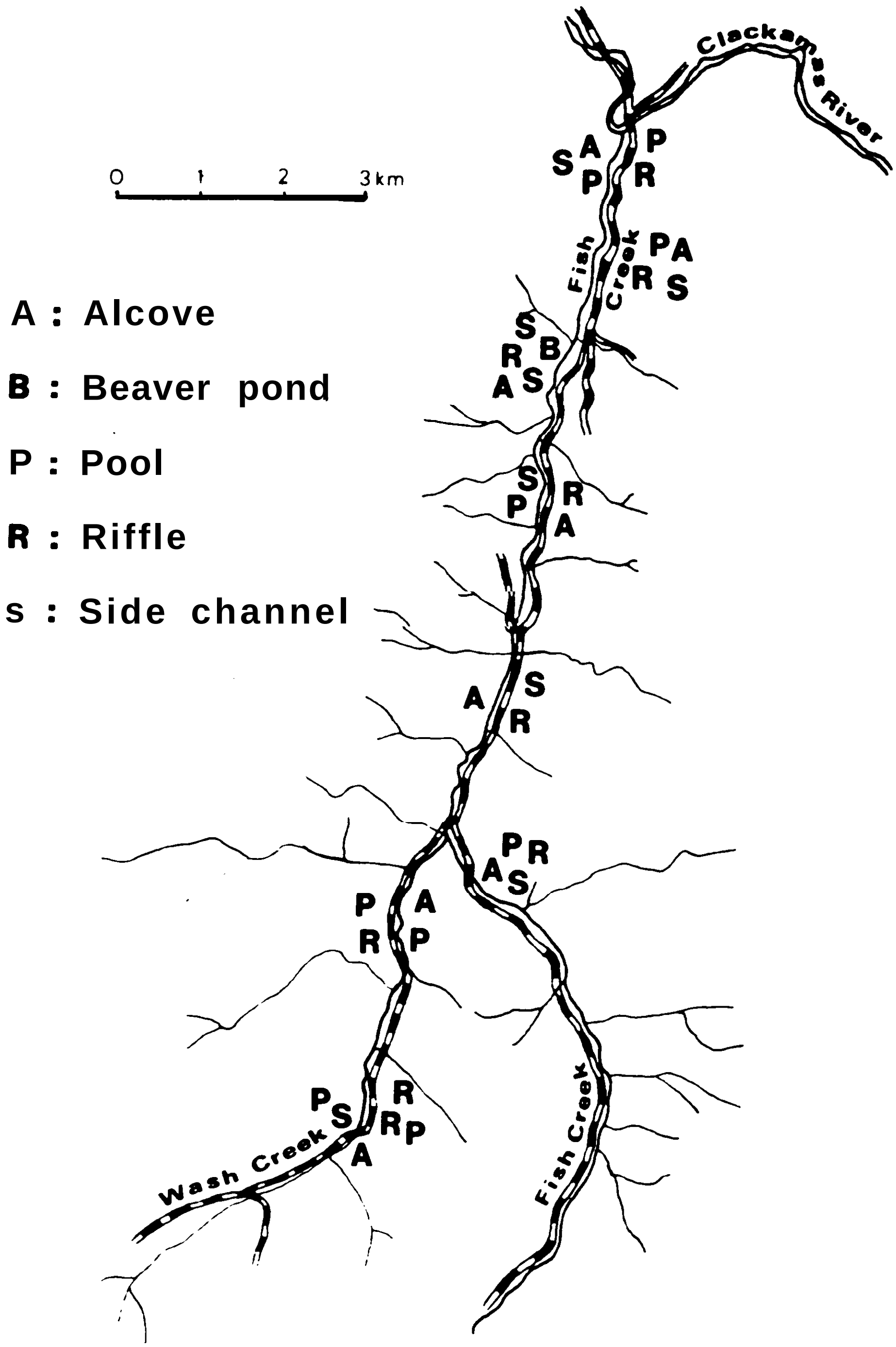


Figure 6. **Fish** populations were sampled at 8 locations in Fish Creek basin. Thirty-five individual habitat units were sampled, 1982-1984.

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

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

Each salmonid captured by electrofishing was measured to the nearest millimeter (fork length) and the first 25 of each species at each site were weighed to the nearest tenth of a gram on an Ohaus Dial-O-Gram balance. Weights 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.

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

Fish Population Estimates 1985, 1986

Fish numbers in 1985 and 1986 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 and Reeves in prep.). 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 cm2 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 digital balance. The standing crop of fish at a site was estimated by multiplying the mean weight of a species or age-class times the estimated number of individuals.

Smolt Production Estimates

Smolt production of steelhead trout and coho and chinook salmon in 1985 and 1986 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 traveling screen (4 mm mesh) is fitted with seven 50 x 50 mm baskets that extend across the entire width of the screen at equal intervals. The screen can be lowered into the water to any desired depth between the surface and within about 20 cm of the bottom. The paddlewheel is powered by the streamflow passing by the trap and turns the traveling screen at speeds up to 15 cm/sec.

The trap was fished 0.3 km upstream from the mouth of Fish Creek by positioning it with cables in high velocity water at the stream thalweg (Fig. 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

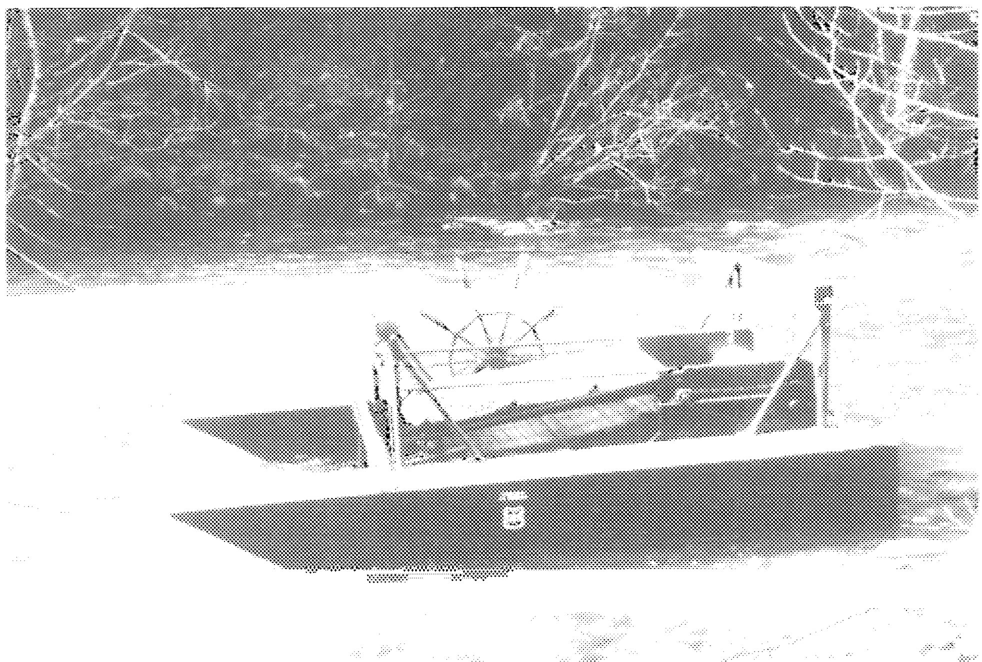


Figure 7. Modified Humphrey trap used to sample downstream migrant salmonid smolts on Fish Creek.

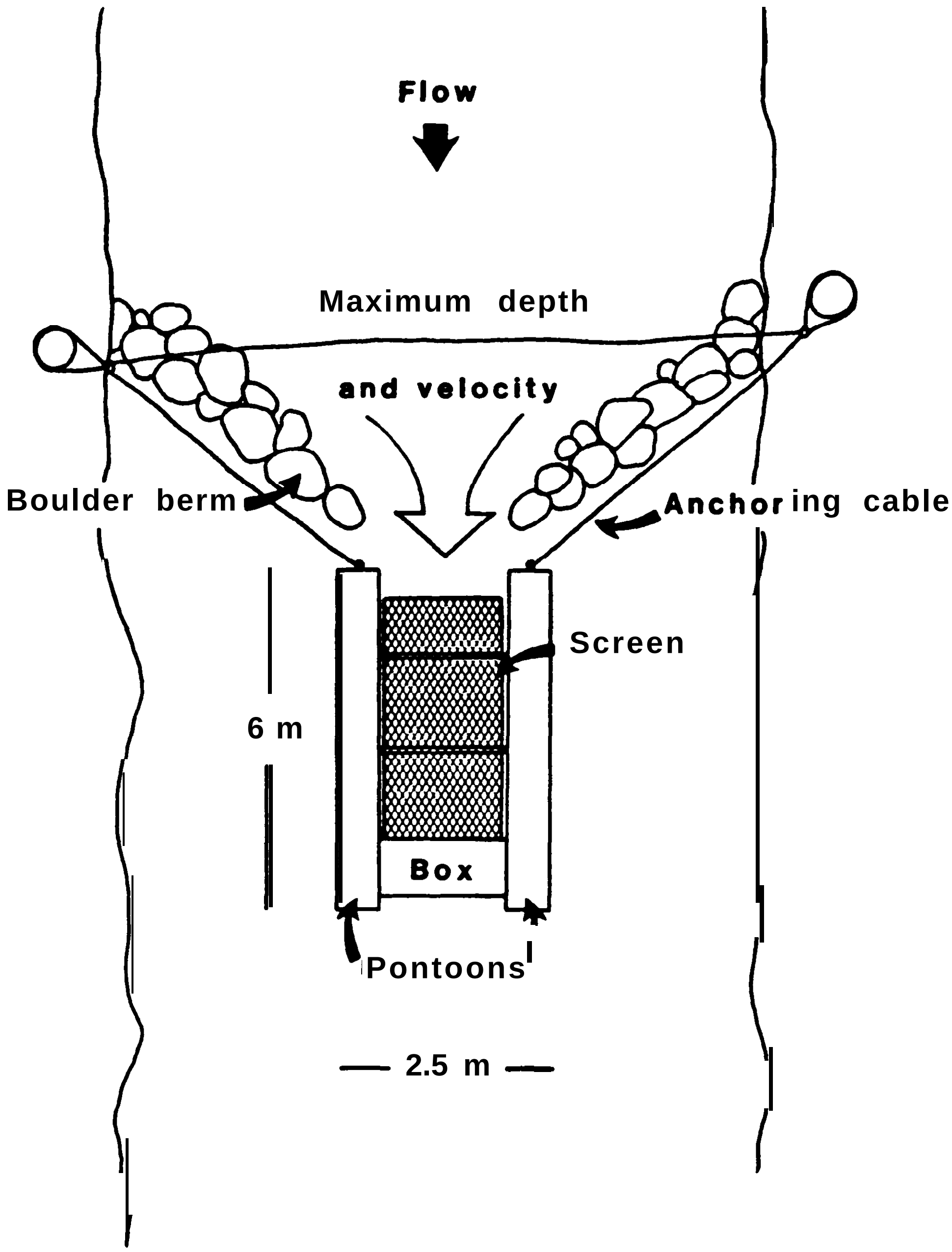


Figure 8. Schematic diagram of Humphrey trap in operating position.

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

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

In 1985 an attempt was made to fish the trap 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 when the trap was out of operation because of mechanical problems, it fished from April 15 until August 25 when streamflow became too low for operation. The trap was started again in late September and fished until mid-November when it was removed from the stream before the onset of winter freshets.

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

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

Boulder Berm Surveys

Physical habitat surveys designed to document changes in channel bed topography were completed at 21 sites in Fish Creek in the summer of 1983, after construction of rock berms, and again in 1986.

Winter Observations

Field

The distribution and density of juvenile salmonids in lower Fish Creek and Wash Creek to the first bridge upstream from the mouth, were sampled monthly in November and December, 1986, and January, 1987. High flows and high turbidity levels precluded sampling in October, 1986. Twenty percent of the pools and glides and 10 percent of the riffles were sampled systematically each time. A single diver began at the downstream end of the habitat unit and proceeded upstream, counting all visable fish. Cobbles and boulders also were turned by divers to determine to what extent fish were hiding in interstitial spaces in the substrate. We also recorded all physical data that were recorded in 1985 observations (Everest et al. 1986).

Evaluation of Habitat Improvement Structures for Over-wintering

The objectives of this survey were to describe habitat created by large woody debris and boulder structure that was constructed in Fish Creek during the summer of 1986, determine fish abundance within those sites, and determine habitat utilization by coho salmon and steelhead trout in winter. Habitat characteristics of interest were depth, velocity and cover. Population statistics were assessed at two levels: (1) a macro-level that considered abundance in relation to total habitat available, and (2) a micro-level which considered characteristics of habitat associated with individual fish. The goal of this work was to determine what habitat characteristics were important to juvenile salmonids during winter.

Ten sites in Fish Creek where logs had been cabled to boulders to provide instream cover for fish were sampled in January 1987. Nine of the sites were located along a 400 m length of Fish Creek beginning 300 m upstream from the confluence with the Clackamas River. The tenth site was located at river km 3.5, immediately downstream from the westside off-channel pond.

An aerial view of each sample site was mapped. Large woody debris, accumulations of slash and debris, boulders, riparian vegetation and undercut banks were drawn on each site map. Current velocity, measured with a Marsh-McBirney flow meter, and depth were measured at selected spots around and in the structure. Stream depth and velocity were classified as shallow-fast (<0.5 m deep, >l ft/sec), deep-fast (>0.5 m, >1 ft/sec), shallow-slow (X0.5 m, <l ft/sec), or deep-slow (>0.5 m, <1 ft/sec). The boundary of each depth/velocity category was delineated on each map in the field.

A side view of each structure was drawn to show the position of various cover types relative to the water surface. A cross-sectional depth profile was included in the side view. The side profile indicates overhead cover, and cover in the water column that is available to fish.

Transects across representative intervals of a site were established at each site to describe and quantify the type of material providing cover in the structure. Seven categories were used to classify cover: slash, boulders, large woody debris (LWD) (>23 cm diameter), LWD and slash, LWD and boulders, boulders and slash, and no cover. Woody stems, not counted as LWD, encountered along a transect were counted and classified into seven size classes based on a modification of the USDA Forest Service fuels inventory procedure. Separate counts were made for stems occurring above and below the water surface.

Juvenile salmonids were sampled using a Smith-Root A.C. Type XI backpack electroshocker. Location where a fish was first observed, species, and age-class were recorded on the aerial maps. A fine mesh seine was used to block the downstream end of each site to retain fish that were shocked but not netted. Multiple electroshocking passes were made to deplete the fish populations. Each pass proceeded from the block net upstream through the habitat unit, then back down to the block net. Population estimates were calculated using the Moran-Zippin method (Zippen 1958). Fish were measured to the nearest 1 mm (fork length), and weighed to nearest 0.1 using an Ohaus digital balance.

* * *

RESULTS

Habitat Availability 1982-1986

The surface area of major habitat types for anadromous salmonids in Fish Creek has been estimated in late summer each year from 1982 through 1986. The differing techniques used in the 1982-84 period, and since 1985, resulted in some changes in estimates of area for the various habitat types (Table 1). The improved method for estimating habitat area used since 1985 is believed to be more accurate than the techniques used previously because habitats have been sampled throughout the entire range of anadromous fish in the basin.

Table 1. Area (m^2) of habitat available to anadromous salmonids on Fish Creek, September 1982-1986.

	Habitat Types						
Year	Pools	Riffles	Glides	Side Channels	Alcoves	Beaver[1/] Ponds	Total
1982	18,450	138.590	--	4,250	2,270	190	159.310
1983	20,850	219,360	--	6,200	2,450	300	249,160
1984	19,180	161,700	--	5,320	2,280	270	188,750
1985	26,380	93,770	21,030	2,580	--	190	143,950
1986	27,470	114,400	27,380	0[2/]	--	190	169,440
Mean	22,446	145.563	24,205	3,670	2,330	223	182,085

1/ Does not include enhanced off-channel ponds.

2/ All side channels were dry when habitats were quantified in September.

The area of habitat types in summer has varied with minimum streamflow between 1982 and 1986. A rough average of the total area in each habitat type measured during the 1982-84 period was: riffles, 86 percent; pools, 10 percent; side channels, 3 percent; alcoves, 1 percent: and beaver ponds, 0.1 percent. Alcoves were eliminated as a habitat type beginning in 1985. Glides were added as a habitat type in 1985, and the ratio of habitat types appeared to change because glides previously had been included primarily with riffle habitat. The average percentage of each habitat type in 1985 and 1986 was: riffles, 66 percent; pools, 17 percent; glides, 15 percent; side channels, 1 percent; and beaver ponds, 0.1 percent. No side channels with water were observed in September 1986. All had been blocked by gravel and/or debris deposits from the February 1986 high flow event.

The total area of summer habitat in the system varied directly and significantly with streamflow (Fig. 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 common rainfall 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 related directly 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

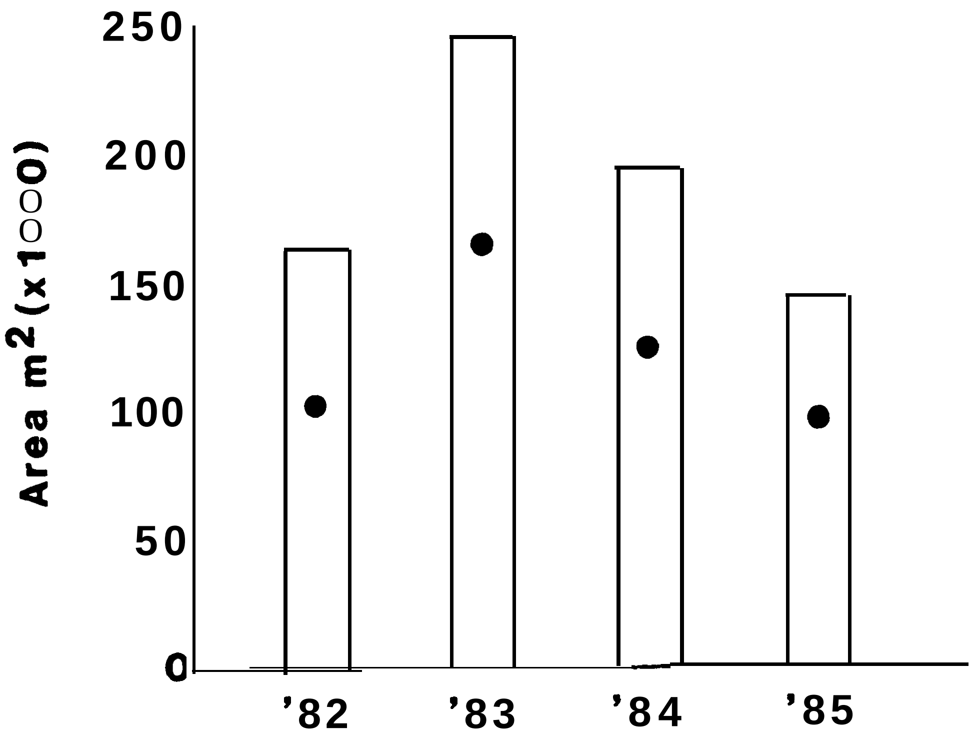


Figure 9. Area of summer rearing habitat available to anadromous salmonids on Fish Creek varies according to low summer streamflow. Dots represent index to streamflow.

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 the salmon species is listed in Table 2. An annual summary of habitat availability and use by salmonids for the 1982-86 period is presented in Appendix I.

Table 2. Area (m^2) of habitat types utilized by coho and chinook salmon on Fish Creek, summer 1982-1986.

	Habitat Types						
Year	Pools	Riffles	Glides	Side channels	Alcoves	Beaver ponds[1/]	Total
1982	8,110	70,350	--	1,600	1,080	190	81,330
1983	9,160	104,820	--	2.230	1.170	300	117,680
1984	8,430	81,610	--	2,000	1,080	270	93,390
1985	11,840	55,810	13.450	2,300	--	190	83,590
1986	7,166	62,944	13,749	0[2/]	--	—	83,829
Mean	89,461	75.107	13,600	1,626	1,110	240	91,962

[1/] Does not include enhanced off-channel habitat.

[2/] All side channels were dry when habitats were quantified in September.

Salmonid Populations and Habitat Utilization 1982-1986

Steelhead trout were the dominant species of anadromous salmonids in Fish Creek during the 1982-86 period. Age 0+ and 1+ juveniles accounted for 90 to 98 percent of the total salmonid population

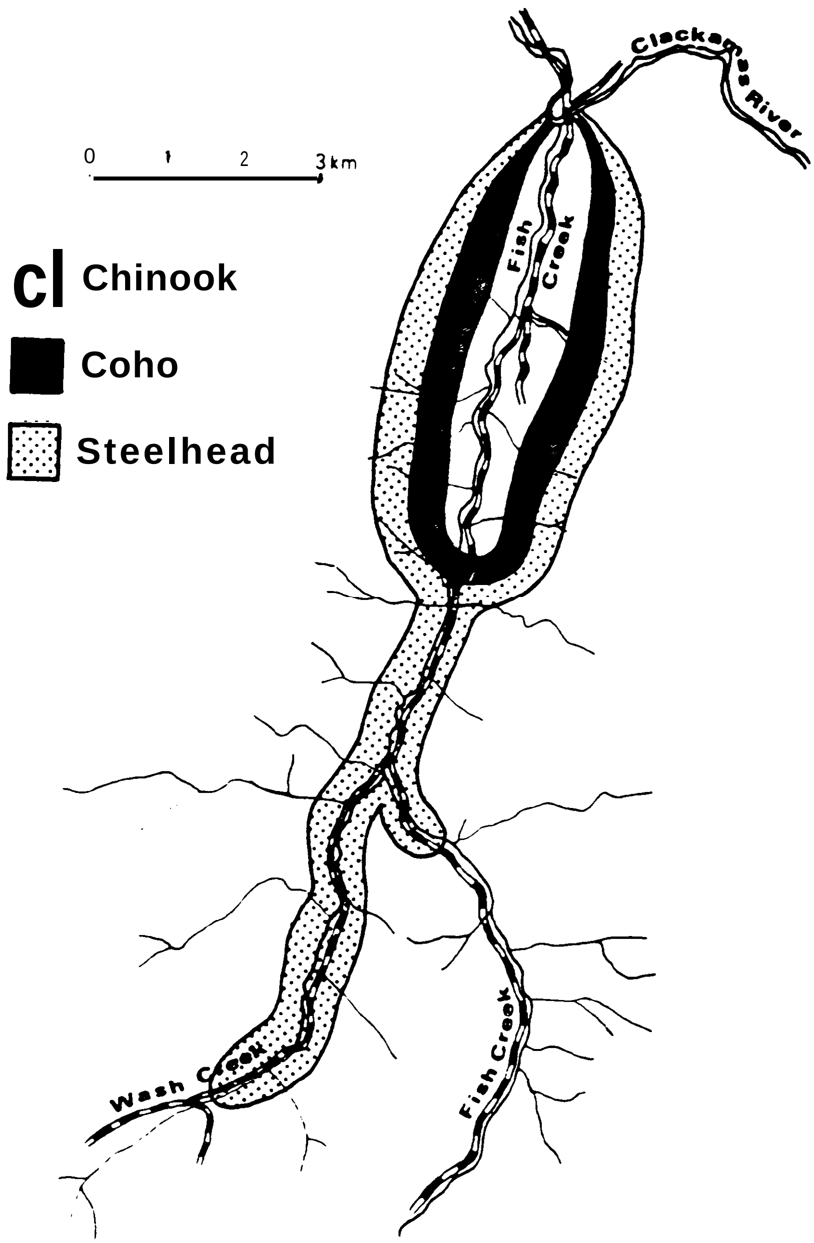


Figure 10. Distribution of juvenile anadromous salmonids in Fish Creek.

(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

Table 3. Estimated numbers of juvenile anadromous salmonids in Fish Creek, September, 1982-1986, and percent of total population.

Year	0+ Steelhead Number	0+ Steelhead Percent	1+ Steelhead Number	1+ Steelhead Percent	Coho Salmon Number	Coho Salmon Percent	Chinook Salmon Number	Chinook Salmon Percent	Total
1982	87,810	78.7	21,680	19.4	1,910	1.7	120	0.1	111,520
1983	60,030	66.5	21,670	24.0	7,430	8.2	1,140	1.3	90,270
1984	88,060	73.1	23,800	19.8	8,290	6.7	290	0.2	120,440
1985	115,770	76.9	18,500	12.3	11,980	7.9	4,350	2.9	150,620
1986	117,870	82.8	20,670	14.1	3,560	2.5	200	0.1	142,300
Mean	93,900	74.4	21,260	18.1	6,630	6.3	1,220	1.3	123,300

0.1 to 3 percent, to the total standing stock of salmonids in the basin (Table 3).

Populations of 0+ steelhead trout have been highly variable during the 5 years of the evaluation, averaging about 93,900 fish ($\pm$ ~ 30 percent) annually (Table 3). The reasons for the high variability are complex and related to both seeding rates (Fig. 11) and environmental variables (Fig. 12). Numbers of steelhead trout fry show a weak direct correlation ($r = 0.55$) 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

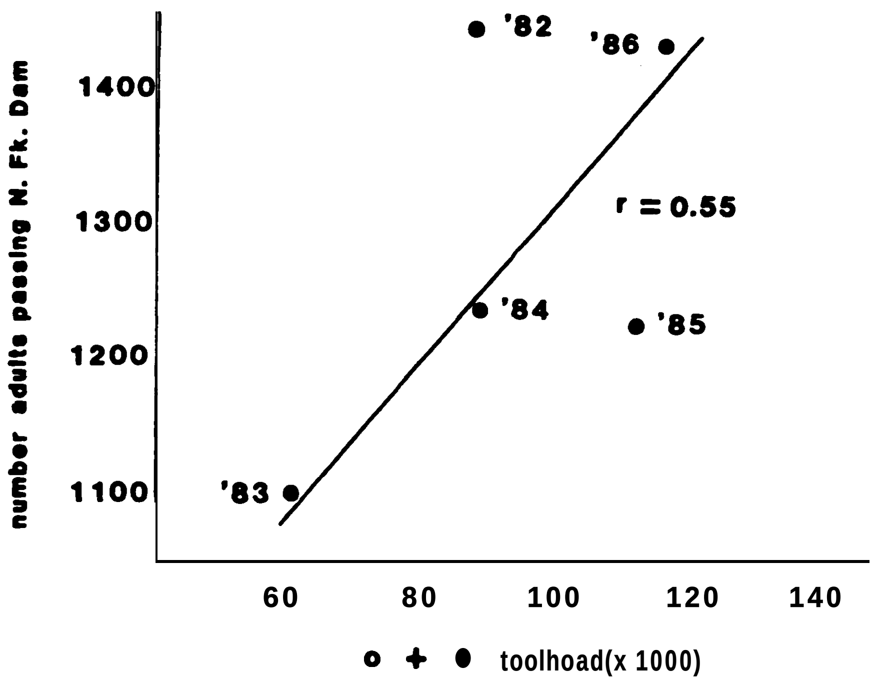


Figure 11. Parent-progeny relationship for winter steelhead trout in Fish Creek, 1982-1986.

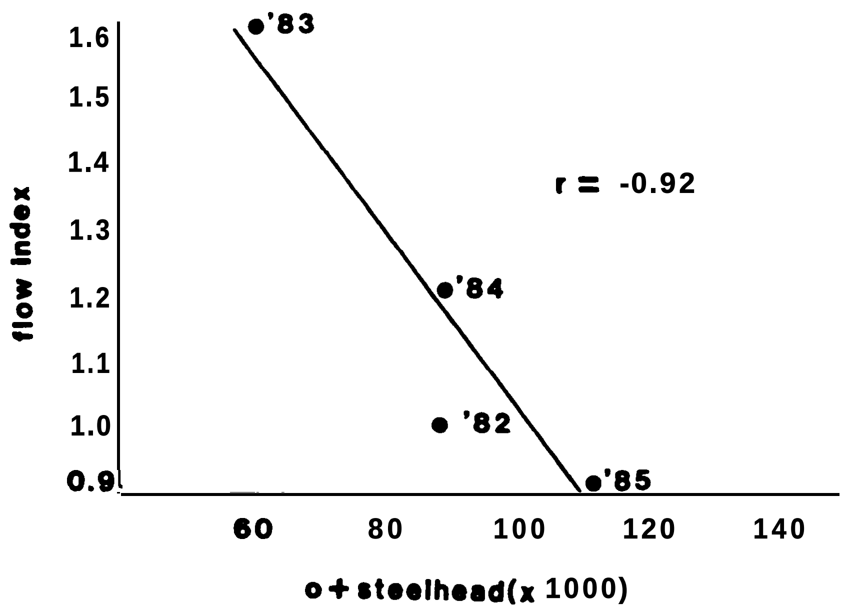


Figure 12. Relationship between index to mean August streamflow and numbers of 0+ steelhead trout in Fish Creek, 19824985.

streamflow. A direct correlation between spawners and fry would be expected when the quantity and quality of spawning habitat isadequate to accomodate increased numbers of adults. The inverse correlation with minimum summer 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 had 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). From 1982 to 1985, 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. In 1986, however, densities were greatest in riffles. This may have been attributable to changes in habitat availability and quality following the high flow event of February 1986. 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.

Table 4. Density 0+ steelhead trout (fish/m2) by habitat type, Fish Creek, 1982-1986.

	Habitat Types						
Year	Pools	Riffles	Glides	Side channels	Alcoves	Beaver[1] ponds	Mean
1982	0.28	0.54	--	1.20	0.97	0.00	0.55
1983	0.18	0.25	--	0.28	0.25	0.03	0.24
1984	0.20	0.50	--	0.45	0.36	0.00	0.47
1985	0.76	0.78	0.96	0.88	--	0.53	0.80
1986	0.51	0.83	0.35	0.00[2]	--	--[3]	0.70
Mean	0.39	0.58	0.66	0.56	0.53	0.14	0.55

1/ Does not include enhanced off-channel ponds.
2/ All side channels were dry in September 1986.
3/ Not sampled in 1986.

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.

Age l+ 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 l+ steelhead trout shows a positive correlation (r = 0.63) with summer

Table 5. Estimated numbers of 0+ steelhead trout by habitat type, Fish Creek, 1982-1986.

	Habitat Types						
Year	Pools	Riffles	Glides	Side channels	Alcoves	Beaver ponds 1/	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
1986	13,970	94,410	9,490	0	--	-- 2/	117,870
Mean	8,390	75,500	14,880	2,300	1,210	28	93,910

1/ Does not include habitat created by enhancement projects.

2/ Not sampled in 1986.

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. 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.

The numbers of juvenile coho salmon in the Fish Creek basin increased steadily from 1982 to 1985 but declined in 1986 (Table 3).

Table 6. Density of 1+ steelhead trout (fish/m2) by habitat type, Fish Creek, 1982-1986.

	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
1986	0.24	0.09	0.12	0.00 1/	--	-- 2/	0.12
Mean	0.19	0.12	0.11	0.07	0.05	0.02	0.13

1/ All side channels were dry in September 1986.
2/ Not sampled in 1986.

Table 7. Estimated numbers of l+ steelhead trout by habitat type, Fish Creek, 1982-1986.

	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
1986	6,620	10,820	3,230	0 1/	--	-- 2/	20,670
Mean	4,340	16,700	2,515	290	110	3	22,310

1/ All side channels were dry in September 1986.
2/ Not sampled in 1986.

The reasons for the increase apparently are 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. The decline in 1986 probably was due to loss of redds from scour and siltation during the February 1986 high flow event.

Table 8. Counts of adult anadromous salmonids at North Fork Dam, 1981-82 to 1985-86.

Year	Steelhead trout			Coho salmon		Spring chinook salmon	
	Summer	Winter	Total	Total	Jacks	Total	Jacks
1981-82	44,138	1,446	5,584	1,282	(112)	3,119	(209)
1982-83	11,948	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	55,549	1,225	6,674	694	(83)	1,693	(140)
1985-86	77.422	1.432	8.854	3.315	(592)	1,960	(163)
Mean	6,024	1,288	7.312	1,968	(254)	2,458	(140)

Beaver ponds are the preferred habitat of juvenile coho salmon in the Fish Creek Basin in summer, as measured by density of fish per m2 (Table 9). Glides, side channels, and pools are also important habitats, but received only a fraction of the use per m^2 that was observed for beaver ponds. Coho salmon prefer moderately deep quiet habitats on the stream margins or out of the main channel.

The greatest numbers 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 1986, the estimated number in riffles declined dramatically. This probably was due to the over-all reduction in numbers of coho salmon. Riffles are the least preferred habitat of coho salmon and would be the last to be

Table 9. Density of 0+ coho salmon by habitat type, Fish Creek, 1982-1986.

	Habitat Types						
Year	Pools	Riffles	Glides	Side channels	Alcoves	Natural Beaver ponds	Mean
1982	0.04	0.01	--	0.11	0.13	1.37	0.02
1983	0.16	0.05	--	0.06	0.19	0.80	0.06
1984	0.22	0.04	--	0.96	0.28	2.19	0.09
1985	0.13	0.07	0.43	0.26	--	1.37	0.14
1986	0.18	0.00 1/	0.16	0 2/	--	-- 3/	0.04
Mean	0.15	0.03	0.30	0.35	0.20	1.43	0.08

1/ Actual density 0.0006 fish/m^2
2/ All side channels were dry in September 1986.
3/ Not sampled in 1986.

Table 10. Estimated numbers of 0+ coho salmon by habitat type, Fish Creek, 1982-1986.

	Habitat Types						
Year	Pools	Riffles	Glides	Side channels	Alcoves	Beaver[1] ponds	Total
1982	290	1,040	--	180	140	260	1,910
1983	1,500	5,340	--	130	220	240	7,430
1984	1,840	3,310	--	1,920	630	590	8,290
1985	1,550	3,850	5,720	600	--	260	11,980
1986	1,350	41	2,170	0[2]	--	--[3]	3,560
Mean	1,310	2,720	3,950	570	330	340	6,630

1/ Does not include enhanced off-channel habitat.

2/ All side channels were dry in September 1986.

3/ Not sampled in 1986.

utilized. 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 been generally highest in pools, although in 1985 near equal numbers occurred in pools, riffles, and glides (Table 12).

Numbers in 1986 were low, probably due to low redd survival from the high flow event in February 1986.

Table 11. Density of 0+ chinook salmon (fish/m^2) by habitat type, Fish Creek, 1982-1986.

Year	Pools	Riffles	Glides	Side channels	Alcoves	Beaver ponds	Mean
	Habitat Types						
1982	0.01	0.00	--	0.00	0.01	0.00	0.001
1983	0.07	0.01	--	0.00	0.01	0.00	0.010
1984	0.03	0.00	--	0.00	0.00	0.04	0.003
1985	0.10	0.03	0.11	0.00	--	0.00	0.050
1986	0.01	0.00	0.01	0.00 1/	--	-- 2/	0.002
Mean	0.04	0.01	0.06	0.00	0.01	0.01	0.013

1/ All side channels were dry in September 1986.
2/ Not sampled in 1986.

Table 12. Populations of 0+ chinook salmon by habitat type, Fish Creek, 1982-1986.

Year	Pools	Riffles	Glides	Side channels	Alcoves	Beaver ponds	Total
	Habitat Types						
1982	110	0	--	0	10	0	120
1983	640	490	--	0	10	0	1,140
1984	280	0	--	0	0	10	290
1985	1,240	1,620	1,490	0	--	0	4,350
1986	100	0	100	0 1/	--	-- 2/	200
Mean	470	422	800	0	10	3	1,220

1/ All side channels were dry in September 1986.
2/ Not sampled in 1986.

The number of adult chinook salmon spawning in Fish Creek appears to be related largely to the timing of fall freshets (Everest et al. 1985). Late arrival of fall rains and runoff can impede entry of spawners. Early rains and runoff provide easy access for adult chinook salmon. Our data show no apparent relationship, however, between the number of spawners using the system in the fall and the number of juveniles rearing in Fish Creek the following summer.

Coho Salmon Smolt Production, Fish Creek

The coho salmon smolt migration from Fish Creek was monitored closely in 1985 and 1986 with the floating smolt trap located at km 0.3. The trap was operated from April 15 until August 25, 1985 when streamflow became too low for effective operation. Coho salmon smolts were captured at the trap between April 18 and June 19, with the peak outmigration occurring on May 19 (Fig. 13). A total of 1,095 coho salmon smolts were captured. The total 1985 smolt migration was estimated at 3,099 fish (Table 13).

In 1986, the smolt trap was installed on March 14 and fished until July 18. Coho smolts were first captured on March 15, about one month earlier than the previous year, indicating that some early migrants might have left the system before trapping began in 1985. Consequently, the 1985 data should be considered a minimum estimate of coho salmon smolt production for that year.

The 1986 migration apparently began earlier and peaked earlier than was observed in 1985 (Fig. 13). Total numbers of coho salmon

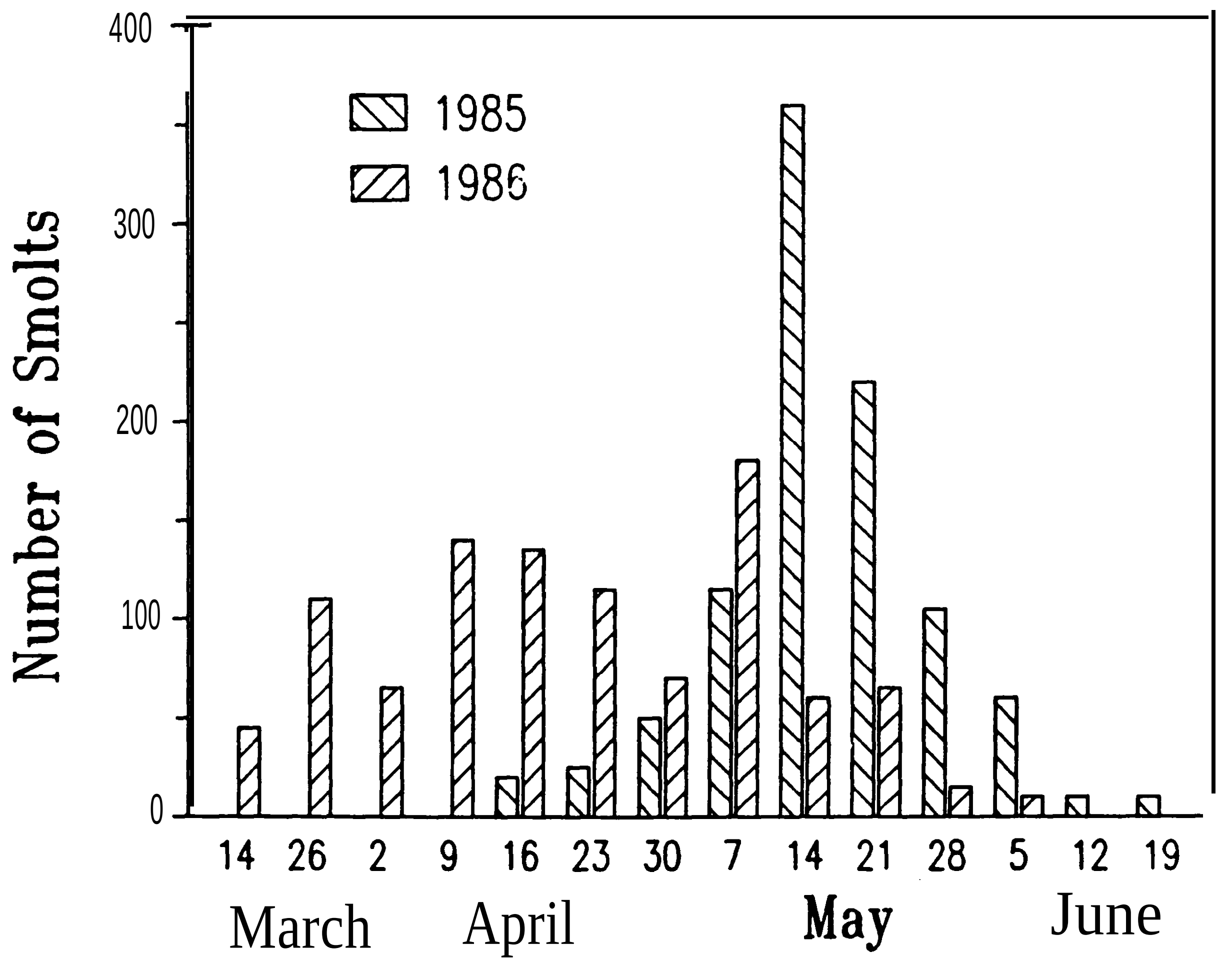


Figure 13. Timing of the coho salmon smolt migration from Fish Creek at the floating trap at km 0.3, 1985 and 1986.

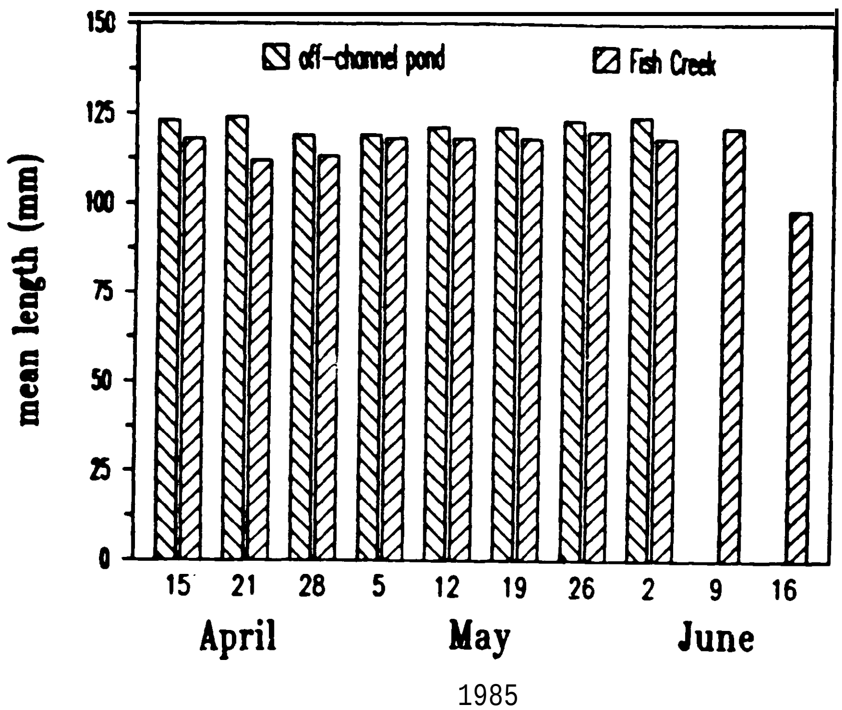
Table 13. Coho salmon smolts captured in a floating trap at km 0.3 on Fish Creek, and estimates of trap efficiency and total smolt migration by two-week intervals, April 15-June 23, 1985.

Dates	Smolts captured	Marked smolts released[1]	Marked smolts recaptured	Trap efficiency percent	Estimate[1] total smolts
04/15-04/28	76	83	38	46	165
04/29-05/12	217	115	55	48	452
05/13-05/26	631	497	235	47	1,342
05/27-06/09	171	281	43	15	1,140
06/10-06/23	0	2	0	--	--
Totals	1,095	978	371	--	3,099

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

smolts leaving the system in 1986 (2,371 fish), however, were 23 percent lower than in 1985 (Table 14).

Coho smolts from Fish Creek in 1985 averaged about 114 mm fork length and ranged from 96 mm to 140 mm. The mean size of smolts varied somewhat on a daily basis, but showed no distinct seasonal trends (Fig. 14). Coho smolts were smaller in 1986, averaging only 107 mm, and ranging from 82 mm to 134 mm, and again showed no distinct seasonal trends (Fig. 14). The flood event of February 1986 (Everest et al. 1986). combined with a relatively cold winter, might account for some of the variation in size between years.



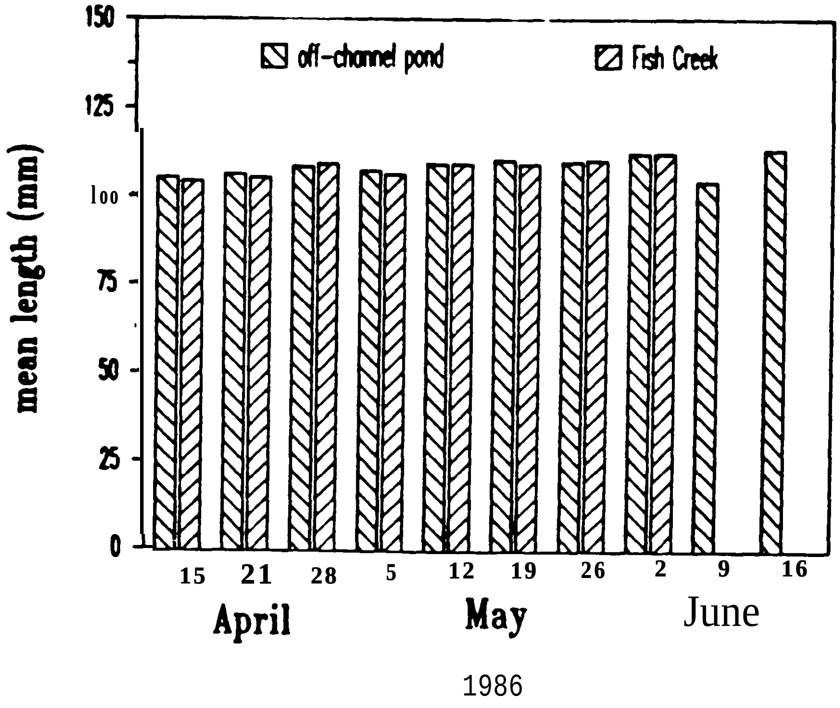


Figure 14. Mean length of coho salmon smolts emigrating from Fish Creek and off-channel pond at km 3, April 15 through June 23, 1985 and 1986.

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

Dates	Smolts captured	Marked smolts released	Marked smolts recaptured	Trap efficiency percent	Estimated total smolts
03/14+03/26	47	46	13	28	168
03/27-04/02	112	115	59	51	220
04/03-04/09	83	127	73	57	146
04/10-04/16	149	131	61	47	317
04/17-04/23	142	220	137	62	229
04/24-04/30	126	195	98	50	252
05/01-05/07	90	115	54	47	191
05/08-05/14	192	236	133	56	343
05/15/02/21	64	185	79	43	149
05/22-05/28	74	161	50	31	239
05/29-07/18	14	81	10	12	117
Totals	1,093	1,612	767	--	2.371

Coho salmon smolts were not only smaller in 1986, but also much lighter in weight than the 1985 cohort. In 1985, smolts averaged about 20 g while the 1986 migrants averaged about 14 g. Smolt weights ranged from 7 to 33 g in 1985 with a near normal distribution (Fig. 15A); in 1986 smolts ranged from 7 to 31 g with the distribution skewed heavily toward the lighter weights (Fig. 15B).

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

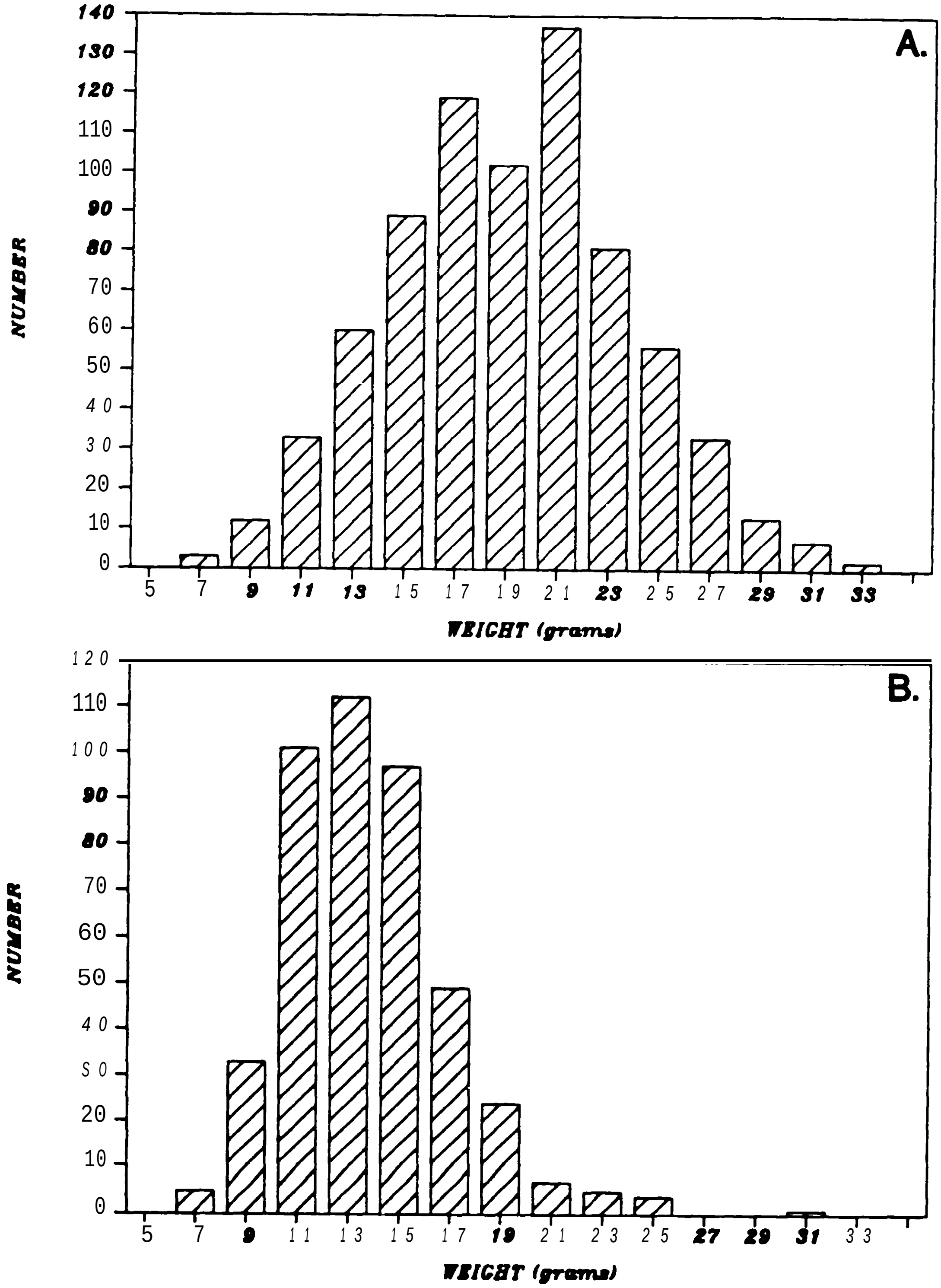


Figure 15. Weight distribution of coho salmon smolts from Fish Creek in 1985 (A), and in 1986 (B).

traveling screen, most fish moved downstream in the upper half of the water column near the thalweg.

Fish Creek is a low producer of coho salmon smolts when compared to other west coast streams. Marshall and Britton (1980) have summarized data on coho smolt production from 21 western rivers and streams of various sizes. Smolt outputs ranged from about 360 fish/km for the smallest streams to 3,000 fish/km in large streams. Streams the size of lower Fish Creek typically produce from 1,500 to 3,000 smolts/km. Fish Creek currently produces from 200 to 500 smolts/km and ranks far lower as a coho producer than other comparably sized streams. The reason for this is the high gradient, incised channel that provides little of the margin and off-channel habitat preferred by coho in summer and winter. The 1964 flood, road encroachment, timber harvest in the basin, and intensive debris removal from the channel over the past 20 years have reduced coho habitat in the basin.

Coho Salmon Smolt Production, Off-Channel Pond

Smolt production from the eastside off-channel pond, constructed on a flood terrace adjacent to Fish Creek at km 3.0 in 1983, was evaluated in the spring of 1985 and 1986. A total of 1,326 coho salmon fry were electrofished from the margins of Fish Creek between March 30 and July 5, 1984 and placed in the pond. The fry exhibited rapid growth and ten 0+ smolts averaging 86 mm fork length left the pond between July 20 and August 16, 1984. The presence of 0+ smolts in natural coho salmon populations is rare. An unknown number of additional coho salmon fry entered the pond in the spring of 1984 from natural reproduction in the north inlet of the pond.

A total of 493 smolts from the introduced and naturally produced fry left the pond between April 15 and June 8, 1985. The timing of the coho salmon smolt migration occurred during the same time interval as that observed on Fish Creek (Fig. 16). but peak migration from the pond occurred the first week in June. Smolts from the pond were significantly larger than smolts from Fish Creek. Mean length of smolts leaving the pond was 124.6 mm, while Fish Creek smolts averaged 113.3 mm. Pond smolts also were much heavier than smolts reared in Fish Creek (Fig. 17). The primarily nocturnal migration of smolts leaving the pond was also similar to the behavior of coho leaving Fish Creek.

Fry were not introduced to the pond in 1985, but in January 1985 seven adult female coho salmon and five males were trapped at North Fork Dam and transported to the pond. The fish spawned naturally in the inlets and an unknown number of emergent fry migrated downstream into the pond in the spring of 1985. The 1986 smolt migration resulting from the natural reproduction was impressive. Between March 14 and July 18, 1986, 1,196 coho salmon smolts left the pond (Fig. 16), approximately triple the number of 1985 emigrants. The migrants leaving the pond in 1986 were smaller in length (mean 108.5 mm) and weight (Fig. 18A, 18B) than in 1985. The mean length (pond 108.5 mm; Fish Creek 105.0 mm) and weight (Fig. 19) of smolts leaving the pond in 1986 was more similar to those leaving Fish Creek

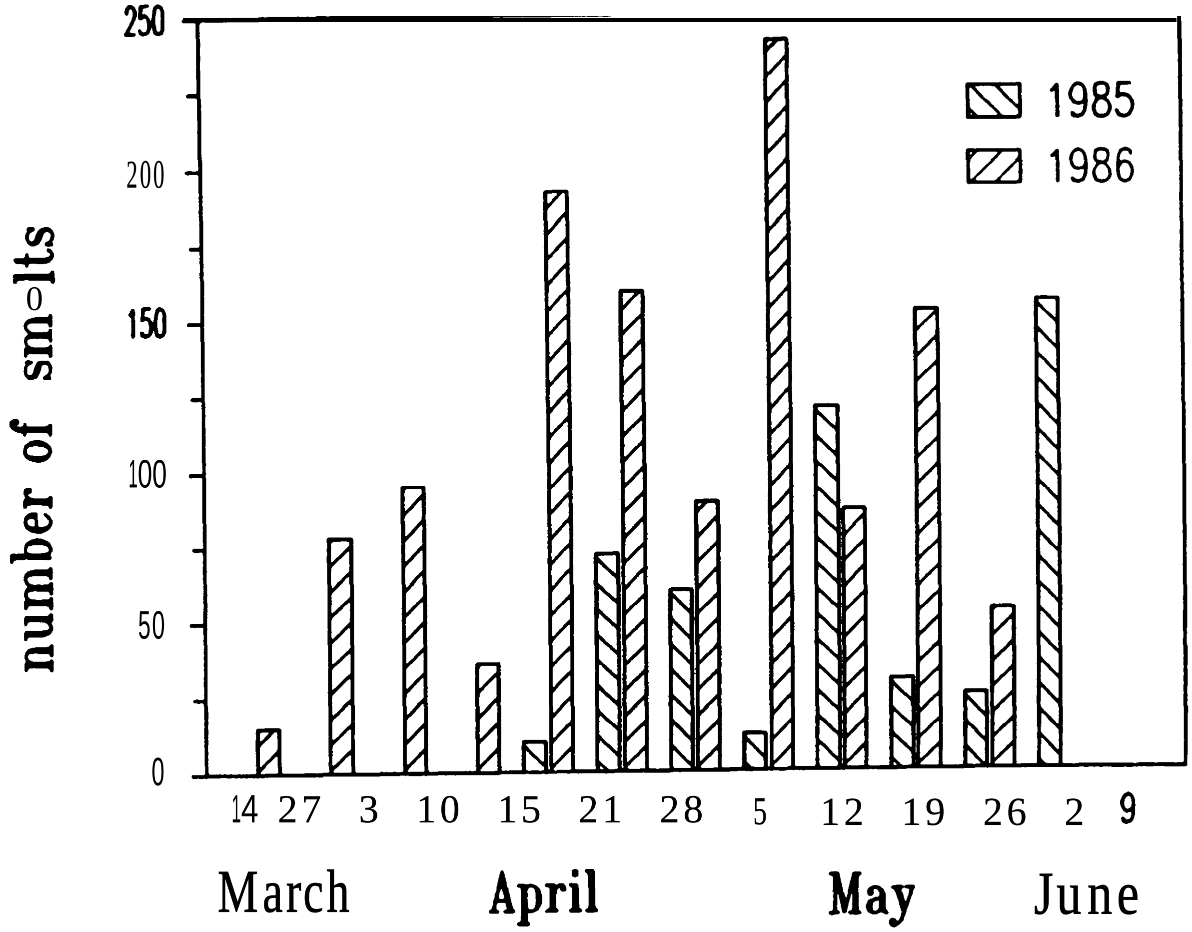


Figure 16. Timing of the coho salmon smolt migration from the off-channel pond at km 3, 1985 and 1986.

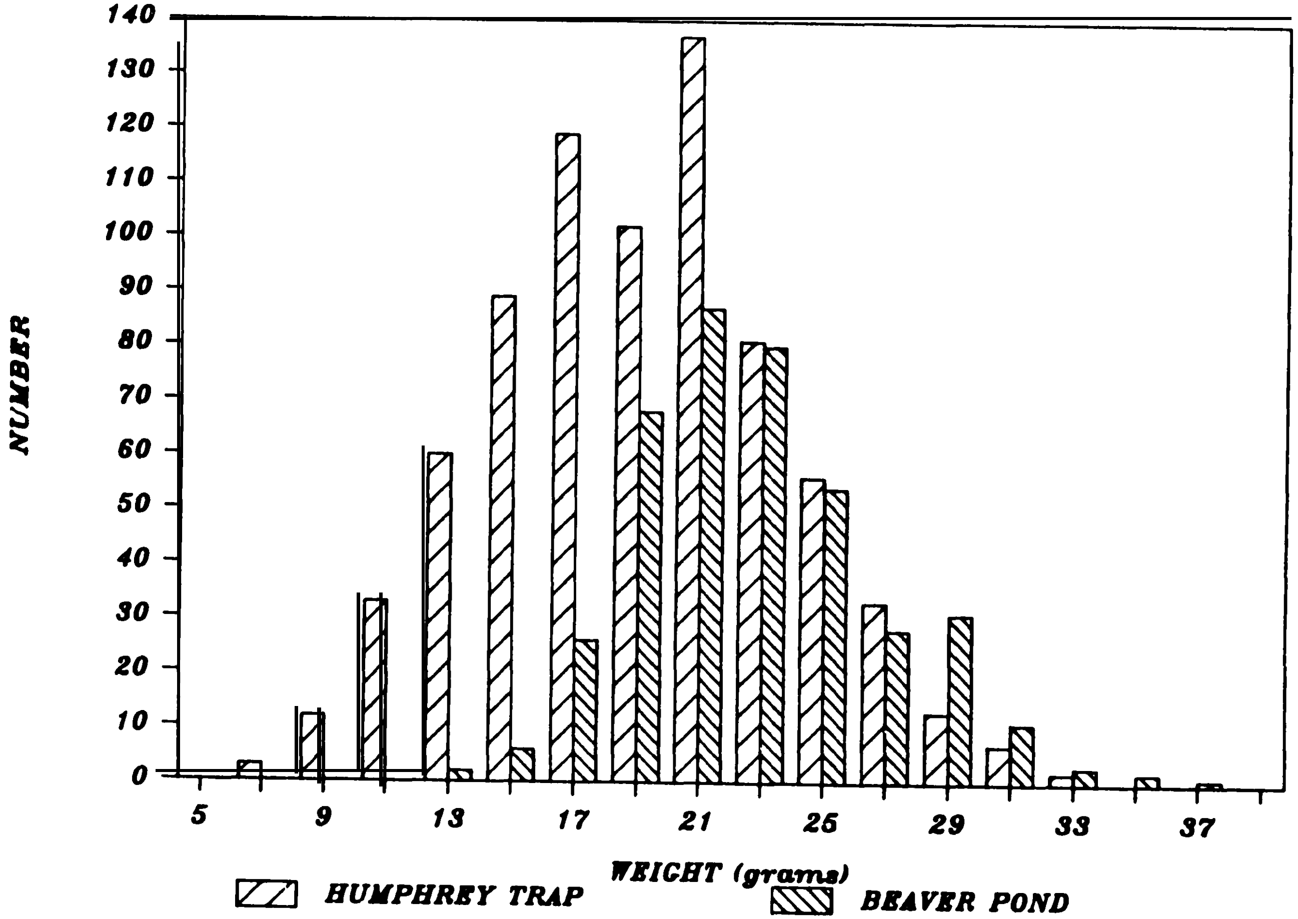


Figure 17. Comparison of coho salmon smolt weight distributions from the Fish Creek Humphrey trap and the off-channel (beaver) pond at km 3, 1985.

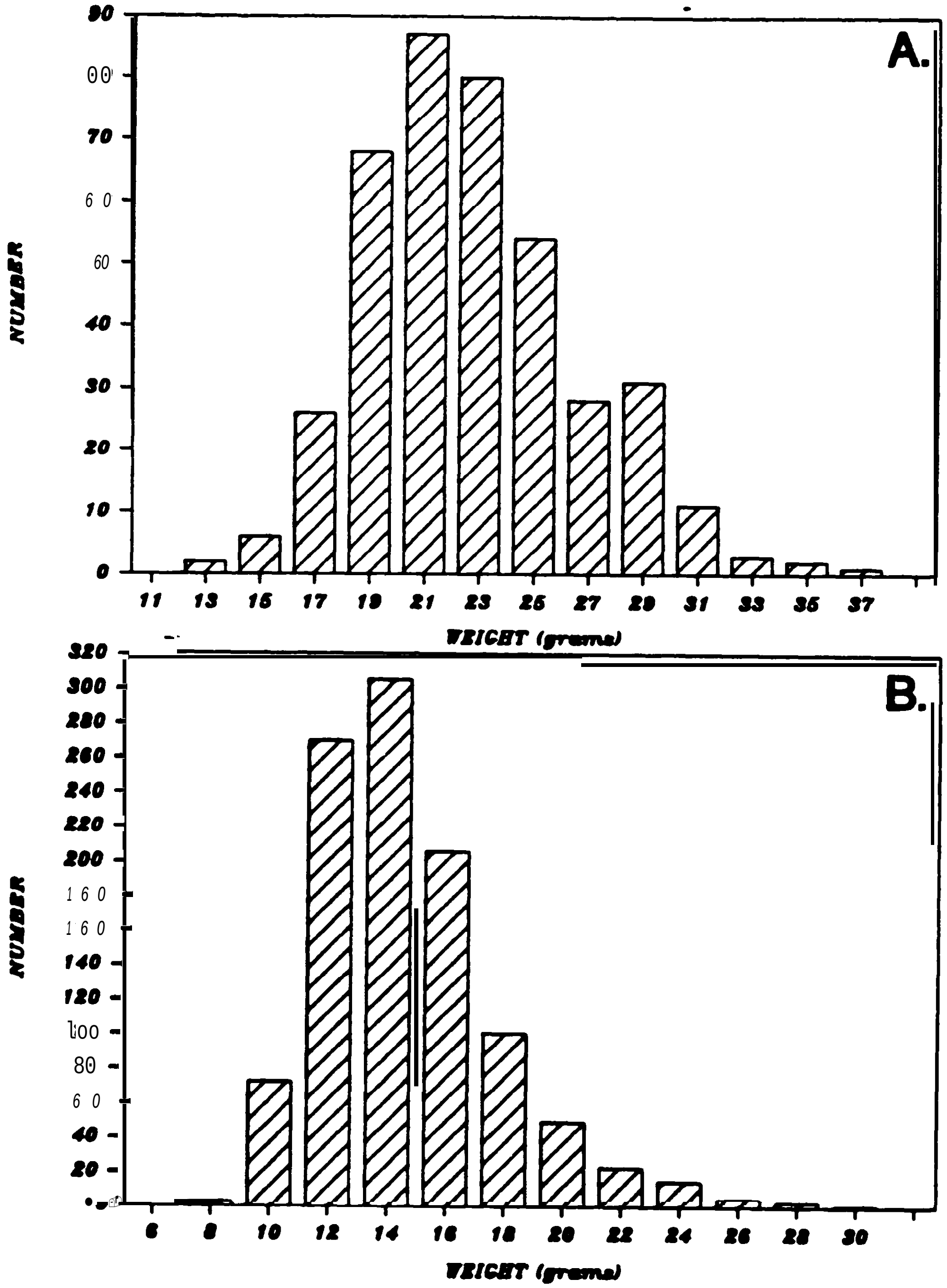


Figure 18. Weight distributions of coho salmon smolts leaving the off-channel pond at km 3 in 1985 (A), and in 1986 (B).

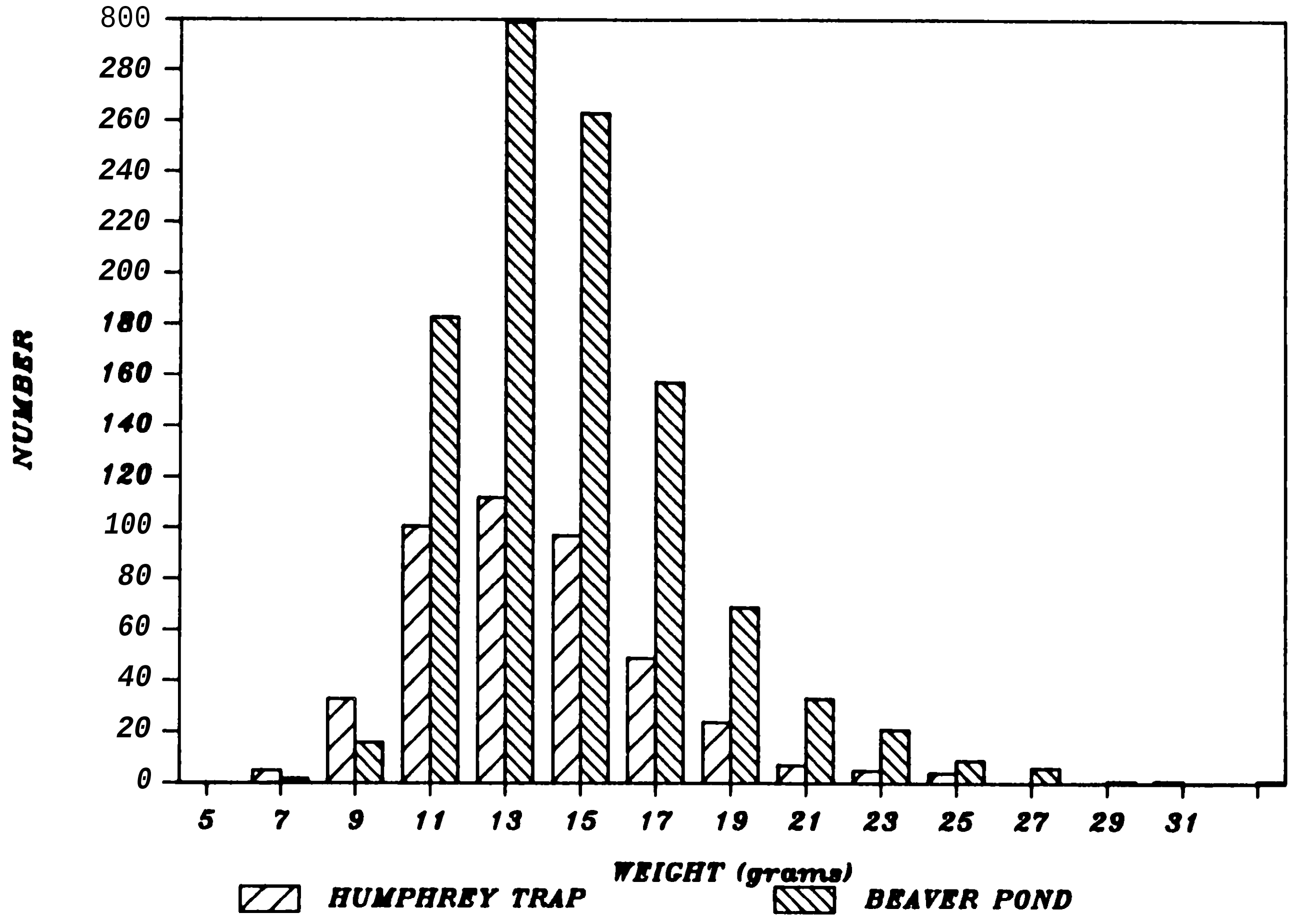


Figure 19. Comparison of coho salmon smolt weight distributions from the Fish Creek Humphrey trap and the off-channel (beaver) pond at km 3, 1986.

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

The off-channel pond, even though not fully stocked with fry, made a significant contribution to coho salmon smolt production in Fish Creek in both 1985 and 1986. Fish Creek, excluding the pond, produced 2,606 coho salmon smolts in 1985 while the pond contributed 493, an 18.9 percent addition to the run. In 1986, Fish Creek produced 1,175 smolts while the pond produced 1,196, a 102 percent addition to the smolt migration (Fig. 20A, 20B). These contributions are particularly remarkable since the pond represents only about 2.5 percent of the habitat area of Fish Creek. The total carrying capacity of the pond remains unknown, but potential coho smolt production probably is substantially greater than that observed to date.

Preliminary Benefit-Cost Analysis of Eastside Off-channel Pond

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

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

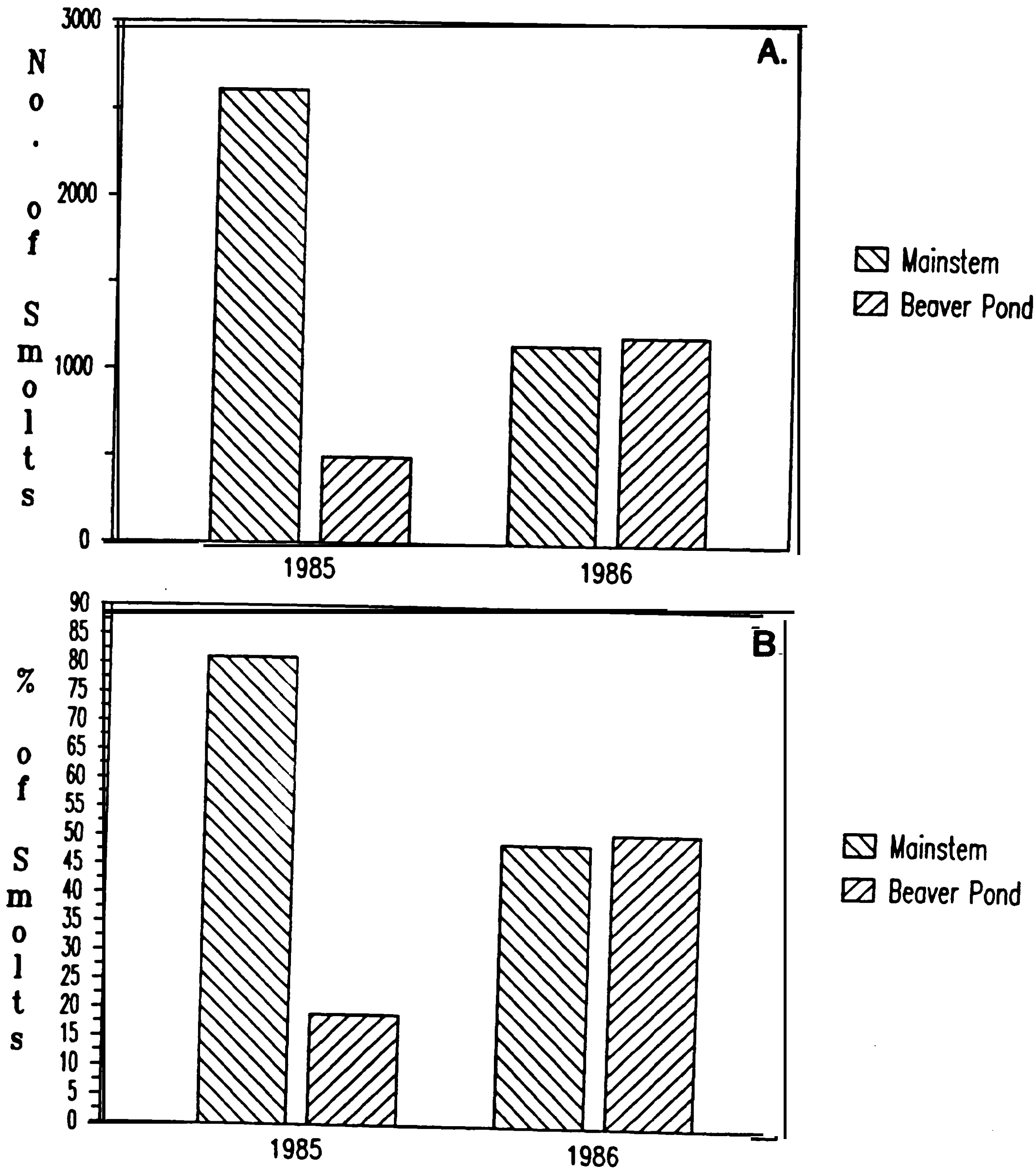


Figure 20. Contribution of mainstem Fish Creek and the off-chnnel pond at km 3 to total coho salmon smolt production from th Fish Creek basin, (A) by number of smolts, and (B) by percent of total migration, 1985 and 1986.

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

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

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

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

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

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

3525 commercial benefit + $2,996 sport benefit = $3,521 annual benefit.

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

1/ Oregon Dept. of Fish and Wildlife, 1981.

2/ Meyer, 1982.

* * *

Overwinter Survival of Coho Salmon on Fish Creek

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

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

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

The off-channel pond, with moderate water temperatures and abundant quiet water, food, and cover, provides ideal winter habitat for juvenile coho salmon. While the number of coho salmon in the pond in September 1985 was unknown, a summer mortality of least 30 percent of the original 1,326 fry would be expected. If that assumption is true, overwinter survival in the pond exceeds 50 percent and could be from 2 to 5 times higher than that observed in Fish Creek proper.

Steelhead Trout Smolt Production

In 1985, the steelhead trout smolt migration from Fish Creek was monitored from April 15 through June 28, when movement of smolts ceased. The migration was in progress when the trap was installed on April 15, and based on observations made in March 1986, several hundred smolts could have left the basin before the trap was activated in 1985. Two distinct peaks of movement occurred in 1985 (Fig. 21). A low steady catch rate averaging 10-12 smolts/day occurred between April 15 and April 27. During the following week the catch increased markedly, averaging 100 smolts/day, and a peak catch of 159 smolts/day occurred on May 2. The catch dropped to an average 14 smolts/day from May 5 through May 10 and peaked again at 171 smolts/day on May 16. The catch declined rapidly after May 17 and the final smolt of the season was caught on June 28.

The total number of smolts moving downstream between April 15 and June 28, was estimated at 7,470 (Table 15). We assumed that the migration had been in progress for at least 15 days before trapping began. Based on the mid-April catch rate, an average of 10 smolts/day would have been trapped during this period. Using an estimated efficiency of about 30 percent for this 15 day period, a total of about 500 smolts probably left the system before trapping commenced. Therefore, the total smolt migration is assumed to be about 8,000.

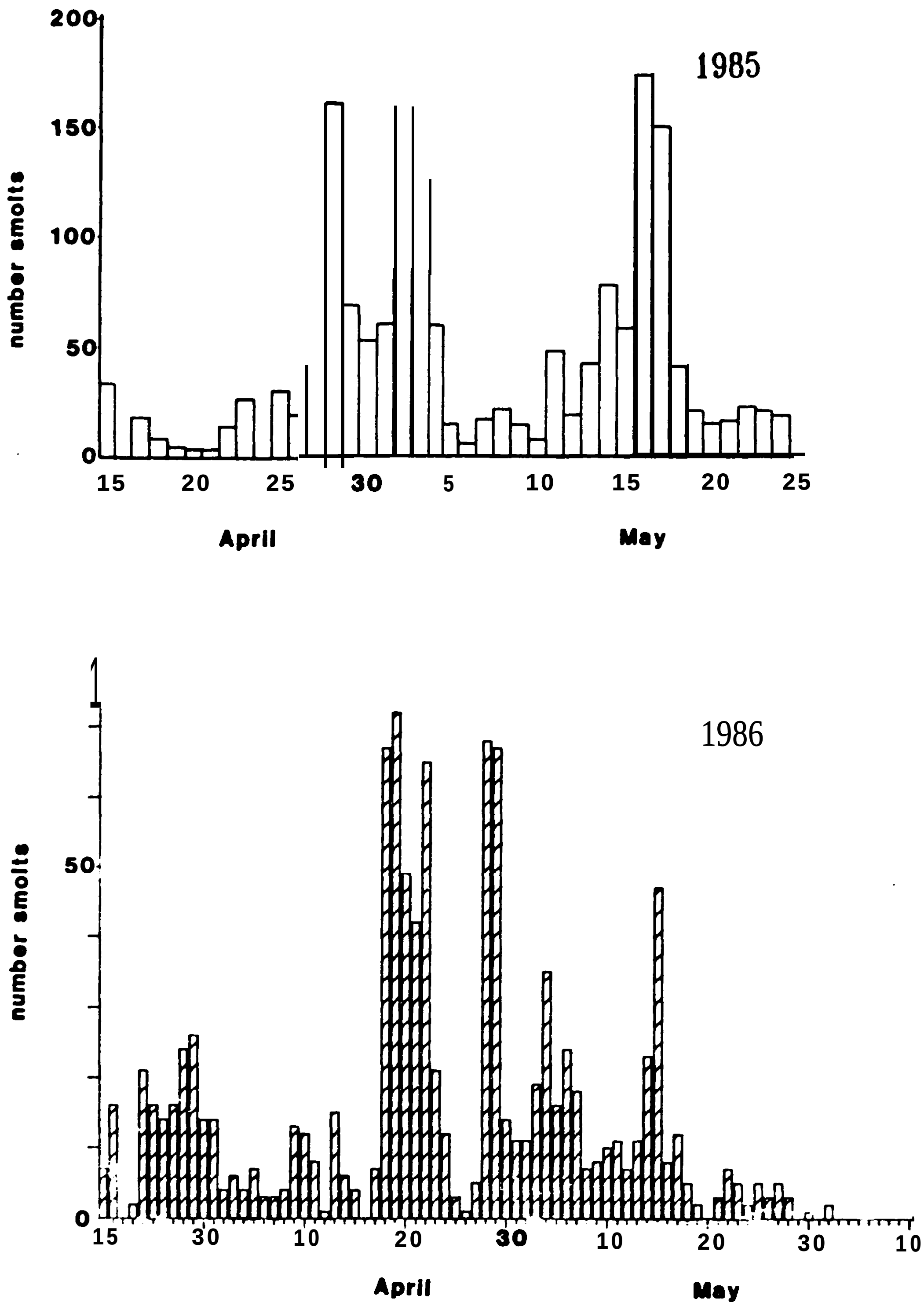


Figure 21. Daily catch of steelhead smolts at the floating fish trap at km 0.3 on Fish Creek, April 15 to June 15, 1985, and March 14 to June 15, 1986.

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

Dates	Smolts captured	Marked smolts released	Marked smolts recaptured	Trap efficiency percent	Estimated total smolts
04/15-04/28	382	49	15	31	1,232
04/29-05/12	708	115	47	41	1.727
05/13-04/26	787	155	57	37	2.127
05/27-06/09	103	82	10	12	858
06/10-06/23	166	122	14	11	1,509
06/24-06/30	2	--	--	10	20
Totals	2,148	523	143	--	7,473

The size of smolts ranged from l23- 242 mm fork length, and varied during the trapping season. The average size was about 160 mm, and the approximate minimum threshold size for smolts was 140 mm, although a few smolts were smaller (Fig. 22). The average size of smolts remained fairly constant from mid-April to mid-May and then decreased from mid-May to mid-June (Fig. 23). Scale analysis from a small sample of early migrants, both smolts and non-smolts, indicated that the group was composed primarily of age 2+ fish, the normal age of most steelhead trout smolts in western Oregon. The smaller June migrants might have been a mix of smaller 2+ smolts, and socially dominant, fast growing l+ smolts.

A generalized growth pattern of juvenile steelhead trout is shown in Figure 24. This figure was developed from examination of the growth pattern observed on scales and by back-calculating the length of fish at the time of annulus formation. The estimated mean length

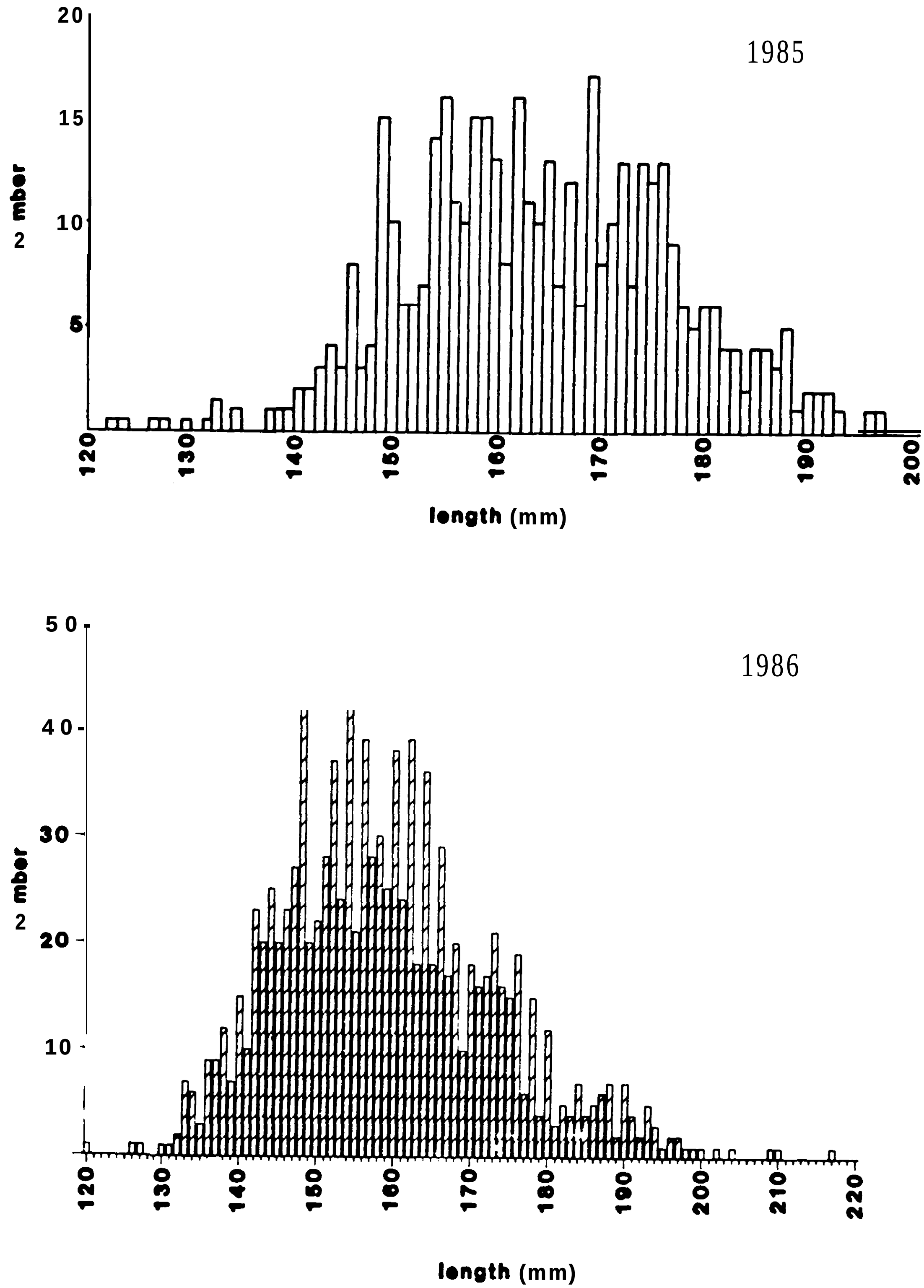
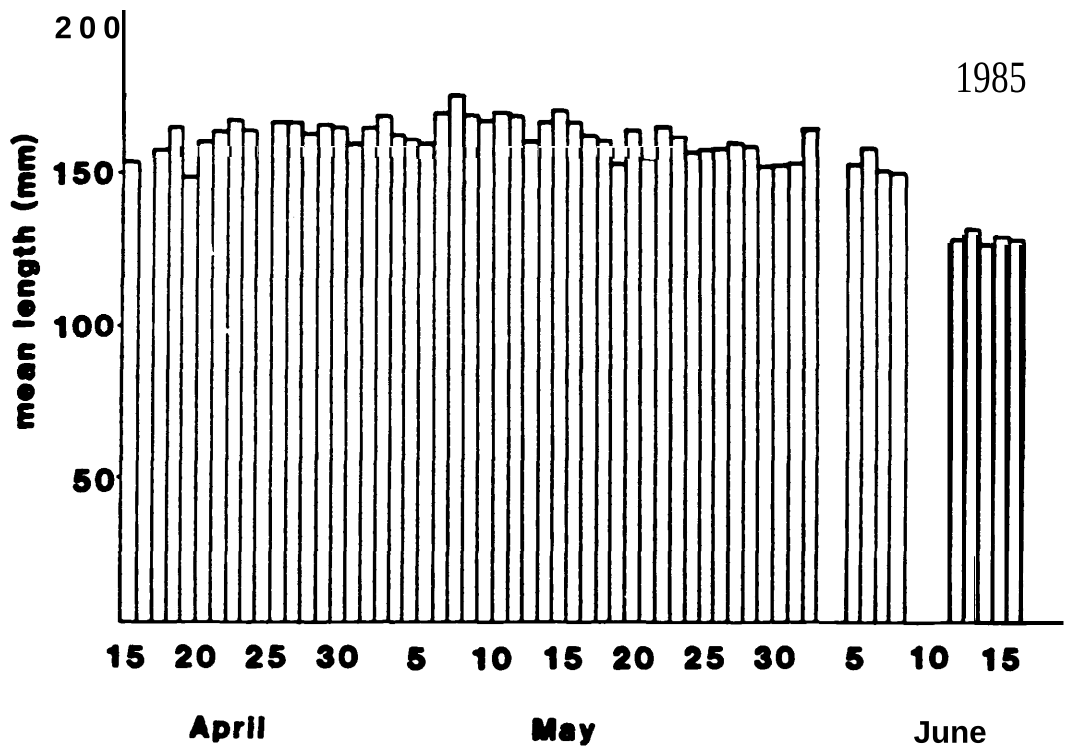


Figure 22. Size frequency of steelhead trout molts from Fish Creek, 1985 and 1986.



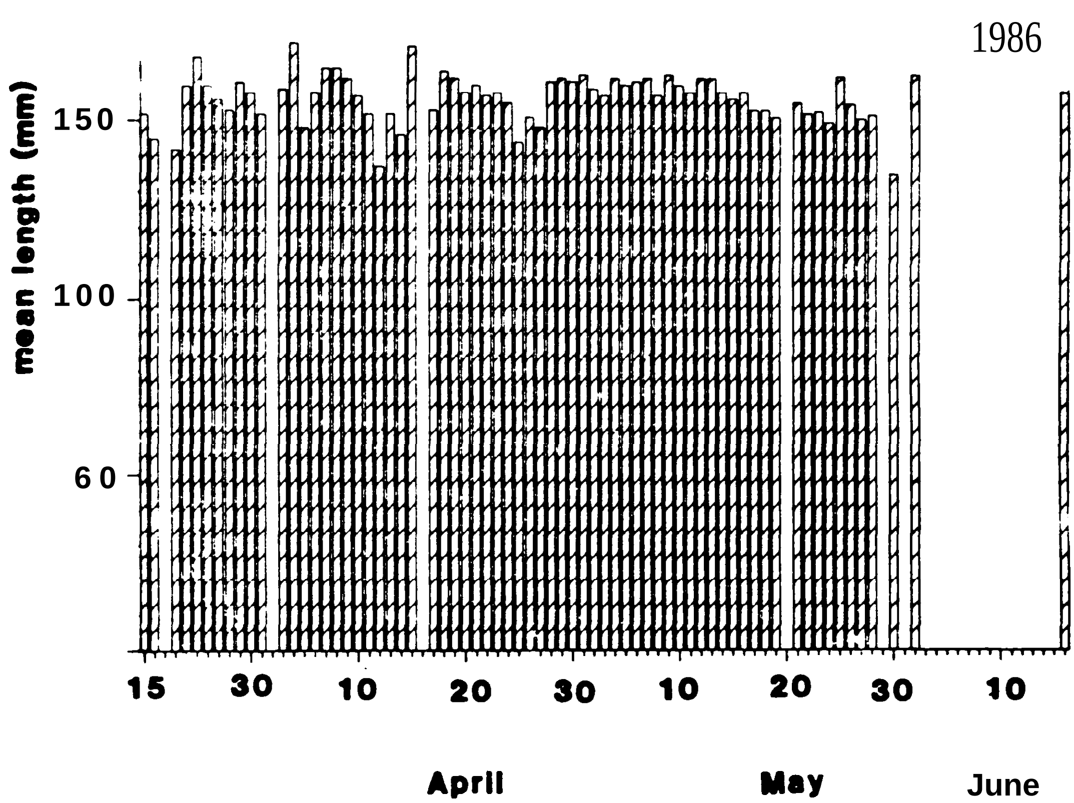


Figure 23. Mean daily lengths of steelhead trout molts leaving Fish Creek between April 15 and June 15, 1985, and March 14 and June 15. 1986.

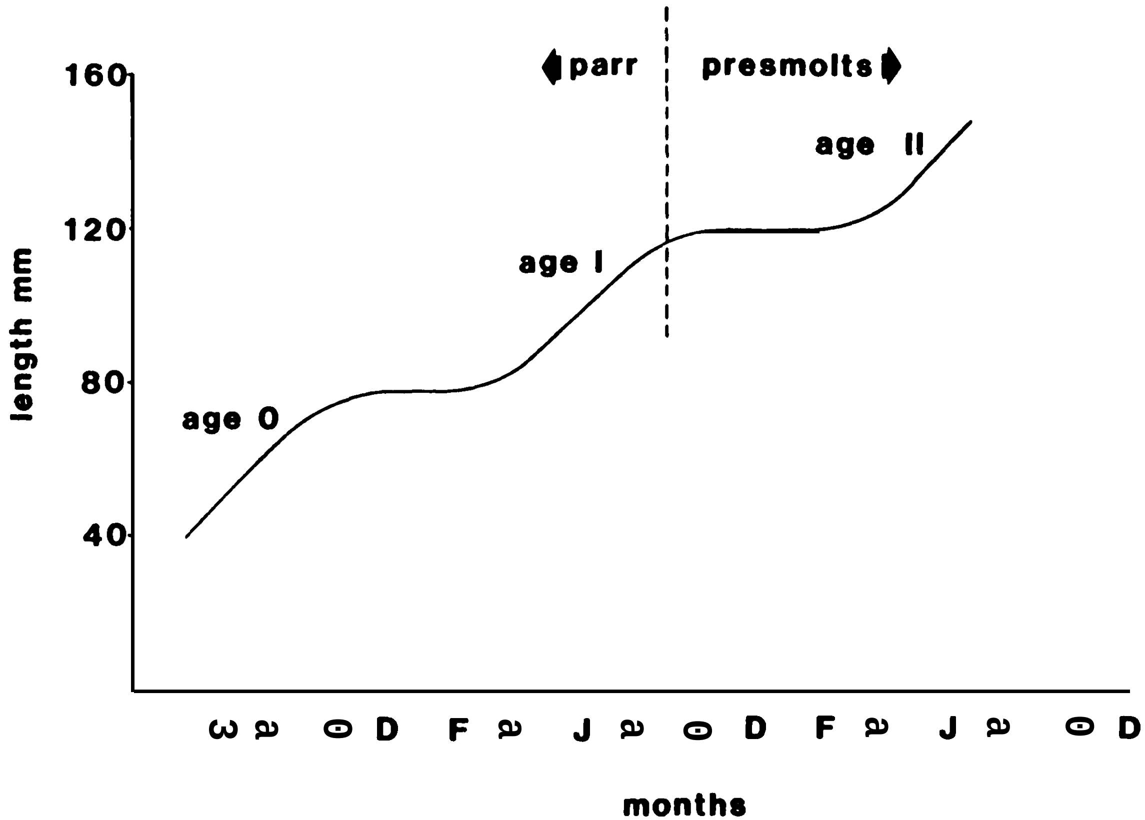


Figure 24 Generalized growth pattern of juvenile steelhead trout in Fish Creek. Emergence occurs primarily in June and smolts leave in May of their second year. Presmolts must be 120 mm fork length to smolt the following spring.

at the time of formation of the first and second annulus was 82 mm and 125 mm, respectively. Thus, we speculate that in ofrder for a fish to reach the minimum size to smolt, 140 mm, it must have attained a length of 120 mm by the end of the growing season the previous fall. It is probably unlikely that fish less than 120 mm would reach the 140 mm threshold by the following spring.

Overwinter survival of pre-smolt steelhead trout appeared to be favorable in Fish Creek in 1985. In the summer of 1984 the Fish Creek basin contained an estimated 23,800 age one and older steelhead trout. Approximately 50 percent of these fish, 11,900, were a minimum length of 120 mm by the fall of 1984 (Fig. 25). Since about 8,000 smolts left the basin in 1985, over-winter survival is estimated at about 70 percent. An additional contribution could be expected from age l+ parr that remain in the system for another growing season.

In 1986, steelhead trout smolts were trapped in Fish Creek between March 14 and June 14. A few fish were migrating when the trap was installed in March, but because of cold water temperatures in the system prior to trap installation, it is unlikely that many smolts left before trapping commenced. Several peaks of movement related to changing water temperatures and flows occurred in 1986 (Fig. 21). Catch during March was fairly consistent at 10 to 20 fish/day with a peak of 27 fish on March 30. Major peaks of movement occurred on April 18 and 27 when about 70 fish/day were caught. Peaks also occurred on May 3 and 14 at 35 and 47 fish, respectively. After May 14 catch of smolts declined rapidly and ceased on June 14.

The total steelhead trout smolt migration in 1986 was estimated at 3,781 fish, approximately half of the number of migrants in 1985

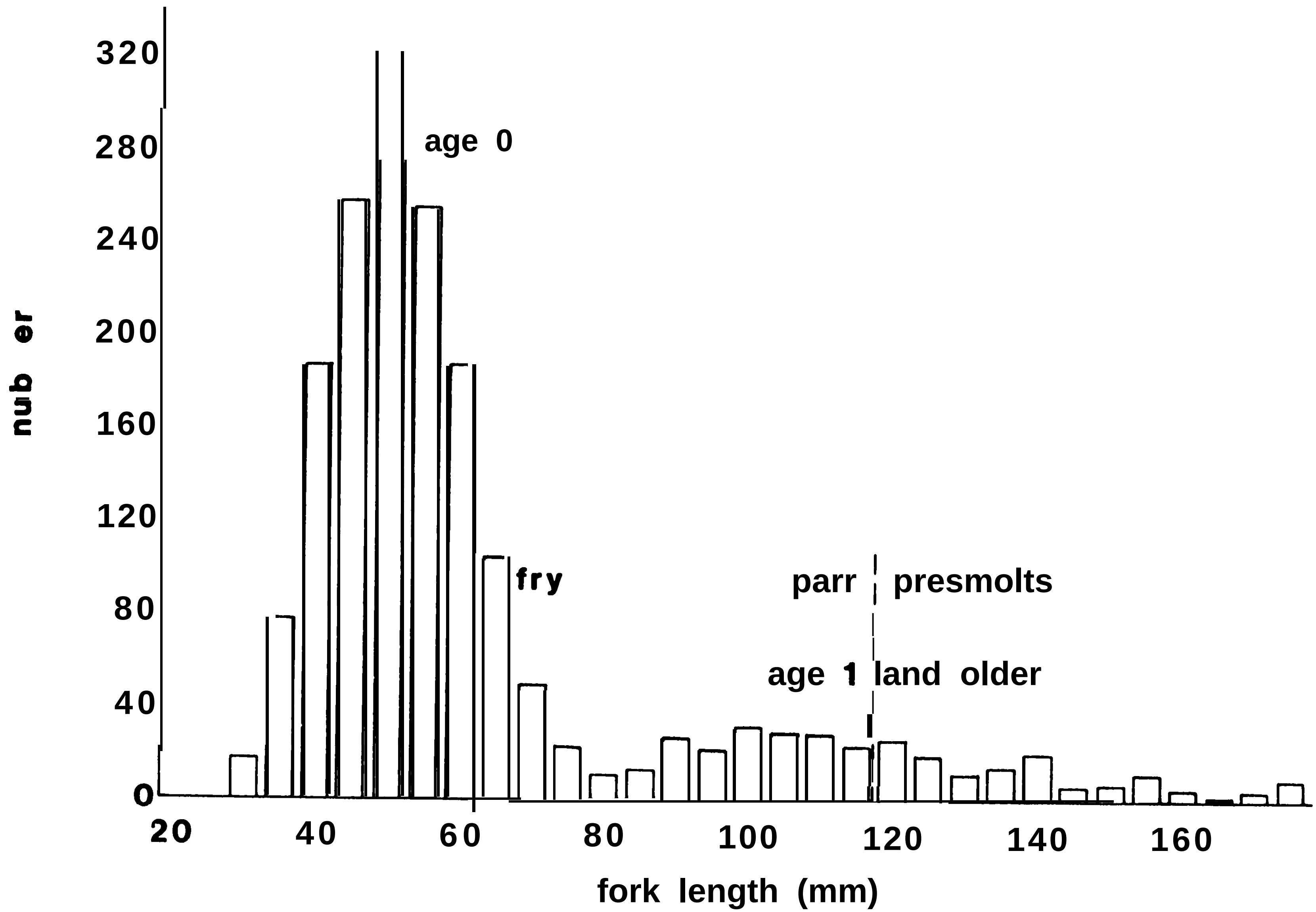


Figure 25. Size frequency of juvenile steelhead trout in Fish Creek, September 1985. Only fish larger than about 120 mm will smolt the following spring.

(Table 16). The smolts were about the same length and weight as 1985 migrants, averaging about 154 mm fork length and 37.7 g. Smolt lengths ranged from 135 mm to 217 mm, and weights ranged from 16.1 to 94 g (Figs. 22, 26). The average size of smolts remained fairly constant througout the migration period (Fig. 23).

Overwinter survival of juvenile steelhead trout in Fish Creek was lower in 1986 than in 1985. Approximately 18,520 age one and older steelhead trout were present in the basin in September 1985 and 3,781 smolts left the basin in the spring of 1986. Overwinter survival is estimated at about 40 percent, as compared to about 70 percent in 1985. The flood event of February 1986 probably is responsible for the difference. Steelhead trout overwintering in the substrate could have been killed by the overturning of the streambed during the flood or entombed by smaller bedload particles that filled interstitial spaces in the boulder-cobble streambed and prevented escape of overwintering steelhead trout.

The behavior of migrating steelhead trout smolts in 1985 and 1986 was typical of other salmonid smolts. Nearly all movement occurred during darkness and migrants apparently move downstream in the upper portion of the water column near the thalweg.

Habitat Enhancement and Steelhead Trout Smolt Production

At this time it is not possible to determine whether prototype projects designed to improve steelhead trout habitat have had any impact on the production of steelhead trout smolts. By 1985, projects had altered only about 5 percent of the habitat in the basin, and

Table 16. Fish Creek steelhead smolt estimate, March 14 to June 5, 1986.

Dates	Smolts captured	Marked smolts released	Marked smolts recaptured	Trap efficiency percent	Estimated total smolts
03/14-03/27	92	51	12	24	383
03/28-04/10	142	137	26	19	747
04/11-04/24	364	191	61	32	1,137
04/25-05/08	304	175	65	37	822
05/09-05/22	151	101	25	25	604
05/23-06/05	22	22	0	-25	88
Totals	2,148	523	143	--	7.473

natural variability of steelhead trout populations has been in the range of +/- 10 percent per year. Construction of boulder berms in 1983 was the only project in the basin to significantly impact habitat for age l+ steelhead trout prior to work completed in the summer of 1986. The effect of the boulder berms on steelhead smolt production appeared to be neglegible based on summer standing crop of presmolts. Habitat improvements in 1986 altered about 10 percent of the steelhead trout habitat in the basin and could significantly affect smolt production in the future.

Winter Observations

Field

The density of 0+ and l+ steelhead trout decreased between November 1986 and January 1987 in all habitats in lower Fish Creek and

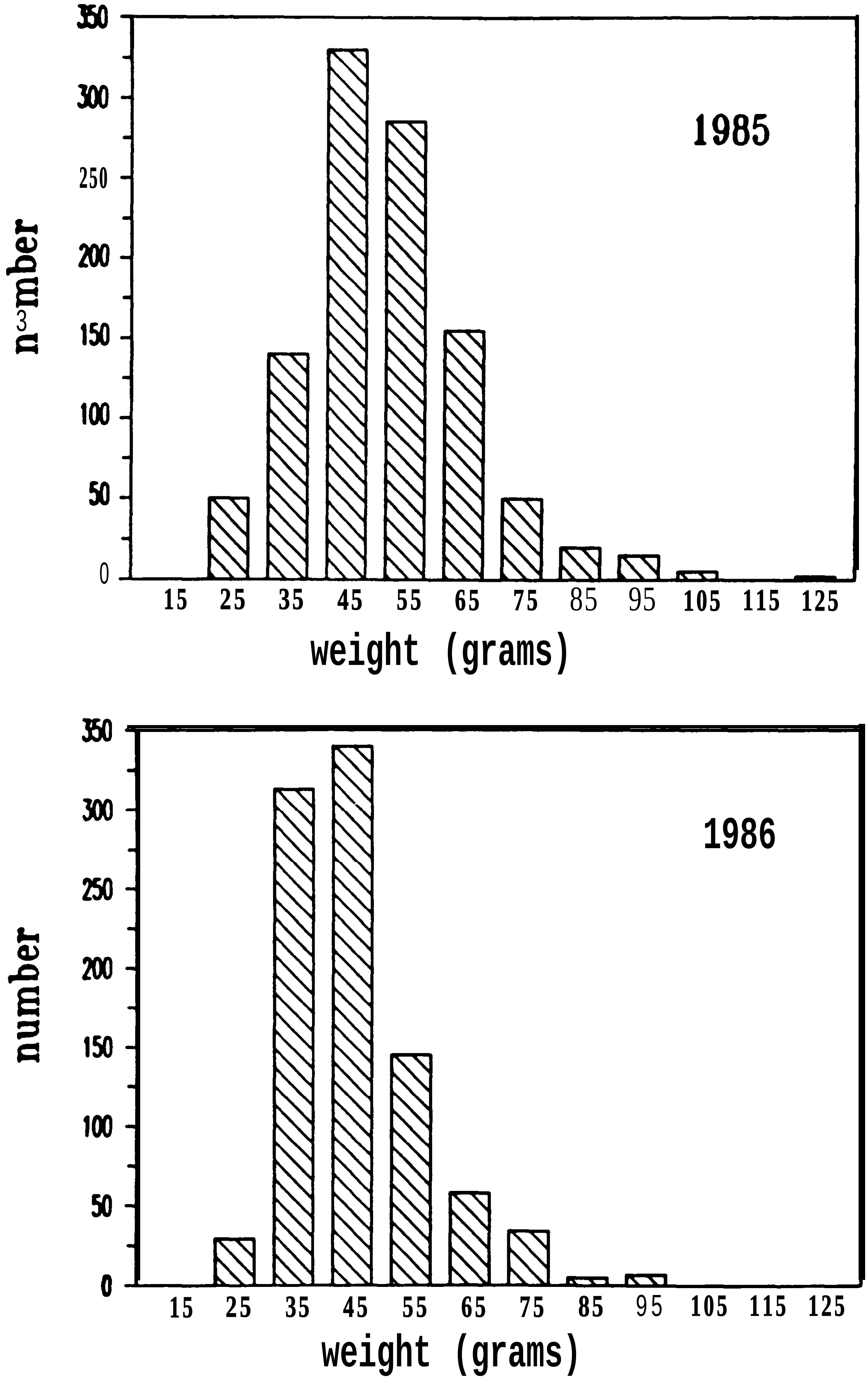


Figure 26. Weight distribution of steelhead molts captured at the floating trap at km 0.3, 1985 and 1986.

Wash Creek (Fig. 27). No fish were observed to be active after early November. Water temperatures were 7° C in November and decreased to 2° C in December. The only 0+ steelhead trout observed in December and January were under large boulders near the margins of the stream or in an overflow channel. The only place 1+ fish were observed was under large boulders in a single pool in Wash Creek in December.

We observed a number of adult summer steelhead trout in both lower Fish Creek and lower Wash Creek when the November counts were made. Approximately 50 percent of the fish observed in lower Fish Creek had their adipose fin clipped, which would indicate that these fish were of hatchery origin. Unclipped summer steelhead are believed to be "wild" offspring of previous generations of hatchery summer steelhead that successfully reproduced in the Fish Creek basin.

The distribution of l+ steelhead trout observed in 1986 was different than that observed in 1985. In 1985, numbers of l+ steelhead trout increased in pools in November, and decreased in other habitats. Everest et al. (1985) speculated that this increase may have been due to movement of l+ fish into pools from other habitats. In 1986, we were unable to sample in October because of high flow and turbidity and therefore were unable to determine if densities declined from September to October and increased in November.

No clear statistical relationship was noted between fish densities and the physical features measured. The highest densities of 1+ steelhead trout generally were found in pools that contained large boulders (>l m) that were embedded 25-50 percent by material 0.5-1.0 m in diameter (Everest et al., Fig. 23). Areas with large

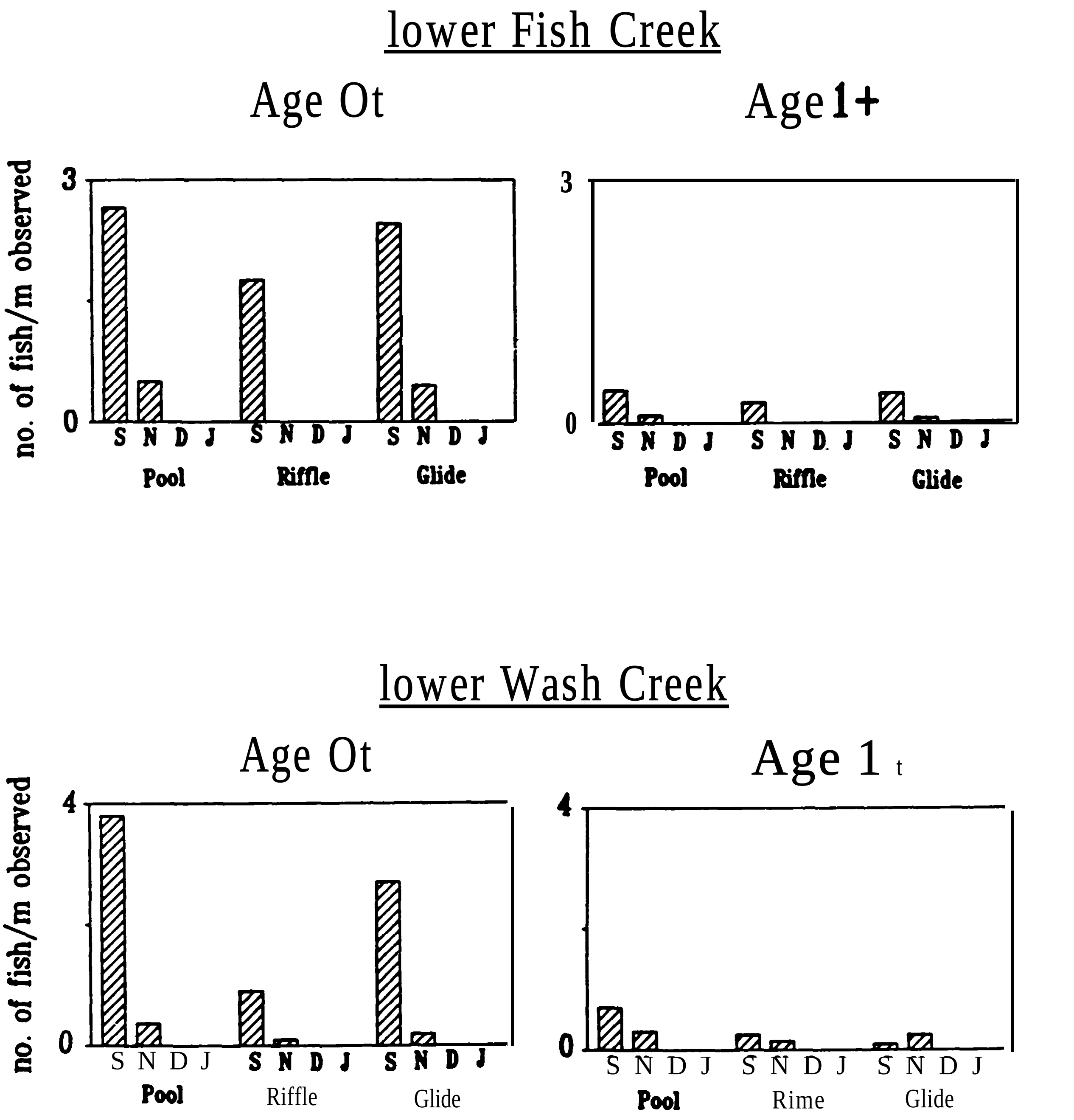


Figure 27. Mean number of juvenile steelhead trout in different habitats in Fish Creek, fall and winter 1986-87 (S = September, etc.).

concentrations of material 0.5-1.0 m also had high densities of fish. These areas were within the low summer flow perimeter (Everest et al, 1985, Fig. 24). Pools with bedrock substrate or with small-sized substrate (<0.25 m) generally had few or no fish. Age 0+ steelhead trout generally were found along the stream margins (Everest et al. 1985). Bustard and Narver (1975) also found 0+ steelhead trout in shallower water and associated with smaller substrate than were older age-classes. Johnson and Kucera (1985) reported that 0+ steelhead trout in three Idaho streams shifted to areas of gravel and cobble in the summer and to cobble and boulder substrates in the fall. Swales et al. (1986) reported highest densities of steelhead trout in areas of cobble and boulder riprap during the winter in two interior British Columbia streams.

Evaluation of Habitat Improvement Structures for Over-wintering

All sites were sampled for fish but only five were mapped. High water conditions prevented mapping at all sites. All mapped sites were in lower Fish Creek. Rigorous analysis would not be meaningful using the current small data set, but some trends are apparent.

Fish were captured in all cover types and depth/velocity categories but the number, species, and age-class composition varied. Age 0+ steelhead trout were most abundant in shallow-slow and deep-slow areas (Fig. 28) and associated with boulders and LWD and slash (Fig. 29). Of the 21 fish in fast water (Fig. 28). 6 were associated with LWD and 8 were associated with boulders (Fig. 29).

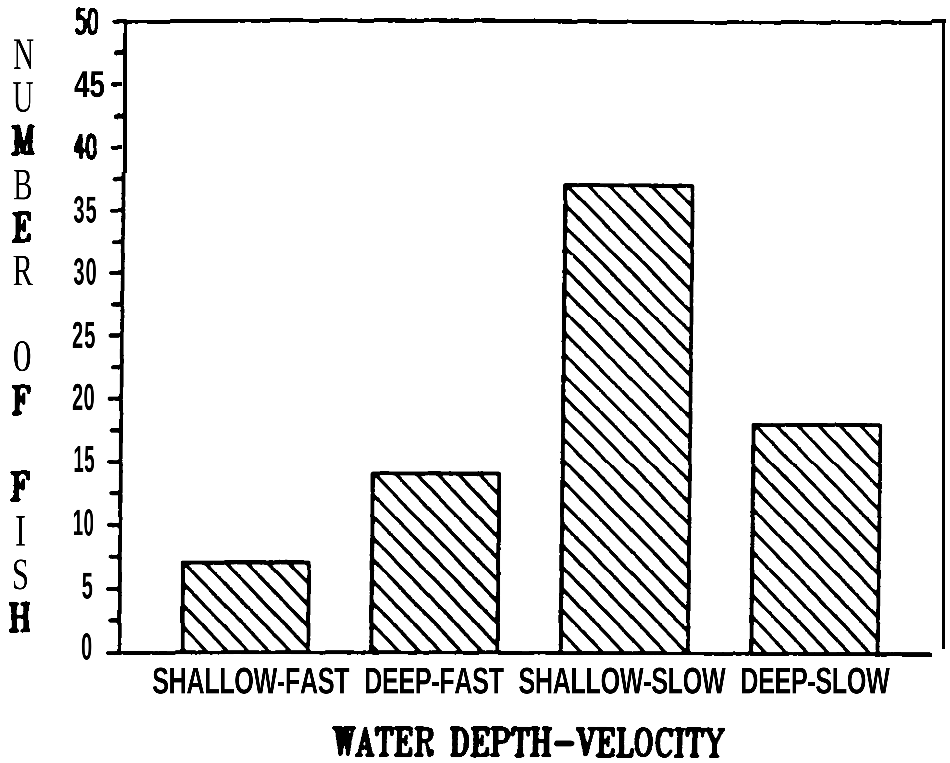


Figure 28. Abundance of age 0+ steelhead trout in water depth-velocity categories in winter, Fish Creek, 1987.

Age 1+ steelhead trout were strongly associated (65.6 percent) with fast water, particularly deep-fast water (Fig. 30). They were found predominatly in areas of LWD and boulders, but as with age 0+ steelhead trout, they utilized several cover types (Figure 31).

Coho salmon were found predominantly in slow water (Fig. 32). Depth appeared to be of secondary importance, with deep-slow areas containing 55.1 percent of the coho salmon captured and 31.9 percent in shallow-slow areas. Most coho salmon were associated with LWD and slash (65.2 percent) and slash (20.3 percent) (Fig. 33).

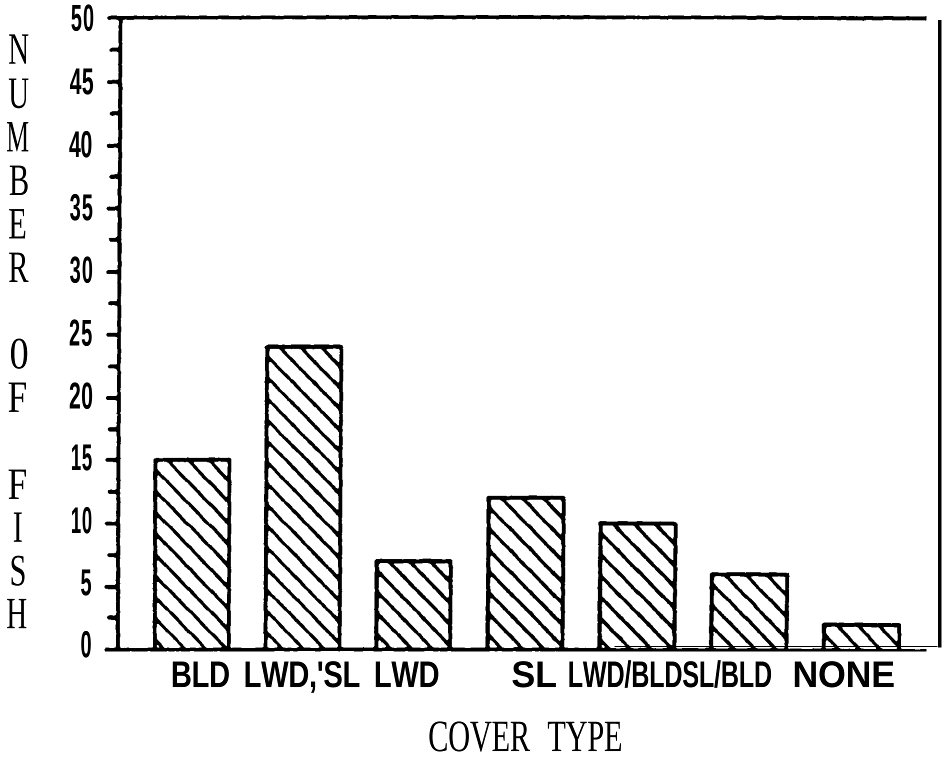


Figure 29 Abundance of age 0+ steelhead trout in different cover types in winter, Fish Creek, 1987.

These observations suggest that the LWD/boulder complexes provided favorable winter rearing habitat for juvenile salmonids in Fish Creek. The species or age-class of fish found in a complex varied with the compostion of the structure. Coho salmon were found in deep-slow and shallow-slow areas and in conjunction with LWD and slash. The combination of LWD and slash slowed current velocities and created cover. Age 0+ steelhead trout also utilized slow water areas with slash but not to the degree that coho salmon did. Age l+ steelhead trout were found primarily in deep-fast water and in association with boulders.

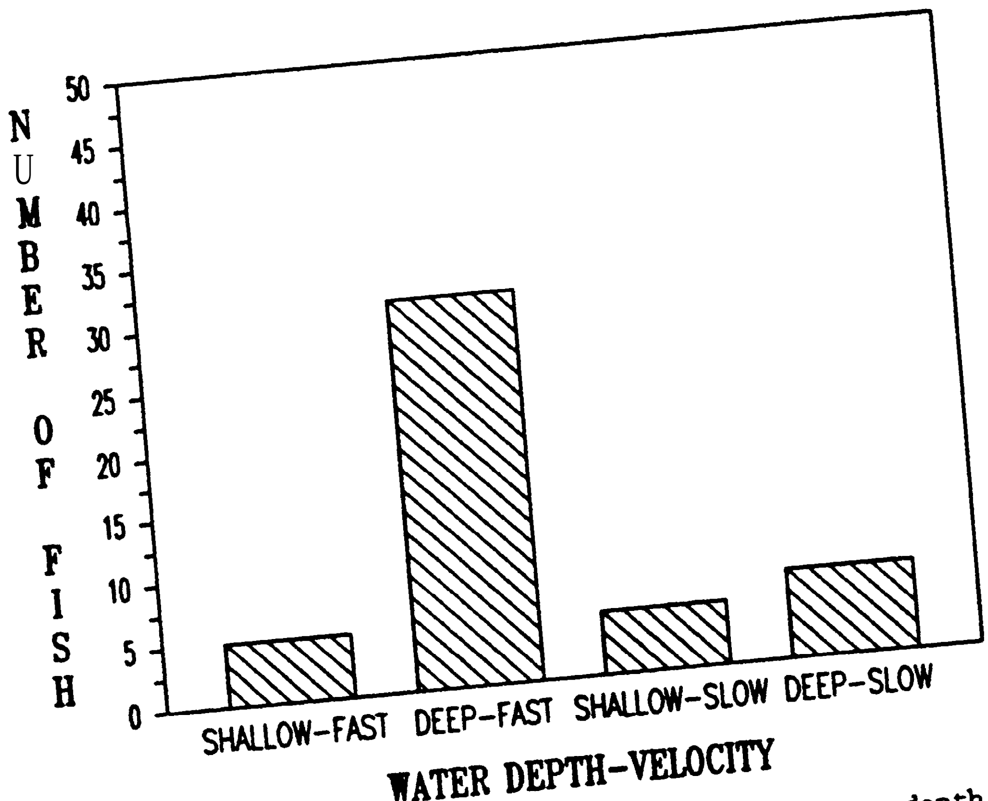


Figure 30. Abundance of age 1+ steelhead trout in water depth-velocity categories in winter, Fish Creek, 1987.

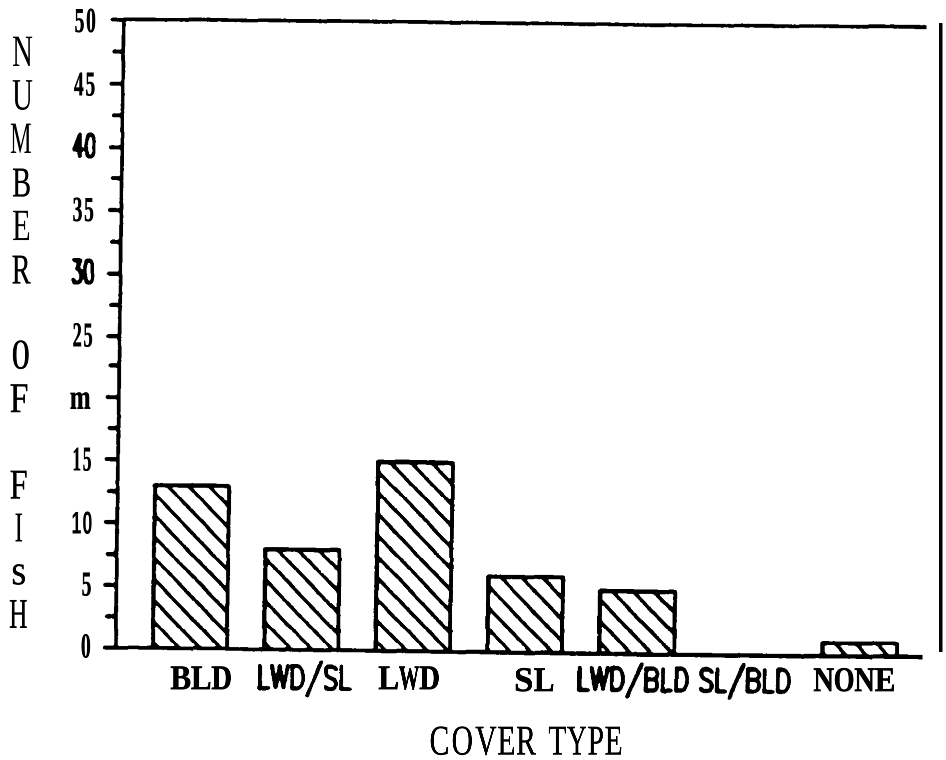


Figure 31. Abundance of age l+ steelhead trout in different cover types in winter, Fish Creek, 1987.

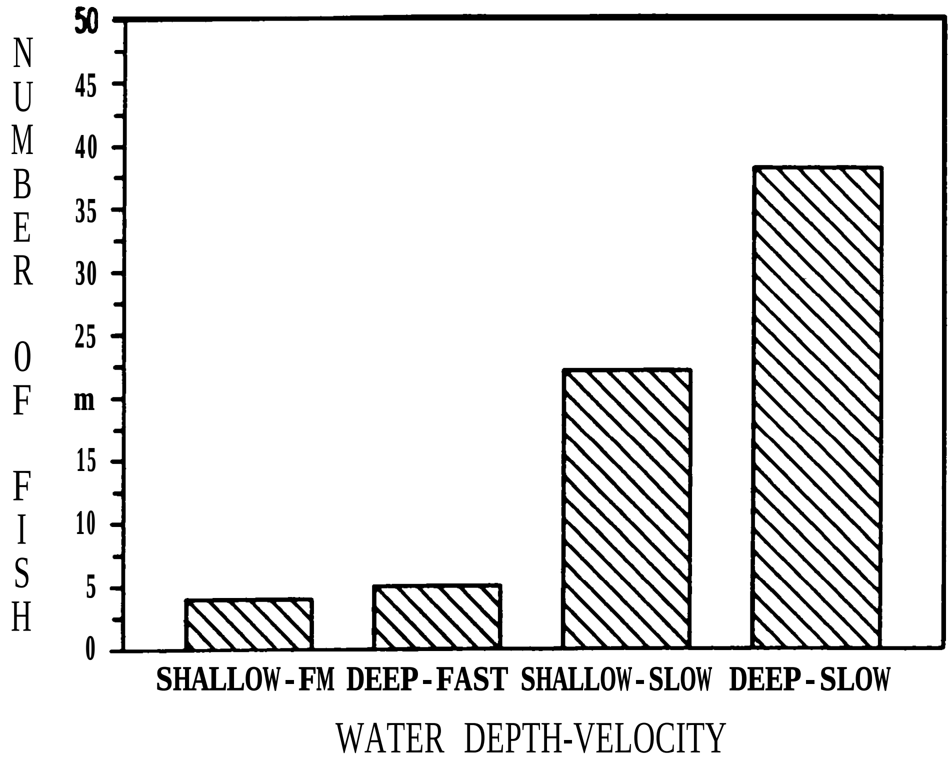


Figure 32. Abundance of age 0+ coho salmon in water depth-velocity categories in winter, Fish Creek, 1987.

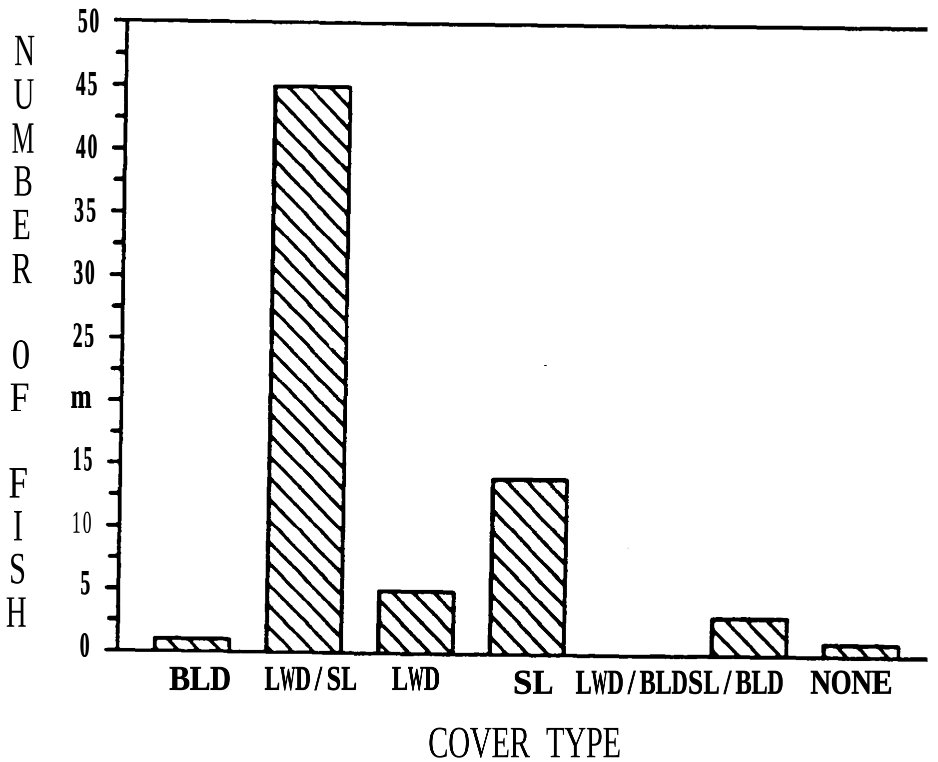


Figure 33. Abundance of 0+ coho salmon in different cover types in winter, Fish Creek, 1987.

These results are preliminary but can be used to make suggestions for future work. The LWD/boulder complexes created in the summer of 1986 appear to have created over-wintering habitat for juvenile salmonids in Fish Creek. The more open structures, consisting primarily of boulders and located in deeper water, tended to be utilized primarily by 1+ steelhead trout (Fig. 34). These structures need to be in the low summer flow perimeter in order to be available to older steelhead trout. Coho salmon and 0+ steelhead trout were in slower areas, more associated with LWD and slash (Fig. 35). These structures tended to be located along the banks, further away from the thalweg.

Slash and debris of varying amounts could be introduced periodically at selected sites and monitored to determine fish response. There may be variable responses of fish to different sources of slash and debris (e.g., cedar versus hemlock), or to orientation, density, and size ranges of LWD, submerged versus overhead cover, height of cover above substrate, and overall height of cover which could impact effectiveness over different flow regimes. Also, different life stages of a species appear to respond differently to depth-velocity-cover interactions.

The wood and boulder structures installed in Fish Creek in the summer of 1986 to increase the complexity of stream edges appear to have improved both winter and summer rearing habitat for salmonids. The intense level of treatment used in 1986, where structures were concentrated in restricted reaches that needed improvement, appeared to be far more effective than the often-used technique of scattering a few structures over a broad geographic area. The intensity of

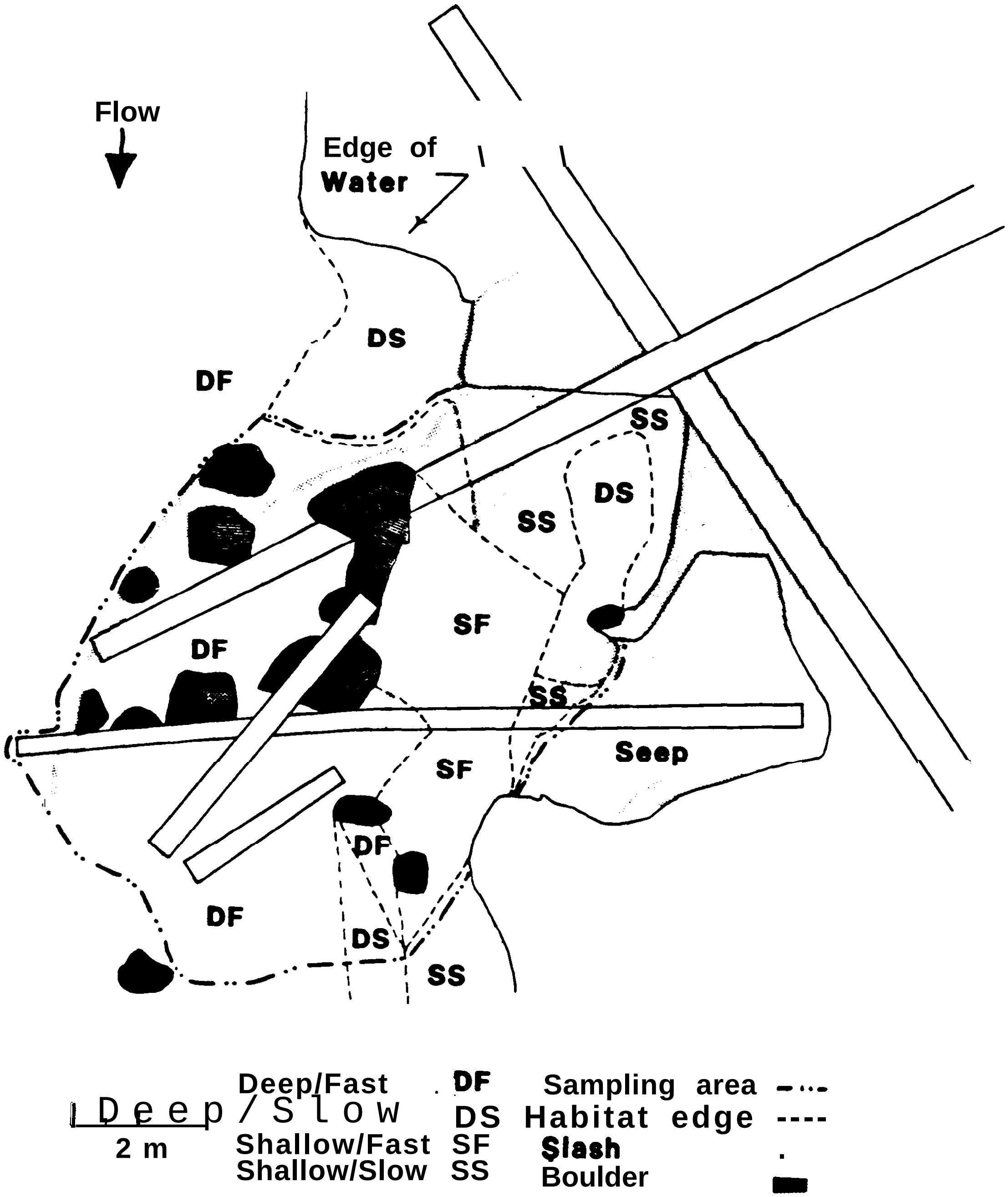


Figure 34. Example of "open" boulder-log complexity added *to* stream margins along lower Fish Creek in 1986 to enhance summer and winter habitat for juvenile salmonids.

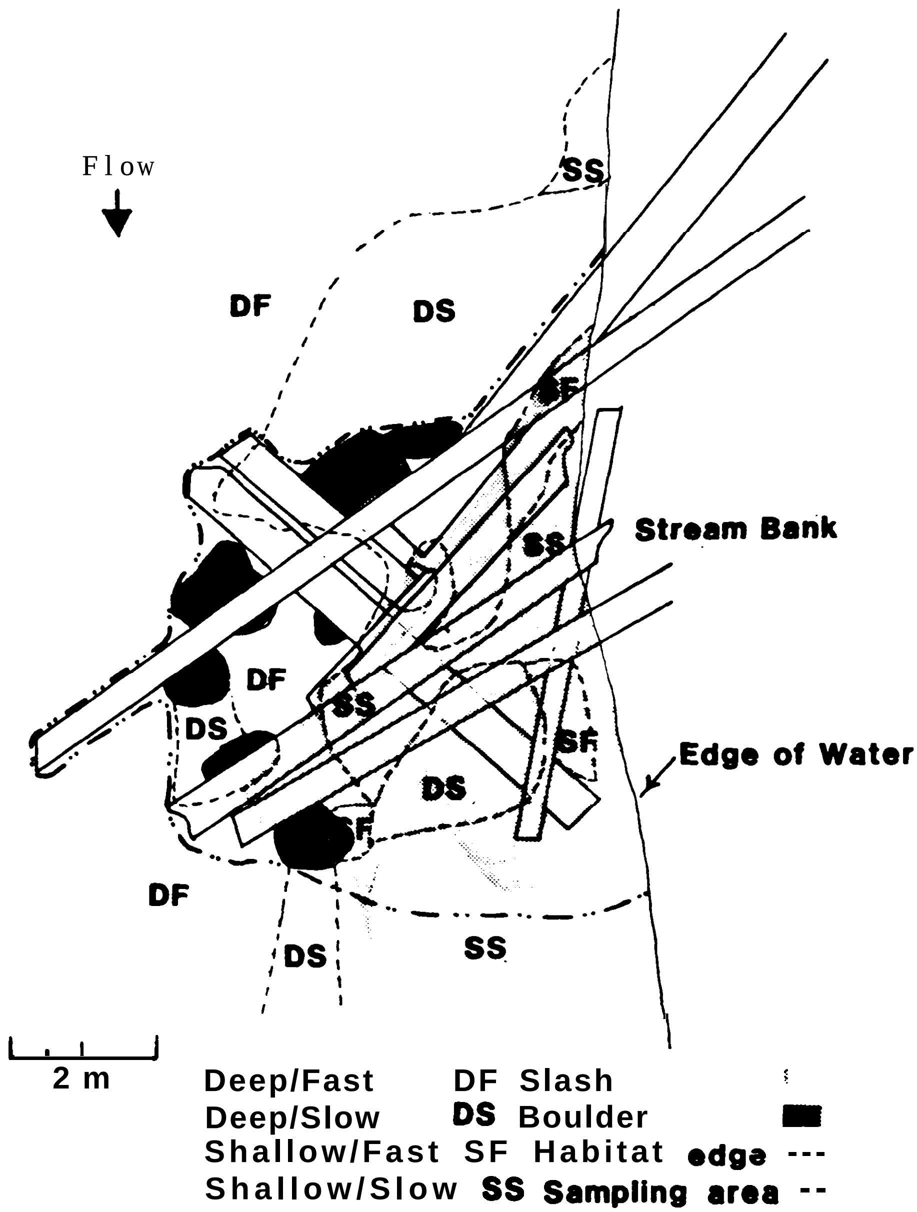


Figure 35. Example of "closed" boulder-log complexity (log interstices filled with slash) added to stream margins along lower Fish Creek in 1986 to enhance summer and winter habitat for juvenile salmonids.

treatment, with structures located about every 30 m along the stream margin, appears to be near optimum.

Riparian Revegetation

Four acres (1.6 hectares) of clearcut riparian habitat in upper Wash Creek basin were planted with two-year-old cottonwood in the spring of 1984. The objective of this work was to accelerate revegetation of the riparian zones to reduce water temperatures and improve streambank stability. The survival, health, and growth of the trees were recorded in September of 1984 and 1986 (Table 17). Observations also were made on the deer and elk browse damage to the seedlings. Survival in September 1984 exceeded 70 percent, with about 44 percent of the trees in good health. Growth of surviving trees averaged about 8 cm on the terminal shoot and deer and elk browse was negligible.

Table 17. Survival, growth, and browse use of two-year-old cottonwood stock planted in a Wash Creek clearcut in the spring of 1984.

Date	Health percent			Growth, cm			Browse	
	Dead	Weak	Robust	Robust	Weak	X	percent	(n)
September 1984	26	30	44	11.1	2.8	7.8	0	128
September 1986	9[1/]	30	61	20.6	3.4	12.0	0	283

[1/] Trees that died in the summer of 1984 were difficult to locate in 1986.

By September 1986, dense native vegetation had obscured the cottonwood seedlings that died during the summer of 1984, so an accurate assessment of survival from the initial planting was difficult to make. It appeared that most of the trees that survived the initial summer were still alive in the summer of 1986. The proportion of trees in robust condition had increased by the summer of 1986, and growth of the terminal shoot averaged 12 cm during the 1986 growing season (Table 17). Deer and elk browse damage remained negligible.

Despite good survival and growth of the planted cottonwood, surviving trees were not noticeably taller than surrounding native vegetation in the summer of 1986. Cottonwood, once well established, is a notoriously fast growing tree and may outstrip the growth of native vegetation. Consequently, several years of observations will be required to thoroughly evaluate the revegetation project.

Boulder Berm Surveys

Twenty-six boulder berms were built in Fish Creek, 5 in 1981 and 21 in 1983, to improve the availability of spawning habitat in the system. Three of the berms built in 1981 collected gravels the first winter after completion and have been used each year since by spawning steelhead trout. A few of the berms built in 1983 collected gravel during the winter after completion and were used as spawning areas (Everest et al. 1984). A major flood event in February 1986 breached 77 percent of the berms, but 46 percent were still meeting design objectives of increasing spawning habitat (Everest et al. 1986). Because this area was included in the 1986 project area, a final physical survey of the streambed in the vicinity of the berms constructed in 1983 was completed in the summer of 1986. The survey consisted of a series of long (thalweg) and cross-sectional profiles in reaches where the berms were constructed.

Results of the 1986 survey were compared graphically to results of a similar survey completed in the fall of 1983 immediately after the berms were built. A comparison of the integrity of the two upstream berms on Wash Creek and the five upstream berms in the Suspender area of Fish Creek in 1983 and 1986 show some interesting contrasts. The Wash Creek site has less than half of the winter flow and energy of the Suspender site and the Wash Creek berms retained most of their original height and configuration except for a few boulders in the center of each berm that were rolled out of position by the high flow (Everest et al. 1986). The area upstream from berm #l degraded slightly (Fig.36A), and the area above berm #2 aggraded slightly (Fig. 36B). Channel cross-section profiles in this area show little change in the stream banks. At Suspender Site 3 the original configuration of the berms was obliterated in the area of the thalweg, and about 30 percent of the thalweg area was degraded substantially (Figure 37). A 4 to 8 m section of the center of these berms was removed by high flows, but the berm wings adjacent to the banks remained intact. Consequently, stream energy was concentrated in the thalweg area and streambed degradation occurred in some areas. The cross-section profiles in this reach show slight aggradation between 1983 and 1986 (Figs. 38, 39). Suspender Site 4 (located just below the concrete bridge at km 7) which contained three half-berms showed substantial degradation along about 90 percent of the long profile

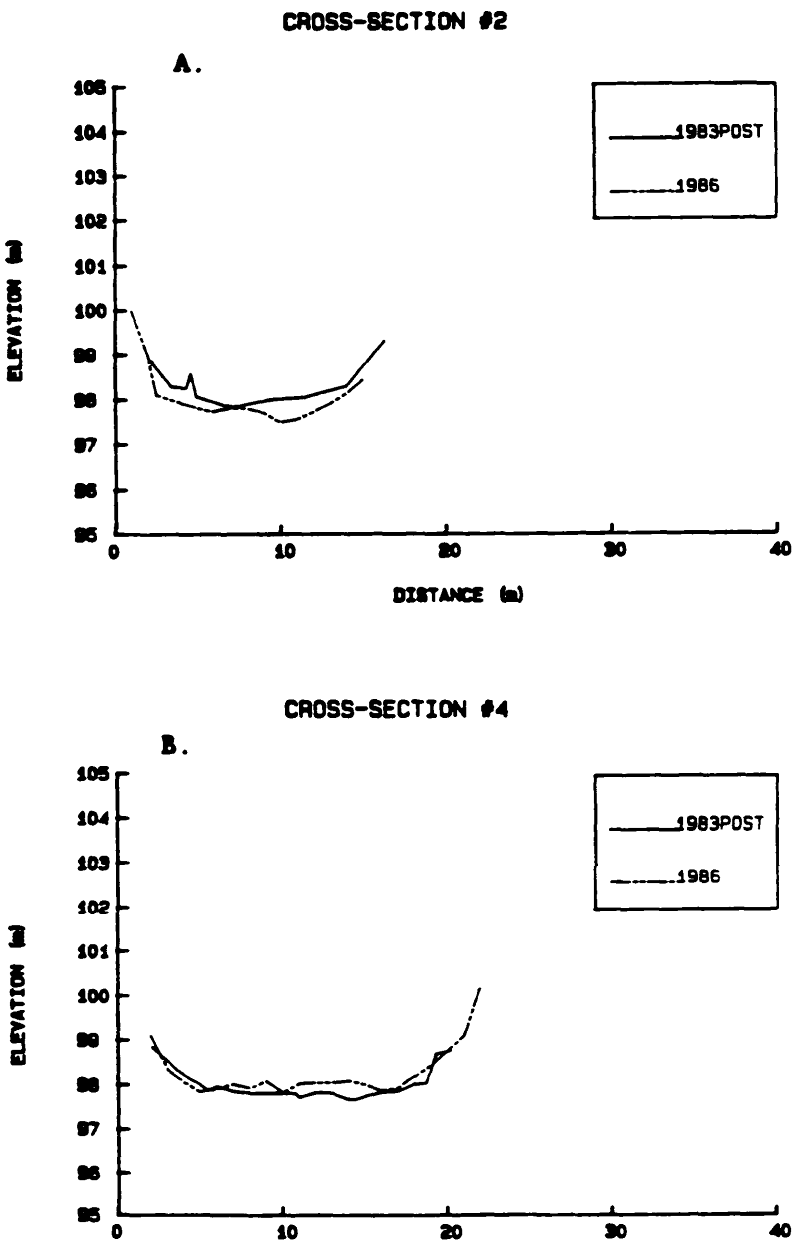


Figure 36. (A) Cross section upstream of Wash Creek berms #l showing channel degradation between 1983 and 1986, and (B) cross section upstream of **Wash Creek berm** #2 showing channel aggradation during the same period. Steelhead trout spawned at this rite.

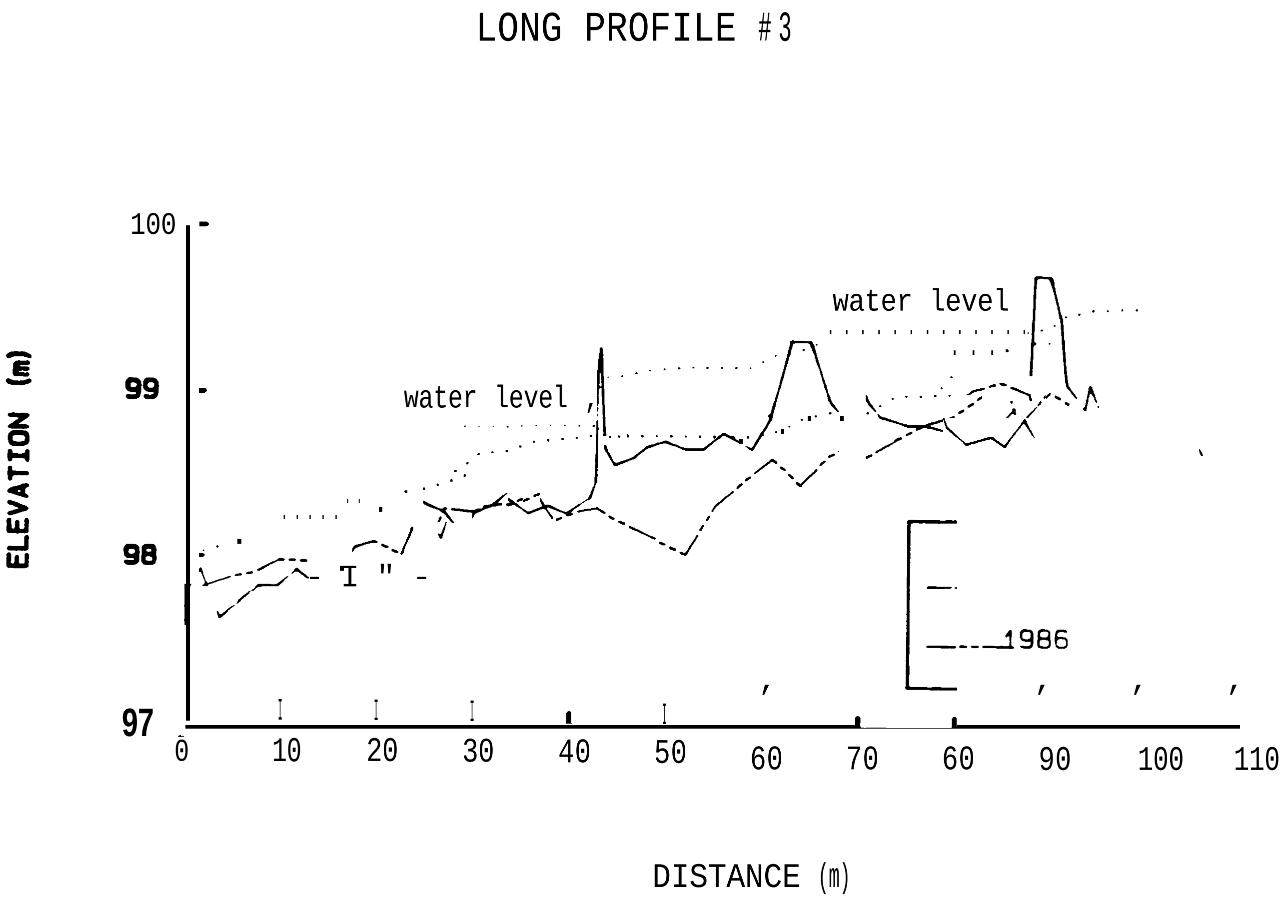


Figure 37. Changes in configuration of the long profile at lower Suspender site on Fish Creek, 1983 after berm construction, and 1986 after a high flow event.

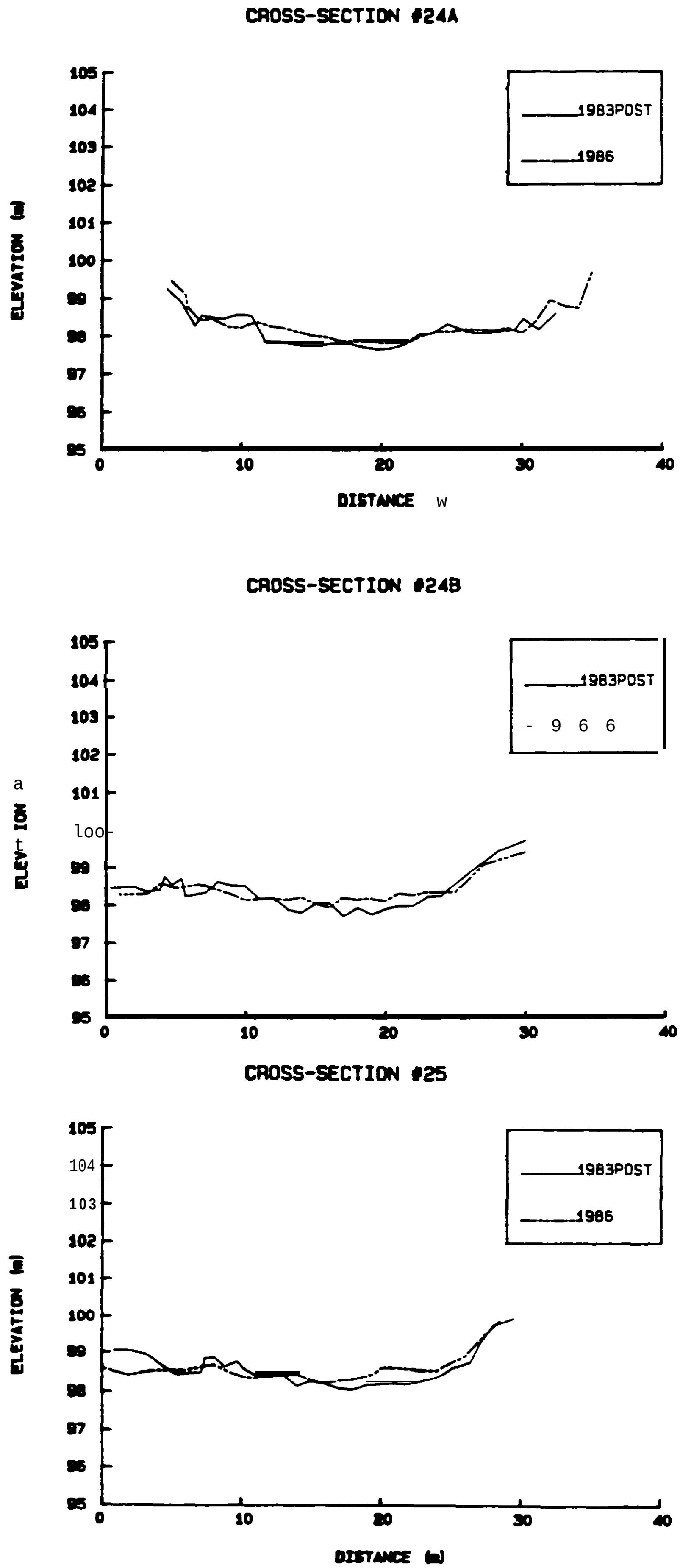
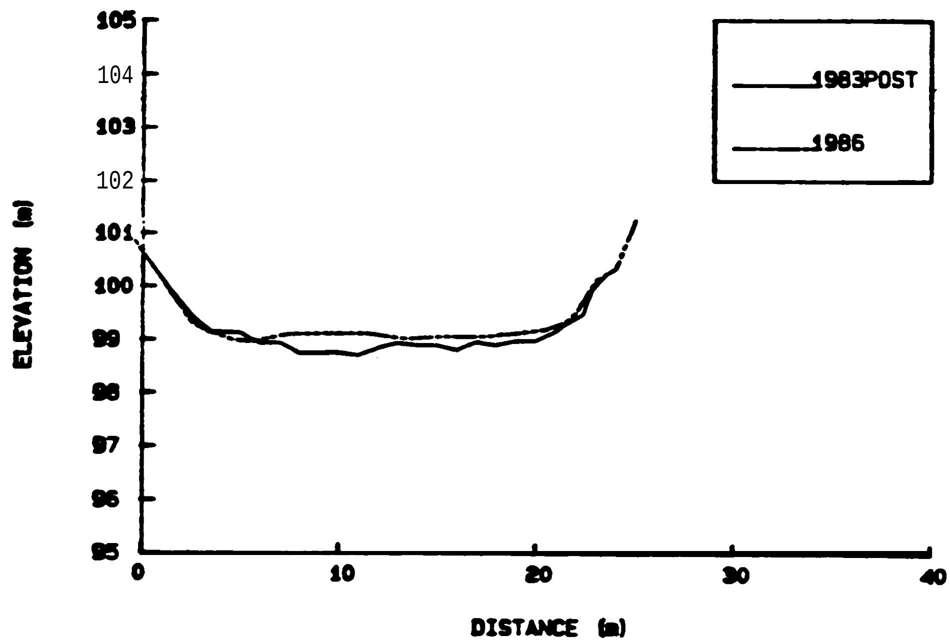


Figure 38. Cross sections upstream of berms #10 and #11 at *lower* Suspender rite. Note minor channel aggradation between 1983 and 1986.

CROSS-SECTION #35



CROSS-SECTION #36

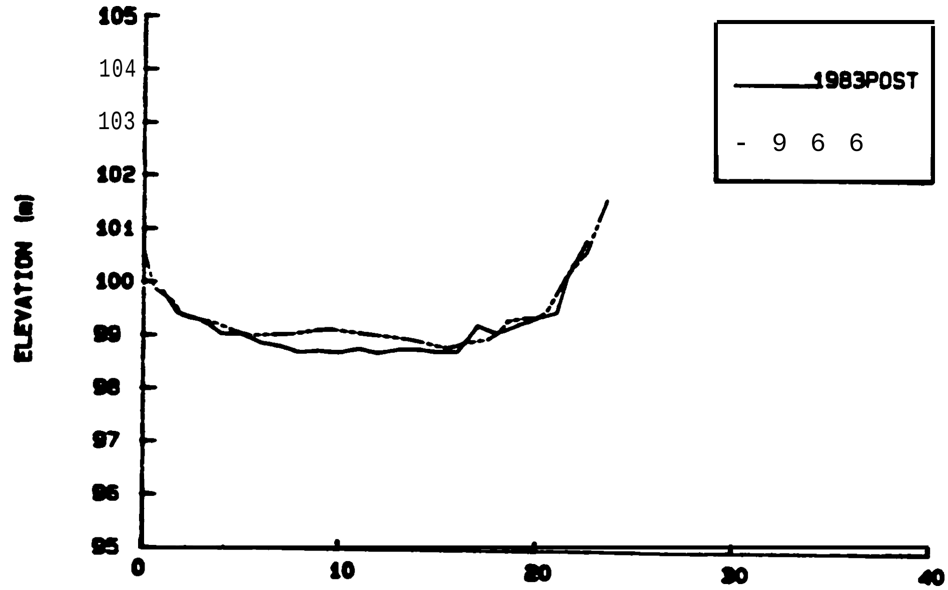


Figure 39. Cross sections upstream of berms #15 and #16 at lower Suspender site. Note channel aggradation between 1983 and 1986.

because the berms concentrated stream energy in the thalweg area (Fig. 40). The cross-section profiles at Site 4 show significant bankcutting and widening of the bankfull channel perimeter (Fig. 41). The bank erosion apparently was due to turbulence created by the berms during high flow events.

The biological consequences of flood-induced changes in the berms appear to be beneficial at Suspender Sites 3 and 4. Destruction of the center portions of the berms in this area during the February 1986 flood substantially increased habitat complexity in the reach. Pre-construction habitat consisted of a long homogenous reach of shallow bouldery high-gradient riffle with essentially no spawning gravel. After the flood, the reach consisted of a series of quiet backwater habitats behind the remaining portions of the berms at the stream margins, and in some areas, deeper bouldery riffle habitat along the thalweg. Summer rearing habitat for both 0+ and one year and older steelhead trout appears to be improved from pre-construction conditions. Accumulation of gravels below the remaining portions of the berms has created new spawning habitat, and some excellent winter habitat for both age 0+ and l+ steelhead trout was created where the berms are keyed into the stream banks.

The final survey of the berms, following a major (10-15 year recurrence) flow event, reinforces the idea that a steep-gradient boulder-armored channel requires large angular rock and well anchored structures to obtain a 20-30 year design life common to habitat improvement structures. Initial construction of the Suspender berms concentrated the relativley small boulder armor layer into the structures and de-armored the spaces between. The subsequent high

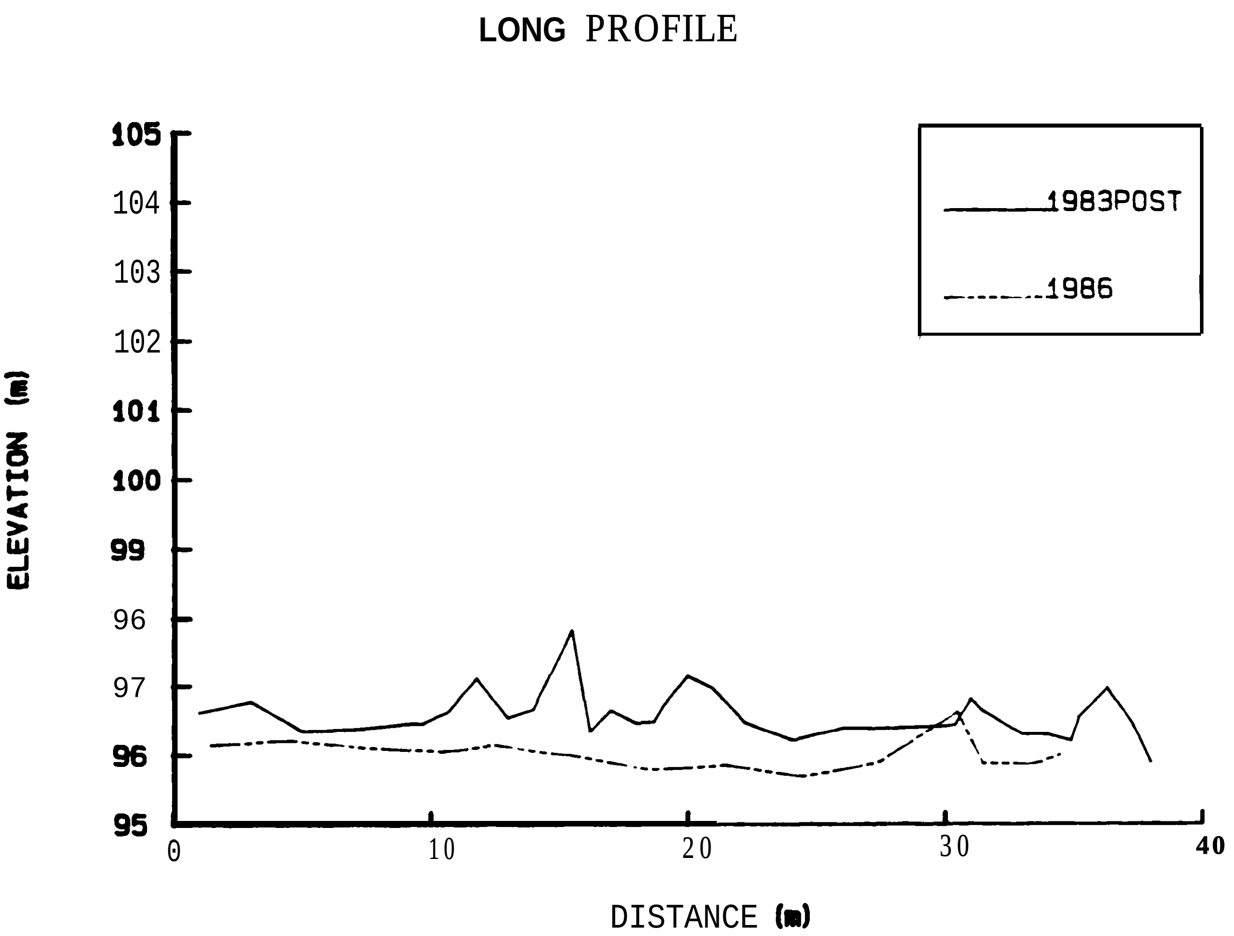


Figure 40. Long profile through Fish Creek half-berms. Note channel degradation in the thalweg area between 1983 and 1986.

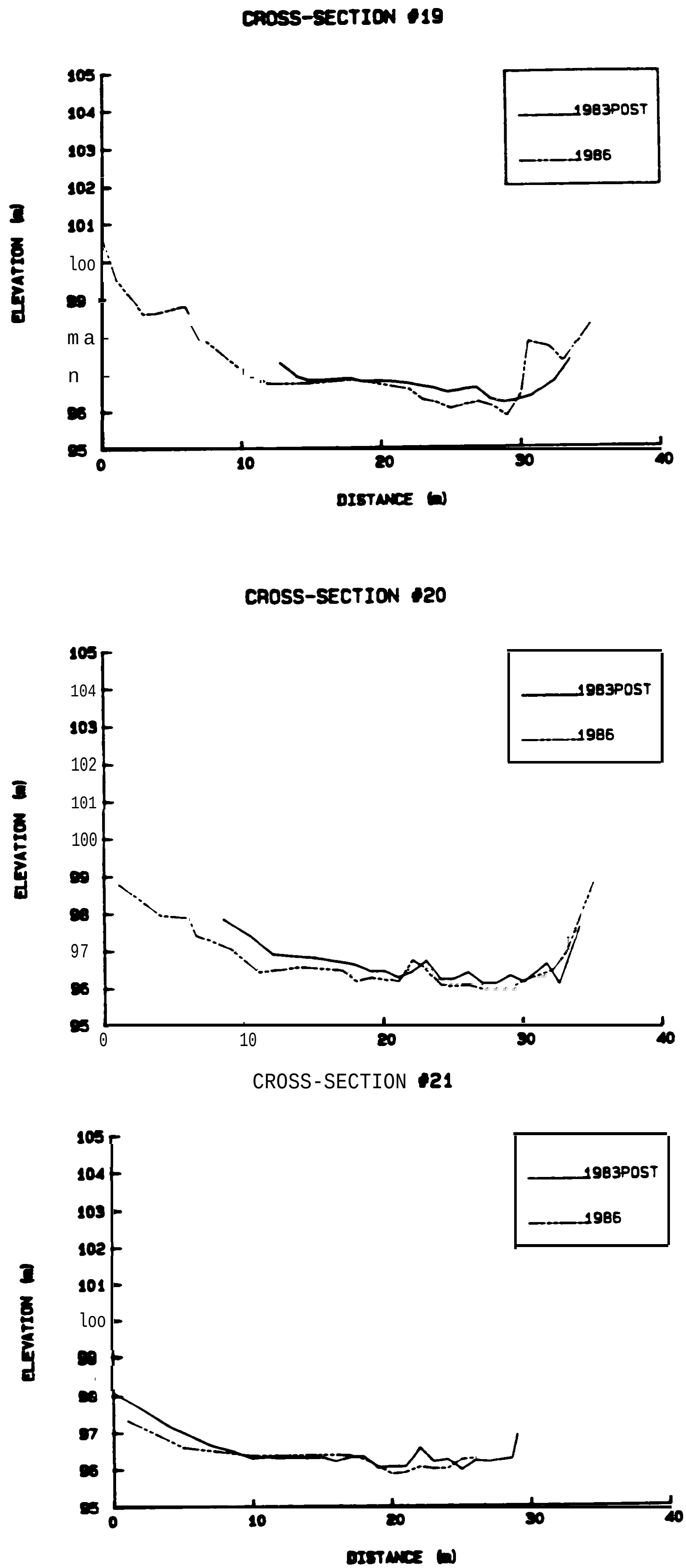


Figure 41. Cross sections upstream from half-berms in Fish Creek. Note erosion of left streambank between 1983 and 1986.

flow event of February 1986 breached the center section of the berms and redistributed the boulders along the stream thalweg. Only subtle changes in the channel remained before the 1986 project work, but those appeared to be beneficial to both spawning and rearing habitat of steelhead trout. These observations were instrumental in development of the final design for 1986 project work. The beneficial physical characteristics of the berm remnants were copies in project design criteria.

* * *

SUMMARY AND CONCLUSIONS

1) Monitoring efforts in 1986 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) Summer 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 1+ steelhead trout, and coho and chinook salmon were estimated at 117,870, 20,670, 3,560, and 200, respectively in 1986.
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) Coho salmon smolt production in 1986 was estimated at 2,371 fish, with a presmolt-to-smolt overwinter survival of 11 percent.
7) 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.
8) The off-channel pond constructed at km 3 on Fish Creek increased coho salmon smolt production from the basin by 102 percent in 1986. Overwinter survival in the pond exceeds 50 percent.
9) A preliminary benefit/cost analysis indicated that the off-channel pond at km 3.0 is cost effective at the observed 1986 smolt productiion of 1200 fish.
10) Preferred winter habitat for age l+ steelhead trout consists of large boulders surrounded by small boulders and cobbles positioned within the wetted perimeter at summer flows.
11) The flood of February 1986 substantially altered some enhancement projects in the basin. Some continue to meet their design objectives while others do not. Properly designed projects can be effective, even in this high energy system.

12) The most effective habitat improvement techniques in the high energy Fish Creek basin appear to be those that manipulate the edges, rather than the entire stream cross section.

13 Structures placed along the stream edges in 1986 show differential use by juvenile anadromous salmonids based on depth, velocity, and cover characteristics at the sites.

* * *

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We would like to thank Carl McLemore, Tracii Hickman, Paul Boehne, Tom Mendenhall, Charlie Dewberry, and Brad Lovatt, for field work and data analysis. Bill Lorenz was responsible for data collection and analysis of the section on winter utilization of recently created structures. Phyllis Taylor-Hill persevered with good humor through the typing and organizing of the tables and text. Kathy Anderson, Dave Heller, and Harv Forsgren provided critical reviews of the manuscript.

* * *

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

FISH CREEK, SEPTEMBER 1982

SPECIES	HABITAT	AREA IN SYSTEM	ESTIMATED NUMBER OF FISH BY HABITAT	ESTIMATED BIOMASS (g) OF FISH 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
	Side channel	1,600	180	1,250	0.11	0.78
	Pool	8,110	290	2,850	0.04	0.35
	Beaver pond	190	260	1,200	1.37	6.34
	Total	81,330	1,910	9,550	0.02	0.12
CHINOOK	Alcove	1,080	10	70	0.01	0.06
	Riffle	70,350	0	0	--	–
	Side channel	1,600	0	0	–	- -
	Pool	8,110	110	510	0.01	0.06
	Beaver pond	190	0	0	--	---
	Total	81,330	120	580	0.001	0.01
0+STHD	Alcove	2,270	2,200	5,010	0.97	2.21
	Riffle	138,590	75,240	211,660	0.54	1.60
	Side channel	4,250	5,100	12,870	1.20	3.03
	Pool	18,450	5,170	13,950	0.28	0.76
	Beaver pond	190	0	0	--	--
	Total	159,310	87,710	253,490	0.55	1.59
1+STHO	Alcove	2,270	120	2,240	0.05	0.99
	Riffle	138,590	17,260	317,210	0.12	2.29
	Side channel	4,250	460	8,400	0.11	1.98
	Pool	18,450	3,840	84,930	0.21	4.60
	Beaver pond	190	0	0		
	Total	159,310	21,680	412,780	0.14	2.59
ALL SALMONIDS	Alcove	2,270	2,470	8,190	1.09	3.61
	Riffle	138,590	93,540	542,250	0.67	3.91
	Side channel	4,250	5,740	22,520	1.35	5.30
	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	ESTIMATED NUMBER OF FISH BY HABITAT	ESTIRATED BIOMASS (g) OF FISH 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
	Side channel	2,230	130	380	0.06	0.17
	Pool	9,160	1,500	6,900	0.16	0.75
	Beaver pond	300	240	670	0.80	2.24
	Total	117,680	7,430	38,710	0.06	0.33
CHINOOK	Alcove	1,170	10	30	0.01	0.03
	Riffle	104,820	490	1,960	0.01	0.02
	Side channel	2,230	—	—	—	—
	Pool	9,160	640	2,950	0.07	0.32
	Beaver pond	300	—	----	--	—
	Total	117,680	1,140	4,940	0.01	0.04
0+STHD	Alcove	2,450	610	1,710	0.25	0.70
	Riffle	219,360	53,870	150,840	0.25	0.69
	Side channel	6,200	1,760	5,610	0.28	0.90
	Pool	20,850	3,780	12,470	0.18	0.60
	Beaver pond	300	10	30	0.03	0.11
	Total	249,169	60,030	170,660	0.24	0.68
1+STHD	Alcove	2,450	90	2,370	0.04	0.97
	Riffle	219,360	23,760	427,140	0.11	1.95
	Side channel	6,200	340	5,780	0.05	0.93
	Pool	20,850	2,800	53,960	0.13	2.59
	Beaver pond	300	0	0	--	--
	Total	249,160	26,990	489,250	0.11	1.96
ALL SALMONIDS	Alcove	2,450	930	5,190	0.38	2.12
	Riffle	219,360	83,460	609,620	0.38	2.78
	Side channel	6,200	2,230	11,770	0.36	1.90
	Pool	20,850	8,720	76,280	0.42	3.66
	Beaver pond	300	250	700	0.83	2.33
	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	ESTIMATED NUMBER OF FISH BY HABITAT	ESTMATED BIOMASS (g) OF FISH BY HABITAT	#/m^2	g/m^2
COHO	Alcove	1,080	630	2,360	0.28	2.19
	Riffle	81,610	3,310	12,740	0.04	0.16
	Side channel	2,000	1,920	6,240	0.96	3.12
	Pool	8,340	1,840	10,950	0.22	1.31
	Beaver pond	270	590	1,730	2.19	6.42
	Total	93,390	8,290	34,020	0.09	0.36
CHINOOK	Alcove	1,080	0	—	--	—
	Riffle	81,610	0	--	—	--
	Side channel	2,000	0	--		—
	Pool	8,340	280	3,140	0.03	0.38
	Beaver pond	270	10	130	0.04	0.48
	Total	93,390	290	3,270	0.003	0.04
O+STHD	Alcove	2,280	830	1,660	0.36	0.73
	Riffle	161,700	81,010	196,850	0.50	1.22
	Side channel	5,320	2,370	6,110	0.45	1.15
	Pool	19,180	3,850	10,240	0.20	0.53
	Beaver pond	270	0	0	-	--
	Total	188,750	88,060	214,860	0.47	1.14
1+STHD	Alcove	2,280	110	3,360	0.05	1.47
	Riffle	161,700	18,420	405,240	0.12	2.51
	Side channel	5,320	440	7,220	0.08	1.36
	Pool	19,180	4,280	112,990	0.25	5.89
	Beaver pond	270	10	330	0.09	1.20
	Total	188,750	23,260	529,140	0.12	2.80
ALL SALMONIDS	Alcove	2,280	1,570	7,380	0.69	3.24
	Riffle	161,700	102,740	614,830	0.64	3.80
	Side channel	5,320	4,730	19,570	0.89	3.68
	Pool	19,180	10,250	137,320	0.53	7.15
	Beaver pond	270	610	2,190	2.26	8.11
	Grand total	188,750	119,900	781,290	0.64	4.14

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

FISH CREEK, SEPTEMBER 1985

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

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

FISH CREEK, SEPTEMBER 1986

SPECIES	HABITAT	AREA IN SYSTEM	ESTIMATED NUMBER OF FISH BY HABITAT	ESTIMATED BIOMASS (g) OF FISH BY HABITAT	#/m2	g/m2
COHO	Glide	13,750	2,170	9,100	0.16	0.66
	Riffle	62,940	40	160	0.001	0.003
	Side channel[1/]	0	0	0	0.0	0.0
	Pool	7,170	1,350	7,130	0.18	0.99
	Beaver pond[2/]	190	--	--	--	
	Total	84,050	3,560	16,390	0.04	0.20
CHINOOK	Glide	13,750	100	420	0.01	0.03
	Riffle	62,940	0	0	0.00	0.0
	Side channel[1/]	0	0	0	--	--
	Pool	7,170	100	940	0.01	--
	Beaver pond[2/]	190	0	0	--	--
	Total	84,050	200	1,360	0.001	0.02
O+STHD	Glide	27,380	19,490	23,350	0.35	0.85
	Riffle	114,400	94,410	244,870	0.83	2.14
	Side channel[1/]	0	0	-	0.00	0.0
	Pool	24,480	13,970	42,050	0.51	1.72
	Beaver pond[2/]	190	--	--	--	--
	Total	166,450	117,870	310,270	0.70	1.86
1+STHD	Glide	27,380	3,230	53,040	0.11	1.94
	Riffle	114,400	10,820	182,640	0.09	1.60
	Side channel[1/]	0	--	--	0.00	0.0
	Pool	24,480	6,620	120,550	0.24	4.92
	Beaver pond[2/]	190	--	--	--	
	Total	166,450	20,670	356,230	0.12	2.14
ALL SALMONIDS	Glide	27,380	14,990	85,910	0.55	3.14
	Riffle	114,400	105,270	427,670	0.92	3.14
	Side channel[1/]	0	0	0	0.00	0.0
	Pool	24,480	22,040	170,670	0.90	6.97
	Beaver pond[2/]	190	--	--		--
	Grand total	166,450	123,300	684,250	0.74	4.11

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

Appendix 2.

Fish Creek Drainage Fish Habitat Rehabilitation and Enhancement Framework

Reviewed by

District Biologist, Estacada Ranger District — Date: 4/2/87

District Biologist, Oregon Dept. Fish and Wildlife — Date: 4/6/87

PNW Fish Creek Evaluation Project Leader — Date: 4/20/87

Forest Fishery Biologist, Mt. Hood National Forest — Date: 4/15/87

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Fish Creek Drainage Fish Habitat Rehabilitation and Enhancement Framework

I. Introduction

The Fish Creek Drainage Fisheries Enhancement Framework is a cooperative effort by the Forest Service (USDA FS, Mt. Hood National Forest) and the Oregon Department of Fish and Wildlife (ODFW). The plan was developed by fisheries biologists from Mt. Hood NF, Pacific Northwest Research Station, ODFW (Clackamas), and Pacific Gas and Electric (PGE). The result of this effort is intended to be the first step in the development of a drainage management plan for the Fish Creek system.

The Fish Creek Framework is intended to:

1. Summarize current information on fish and fish habitat resources in the drainage.
2. Identify and formalize cooperative management objectives.
3. Establish responsibility for management and facilitate interagency coordination.
4. Establish overall enhancement strategy for Fish Creek drainage.
5. Establish individual project priorities and timelines consistent with management objectives and drainage enhancement strategy.

II. Physical Description

The Fish Creek basin lies in north central Oregon on the west slope of the Cascade Range and drains into the upper Clackamas River at km 66.5 The watershed is 21 km (12.6 mi) long, averages approximately 10 km (6 mi) in width, and covers 171 km^2 (62 sq mi). 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. The Fish Creek drainage lies entirely on public lands, 99 percent Forest Service and 1 percent Bureau of Land Management.

Fish Creek heads near the summit of the Cascade Mountains at an elevation of about 1,400 m (4600 ft) and flows generally north for about 21 km (12.6 mi) to its confluence with the Clackamas River approximately 14 km (8.4 mi) east of North Fork Reservoir. The channel gradient is steep throughout this distance, generally exceeding 3 percent except for the lower 6 km (3.6 mi) where gradients average 3 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/sec (15 cfs) in late summer to more than 100 m^3/sec (3000 cfs) during winter freshets.

The 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 (6.6 mi). The Wash Creek subbasin covers 25 km2 (9 sq mi) and has a mainstem length of 8 km (4.8 mi). 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 (9 cfs).

The Fish Creek drainage supports summer and winter steelhead, spring chinook salmon, and coho salmon. Upper areas of the basin contain resident rainbow trout. Few resident salmonids are assumed to be within the range of anadromous fish. Approximately 16 km (10 mi) of habitat are used by anadromous salmonids, including 11.7 km (7 mi) on Fish Creek and the lower 4.5 km (2.7 mi) of Wash Creek. The upper reaches of both Fish and Wash Creeks are blocked to anadromous salmonids by major waterfalls. 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 reach stressful levels for salmonids. For example, in early September 1980, temperatures in lower Fish Creek reached 24° C for several consecutive days.

The Forest Service began habitat enhancement activities to increase the numbers of anadromous fish in 1981 and contracted with the Pacific Northwest Range and Experiment Station to monitor and evaluate the results of this work on a drainage basis shortly thereafter. In 1983 the Forest and BPA entered into an agreement to continue this work and to expand the scope of the PNW evaluation. This is currently the only intensive, basin level evaluation in the Columbia River Basin and provides a unique opportunity to test enhancement hypotheses. It is with this in mind that the Forest has taken an aggressive approach to fisheries habitat enhancement for the Fish Creek drainage.

III. Land Use

The three primary land use activities affecting fish habitat in the Fish Creek Drainage are timber harvest, roads, and dispersed recreation.

The Fish Creek drainage is classified as commercial Forest land. Timber harvest began in earnest in the 1960's. In the past 25 years more than 40 percent of the timber in the drainage has been cut. Most of this harvest has been in tributary areas. Stands of old growth timber are being converted to second growth. The change is most dramatic within riparian areas, where large Douglas-fir, cedar, and hemlock are being replaced by alder.

IV. Fish and Fish Habitat Resources of the Drainage

1) Background

Fish species generally found in the upper Clackamas River system are found in Fish Creek. Although the Fish Creek drainage constititutes only 10 percent of the habitat available to anadromous fish in the Clackamas River it is estimated to contribute 23 percent of the steelhead, 3 percent of the coho, and an unknown percent of the spring chinook smolts leaving the upper Clackamas annually (Fred Everest, personal communication). A possible explanation for the high proportion of the total run of steelhead produced by the Fish Creek drainage is that after passage was reestablished over River Mill Dam the remnant run colonized the lower tributaries and subsequent seeding has been insufficient to reestablish runs throughout the basin.

Prior to construction of dams on the Clackamas River, large numbers of anadromous fish used the river and its tributaries for spawning and rearing. Historical records indicate these runs were seriously depleted by construction of a grist mill dam near Gladstone, Oregon in 1891. A State fish hatchery located four miles upstream from this dam reported a decrease in chinook salmon egg take from 5,860,000 in 1890 to only 800,000 eggs in 1891 (Thompson, et.al., 1966). Problems with salmon runs were further compounded when Cazadero Dam (now called Faraday Diversion Dam) was constructed in 1905. Although this dam was constructed with a fish ladder, Federal fish hatchery egg taking operations allowed very few salmon to pass over the dam (Eicher, 1977). Reports are vague as to numbers of coho salmon and steelhead trout reaching the upper reaches of the Clackamas River during this period.

In 1911, River Mill Dam was constructed with fish passage facilities. However, continued egg taking operations below the dam prevented any great number of chinook salmon from reaching the upper river system. Six years later in 1917, the fish ladder over Cazadero Dam was destroyed by a flood and was not rebuilt until 1939. During the interim period, no salmon or steelhead reached the upper river system.

During the 1940's, Federal hatchery egg taking operations ceased, and the salmon were permitted to pass upstream into the upper river. In 1959, the North Fork Dam was completed with a fishway extending from the base of Faraday Diversion Dam to the crest of the North Fork Dam, a distance of 1.7 miles. This facility was provided with upstream and downstream migrant counting equipment.

2) Anadromous Species

There are three species of juvenile anadromous fish which utilize the Fish Creek drainage for rearing. They are chinook salmon, coho salmon and steelhead trout. Juvenile chinook and coho salmon rear in the first 5.2 km of the Fish Creek drainage. Steelhead trout juveniles are distributed throughout the entire 11.7 km of Fish Creek to the falls just above Calico Creek and 4.5 km of Wash Creek to the base of an impassable waterfall.

Very few fall chinook, if any, utilize the main channels of the Clackamas River above the dams for spawning. Fall chinook spawning in the lower portion of the Clackamas system do so in October. The resulting fry emerge in December and January.

Spring chinook enter the Clackamas River system in late spring and hold over to spawn in September and October. Runs have been supplemented by hatchery outplanting and now average 2,600 fish/year over North Fork dam. Entry into Fish Creek appears to be opportunistic, depending on high flows at the mouth to allow sufficient depth for passage. Full seeding for spring chinook is estimated to be 150 adults. The bulk of the fry emerge from the gravels from late December through March.

Chinook salmon juveniles are transient in the Fish Creek system. There appears to be three outmigrations of chinook juveniles. The first outmigration consists of fry in February and March, and along with the second outmigration occurring in late summer of their first year probably, consists of fish that drop down and rear in the mainstream Clackamas, hydropower reservoirs on the Clackamas, and in the Willamette River on their way to the sea. The third outmigration peaks in March thru May and may consist of fish ready to smolt.

Two distinct runs of coho spawn in Fish Creek and numbers vary widely by year, averaging a total of 180 fish/year. Unlike chinook, coho utilize small streams, many of which are second order, for spawning purposes. The early run coho (hatchery stock) enter the Clackamas River in August, September and October, with most spawning occurring in October and November. The later run, wild stock moves over North Fork in December through February and spawns in Fish Creek in February and March. Although these two stocks spawn approximately three months apart there is only one peak in outmigration, which occurs in May and June. Full seeding for coho salmon is estimated to be 200 adults.

Coho salmon juveniles prefer side channels, alcoves, quiet pools, and off-channel areas, most of which are located within the lower 5.6 km of Fish Creek. Estimates by the PNW evaluation suggest that only a small percentage of the habitat in Fish Creek is optimal for coho. Fish Creek produced about 3,100 coho smolts in 1985.

Winter steelhead counts at the dams, like coho, show widely varying totals by years. The Clackamas River system supports both early and late run winter steelhead. The early run fish (a hatchery stock) enter the upper river system in November and December. The peak of spawning for these fish occurs in January and February. Late run steelhead pass the dams in February through May and reach the peak of spawning activities in May. Normally, the bulk of the winter steelhead fry have emerged from the gravels by late June and early July. While winter steelhead utilize both small and large streams, it is important to note that a significant proportion of steelhead spawn in smaller tributaries. Full seeding for steelhead in the Fish Creek drainage is estimated to be 700 adults.

Summer steelhead have been stocked in the Clackamas River annually for the last 15 years. Because this race enters the river during the summer months, and actively bites in freshwater, it is a very popular sport fish. The management objective for this stock has been to plant smolts and harvest all the adults with the assumption that there is no natural production. It is uncertain to what extent this hatchery stock is spawning successfully in the Clackamas River drainage but there appears to be naturally produced adults returning to Fish Creek and competition with the native late winter steelhead is very possible.

Steelhead trout juveniles prefer fast water riffles which constitute the most abundant habitat type in Fish Creek. Young-of-the-year (0+) steelhead prefer the low velocity margins of riffles while older steelhead (l+) prefer to live and feed in deep swift habitats of boulder riffles and pools. Approximately 8,000 steelhead smolts were produced in Fish Creek in 1985.

Searun cutthroat rarely pass North Fork Dam. Most of these fish spawn in the lower reaches of the Clackamas River during January, February, and March. Fry emerge in late spring.

3) Resident Salmonids

Very few cutthroat trout are found in the Fish Creek drainage. Because of the difficulty in separating young steelhead from resident rainbow trout it is uncertain what proportion of the trout population in Fish Creek is resident.

Being typical of cold westside streams, growth rates in much of the Clackamas River are slow. With few exceptions, adult cutthroat and rainbow trout rarely attain lengths greater than ten inches.

Brook trout have been planted in numerous lakes and many streams fed by these lakes also contain brook trout. However, brook trout compose a minor portion of stream populations.

Mountain whitefish inhabit most of the larger streams of the area. Their numbers appear to be low and there is not a large sport fishery for them.

4) Description of Habitat

The four basic habitat types currently used in the Fish Creek Evaluation are: riffles, glides, pools, and side channels. Beaver ponds are a fifth specialized type of habitat. Riffle habitat made up about 87 percent and 80 percent of the total habitat surface area in Fish Creek in 1982 and 1985 respectively. Pools made up only 1204 and 18 percent. Side channels make up 9 percent, quiet alcoves about 1 percent and a beaver pond on an old channel about 0.3 percent. Quiet water habitats are scarce in Fish Creek.

These survey results reflect a high gradient stream system with a few deep pools which are fast-moving plunge or scour pools at high water. Side channels are restricted to a few areas in the basin.

The reaches of Fish Creek and tributaries accessible to anadromous salmonids are in large, steep gradient streams, consequently spawning gravels in the area are scattered. The substrate throughout the system is composed predominately of boulders and rubble with isolated patches of gravel suitable for spawning. Gravels suitable for reproduction are often found along the stream margin where physical features such as boulders and large organic debris have caused deposition. Spawning gravels also occur at the tail of some large pools and in a few side channels and braided sections of the main channel. There are few large expanses of spawning gravel and those that do occur are in the lower 2.5 km of stream. Most gravel occurs in 5 to 15 m^2 pockets scattered throughout the system. A total of about 2,100

m^2 of spawning gravel is available to anadromous salmonids (Everest et al 1984). A previous survey completed in 1976 by Chuck Whitt (Mt. Hood N.F.) quantified spawning gravel resources at 911 m^2 for anadromous fish. Gravel resources appear to have increased substantially since that time.

Fish Creek as presently described varies significantly from what it was historically. A survey in 1959, before the catastrophic flood of 1964, indicated that approximately 45 percent of Fish Creek consisted of pool habitat. A resurvey of the same area in 1965 estimated that only 25 percent was then pool habitat. The percentage of boulder habitat had increased from 45 to 70 percent in the upper 7.2 km of Fish Creek and from 25 to 60 percent in Wash Creek. This same series of surveys indicated that approximately a third of the spawning habitat in Fish Creek had been lost. The conclusions reached by the project leader heading the survey effort include 1) that the greatest change in fish habitat in Fish and Wash Creeks was the loss of rearing habitat, and 2) that this change was sufficient to "significantly limit the salmon-producing capabilities of these streams" (Sams, 1965).

V. Impacts to Fish Habitat

As is true of most drainages in Oregon, the Fish Creek drainage has been affected by development activities of man. These impacts have been short and long term, and from a variety of sources. Some of the most obvious include:

1. Construction of the Fish Creek road (#5400) encroached on the floodplain, narrowing the channel and limiting its ability to meander. Culverts used at stream crossings have created migration barriers at three tributaries, eliminating 2 to 3 miles of habitat.
2. Removal of wood for a variety of reasons, over a long period of time, resulted in substantial loss of structure and habitat complexity. The loss of structure has probably been instrumental in the downcutting of the channel and loss of side and off channel stream area.
3. Timber harvest in tributary areas has probably impacted water temperature and slope failure rates. Elevated summer water temperatures result from the loss of stream shading. Slope failures can be accelerated with the loss of root strength of harvested trees, poor road drainage, and sidecast road construction. Some of these slope failures have resulted in debris jams that have blocked passage in tributary streams.
4. Roadbuilding and timber harvest have resulted in a decrease in watershed stability, with increased frequency of large magnitude rain-on-snow events and delivery of water to streams. This has probably increased channel scouring and loss of channel structure.
5. **Increased levels of** motorized dispersed recreation is an increasing management concern along Fish Creek. Major conflicts with current use patterns include: harassment and

illegal harvest of spawning fish, removal of down wood, and harvest of smolt and presmolt anadromous fish.

VI. <u>Management Objectives</u>

The goal for anadromous fisheries management in the Fish Creek drainage is to provide and maintain optimal habitat conditions for the wild/natural production of spring chinook, coho, and winter steelhead. To achieve this goal the management objectives are:

1) Maintain/enhance the aquatic habitat capability of Fish Creek for the production of winter steelhead, coho, and spring chinook,

2) Manage the riparian resource to reduce the impacts of high water temperatures and provide long term supplies of LWD,

3) Manage the dispersed recreation along Fish Creek to maximize the quality of the campsites, minimize the harassment of adult fish, and inform the public of the nature of the work and the evaluation, and

4) Correct all migration barriers to anadromous fish in the lower 1104 km of Fish Creek and the lower 4.7 km of Wash Creek. The emphasis for passage improvement is on the return of formerly available habitat that has been blocked by road construction.

VII. <u>Management Approach</u>

These management objectives can be attained by implementation of the following measures:

1) Develop a habitat improvement strategy for the drainage that will allow the testing of different hypotheses for increasing the

productivity of the drainage/survival of anadromous juveniles to smoltification.

2) Request that ODFW suspend the release of hatchery rainbow legals for a period sufficient to assess the habitat improvement projects.

3) Cooperate with ODFW and local sportsman's groups to decrease the mortality of smolts moving through the early trout season on the Clackamas River.

4) Funding of the evaluation of habitat improvement techniques and the benefits attributable to these projects will be supported for a period of time sufficient to adequately assess these questions.

5) Implement a public information/education program to provide the public with the objectives of project work on a drainage wide level.

VIII. Opportunities for Rehabilitation/Enhancement

1. General Habitat Improvement Strategy.

Agressively develop and refine habitat enhancement techniques for steelhead trout, coho salmon, and where possible, chinook salmon with emphasis on evaluation of their technical, biological, and economic feasibility. The focus of enhancement efforts is on increasing fish habitat complexity for the long term.

2. Species Specific Habitat Strategy

For steelhead develop and implement a wide range of techniques aimed at providing preferred habitat over the full range of seasonal conditions in lower, mid, and upper Fish Creek and lower Wash Creek.

a. Glide/deep water riffle and pool habitat for l+ steelhead, especially for low flow, late summer periods.

b. Alcove/edge habitat for 0+ steelhead, especially for transition and winter periods.

For coho develop and implement techniques to increase the amount and quality of slow water, sidechannel, offchannel, and edge habitats and maximize tributary spawning opportunities. For spring chinook improve passage at the mouth of Fish Creek and maintain or improve holding habitat in the lower reach of Fish Creek.

IX. Work to Date

A five year fisheries habitat enhancement program was begun in 1983. The program is a cooperative effort between the USDA Forest Service and BPA to increase natural production of anadromous fish, and to evaluate changes in habitat and smolt production within the drainage as a result of habitat improvement projects. Five objectives have been identified for the program. They are: 1) improve spawning habitat for spring chinook and steelhead trout, 2) increase rearing habitat for coho salmon, 3) improve overwintering habitat for coho salmon and steelhead trout, 4) rehabilitate riparian vegetation to improve stream shading to benefit all species, and 5) evaluate improvement projects on a drainage wide basis.

Several prototype enhancement projects were constructed during the first three years of the study with the intent of identifying the most successful techniques that could then be broadly applied within the basin. This stepwise procedure has been largely successful in identifying the most promising enhancement techniques for the Fish Creek drainage. These projects include:

a) Offchannel rearing ponds - one built in 1983 and another added in 1985, to provide rearing area for coho salmon, have a combined area of 1 hectare (when the 1985 pond is finished). The 1983 offchannel pond increased coho smolt production in Fish Creek by an estimated 18.8 percent although it represents only 2.5 percent of the habitat available in Fish Creek (Everest, et al 1986). These ponds will be seeded with fry propagated from the native late run coho trapped in a cooperative effort between the Forest, ODFW, and PGE.

b) Boulder berms - a total of 25 berms built in 1981 and 1983 to collect spawning gravels and provide rearing area. Gravel collection has been limited to about a third of the structures and future berms would be constructed with large, angular quarried rock to increase durability and reduce on-site habitat disturbance.

c) Perennial side channel - built in 1984 to provide 1,200 m2 of offchannel spawning and rearing habitat with emphasis on improved overwinter habitat for juvenile salmonids. Preliminary observations indicate that the side channel is providing spawning habitat for spring chinook and coho and spring/summer habitat for coho and steelhead.

d) Four acres of riparian habitat were planted with fast growing cottonwood trees to promote stream shading.

The preliminary results of the Fish Creek evaluation continue to refine our understanding of factors limiting fish production by species. Past work has concentrated on the most obvious limiting factors and future proposed project work will focus on limiting factors as identified in the evaluation. Rearing habitat for coho salmon, and overwintering habitat for coho and steelhead trout appear to be limiting fish production in Fish Creek. Results of the first winter sampling indicate that spring chinook juvenile rear to some extent in Fish Creek. Habitat for these fish to overwinter may be limited also. A midwinter survey identified numerous sites with excellent potential to provide additional rearing/overwintering habitat. Spawning habitat should be developed in association with rearing habitat to insure adequate seeding with juvenile salmon. To further improve the accuracy of assigning numbers of smolts produced to the Fish Creek basin, operation of the smolt trap near the mouth of Fish Creek will continue for at least 2 additional years. The termination date for the evaluation will be determined in consultation with BPA.

The intensive evaluation of instream habitat improvement projects on a drainage wide basis provides a unique opportunity to test enhancement hypotheses. It is with this in mind that the Forest has taken an agressive approach to fisheries habitat improvement for the Fish Creek drainage.

X. Future Project Priorities

The full treatment of fish habitat in the Fish Creek drainage is scheduled to be implemented over the next two field seasons (FY 86 and 87). The winter surveys of 1984 and 1985 identified 13 general areas according to access that have good potential for habitat improvement. In 1986 the priority for action includes the following:

A) Passage improvement at the mouth of Fish Creek and the accessible tributaries. Passage at the mouth will be aimed at providing low flow access to spring chinook and passage at the tributaries will focus on steelhead.

B) Treatment of two intensive sites, selected to represent the 2 lower reaches of Fish Creek. Implementation at these sites will emphasize 1) a variety of techniques to improve low flow rearing habitat, primarily for 1+ steelhead, 2) providing habitat during all flow events, and 3) designing the type of improvement that will take full advantage of the specific site characteristics.

C) Improve the rearing pond built in 1985 to stabilize the flow into and through the beaver pond area. This will require the completion of the berm just below the inlet structure to raise the water level, maintenance of the lower pond dike, and completion of the fish collection facility at the outlet.

D) Implement the first phase of a public education plan, focusing on an informational sign at the mouth, signs at project work sites, and signs at the major wood accumulations to educate the public on the need for structure to maintain habitat complexity.

Priorities for 1987 include:

A) Passage improvement on Pick and Third Creeks. Both of these projects have had significant planning completed already and implementation is contingent upon securing funding for them.

B) Treatment of three intensive sites, intended to complete the majority of work within all three reaches of Fish Creek. Project sites for 1987 are shown on figure 5. Implementation at these sites will emphasize 1) the use of large logs and boulders in a variety of configurations, 2) providing habitat during all flow events, and 3) designing the type of improvement that will take full advantage of the specific site characteristics.

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