TRINITY RIVER FLOW EVALUATION

ANNUAL REPORT - 1989

FISH AND WILDLIFE SERVICE

U.S. DEPARTMENT OF THE INTERIOR

ANNUAL REPORT

TRINITY RIVER FLOW EVALUATION

1989

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PREFACE

The following report is the fifth in a series of annual reports prepared as part of the Trinity River Flow Evaluation Program, a 12-Year effort which begin in October, 1984. The U.S. Fish and Wildlife Service has been directed to conduct the evaluation as part of the January 1981 decision by the Secretary of the Interior to increase Trinity River releases at Lewiston Dam from the 120,000 acre-foot per year level which had been in effect since the Trinity River Division of the California Central Valley project was completed in 1960.

Through this undertaking, we hope to gain a better understanding of the dynamic forces which influence and control the destiny of the Trinity River salmon and steelhead. At the completion of the evaluation period, the Service will provide a report to the Secretary. The report will summarize the knowledge gained through the evaluation period and recommend an appropriate course of action for future management of Trinity River flows. Through this effort the Secretary can then fulfill his responsibilities for the preservation and propagation of the Trinity River's indigenous fishery resources.

To those who are interested, comments and information regarding this program and the habitat resources of the Trinity are welcomed. Written comments or information can be submitted to:

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SUMMARY

The Trinity River Flow Evaluation, a study designed to monitor fishery habitat in the Trinity River and report to the Secretary of the Interior in 1996 on the effectiveness of the Secretary's 1981 decision to increase releases from Trinity and Lewiston dams, has completed its fifth year. Various activities undertaken in 1989 are as follows:

Mainstem Habitat Availability

Hydraulic habitat measurements were taken in the mainstem at sites from Lewiston to Del Loma during a May Lewiston Dam release of 2000 cubic feet per second. Results for the river above Douglas City were collated, and showed an approximate doubling of chinook fry habitat over that measured at lower flows, and a lesser increase in steelhead fry habitat. Increases in fry habitat were caused by the inundation of areas above the channelized steady-flow banks. Available habitat for chinook and steelhead juveniles decreased at high flow, because increases in edge habitat did not compensate for losses of medium-velocity midstream habitat.

Studies at 2000 cfs indicate that restoring Trinity River salmonid populations may require more water than is currently allocated for fisheries. Since debate on habitat estimation methods is expected, interested parties are encouraged to focus discussion by completing independent studies.

Mainstem Habitat Mapping

Transect habitat data was extrapolated to river segments on the basis of mapped habitat types, and compared to representative reach extrapolations. Comparisons showed small differences in the total amount of estimated habitat, and insignificant differences in the shape of flow/habitat curves. Results indicate that minor variations in transect or site selection will not significantly affect habitat estimates in the upper Trinity River

Habitat Availability in Constructed Side-channels

Physical Habitat Simulation (PHABSIM) modeling studies were conducted on four side-channels constructed in 1988. Three side-channels near Cemetery Hole, Rush Creek, and Bucktail Hole were built by the Trinity River Restoration Program. The fourth side-channel was built by the Bureau of Land Management near Steiner Flat.

Construction of these four side-channels created an additional 10,461 and 37,514 square feet of Weighted Usable Area (WUA) for fry and juvenile chinook salmon respectively. Fry steelhead trout rearing habitat increased by 27,988 square feet of WUA and juvenile steelhead trout rearing habitat increased by 43,127 square feet of WUA. During Trinity River flows of 300 cfs, the Bucktail side-channel provides the greatest amount of fry chinook salmon habitat at 2,827 square feet of WUA per thousand linear feet of side-channel. The Steiner Flat side-channel provides the greatest amount of juvenile chinook salmon habitat at 9,757 square feet of WUA per thousand linear feet of side-channel.

The greatest amount of fry and juvenile chinook salmon WUA was provided by natural runs that contain slow water velocities, gently sloping banks, and abundant cover. As flows increased in these habitat types the amount of WUA increased as banks were inundated. In channelized habitat types fry and juvenile chinook salmon WUA decreased with increased flow. Fry and juvenile chinook salmon habitat in the channelized sections could be improved by constructing meanders with gently sloping banks along inside bends. In high velocity areas where meandering alone will not adequately reduce water velocities, construction of cobble and boulder clusters, wing deflectors, or hydraulic controls will increase rearing habitat by creating velocity shelters near shear velocity zones.

Over-wintering habitat for juvenile steelhead trout is in limited supply when compared to the available rearing habitat for both fry and juvenile lifestages. Placement of cobbles and small boulders within each side-channel will increase the amount and quality and over-wintering habitat for juvenile steelhead trout. Cobble placement will also benefit rearing salmonids by increasing cover and food production areas.

Adjacent-velocity Habitat Criteria

During the summer of 1989 we began collecting habitat suitability criteria for juvenile steelhead trout for use in the HABTAV program of the Instream Flow Incremental Methodology. HABTAV provides IFIM with the ability to consider feeding lane water velocities as well as focal point water velocities when computing the habitat joint preference factor that is used to predict Weighted Usable Area for a given species. Thus far we have collected 145 microhabitat observations on feeding juvenile steelhead trout. Preliminary findings indicate that juvenile steelhead trout select focal points near the bottom in water velocities of 0.8 to 1.0 feet per second. Juvenile steelhead trout travelled an average of 2.2 feet to capture prey in water moving approximately 2.1 feet per second.

Water Temperature Monitoring

Water temperatures were monitored on the main-stem Trinity River over the course of the year. Results suggest upper river temperatures to be controlled mainly by discharge from Lewiston Dam, while middle and lower river temperatures are driven by meteorological events. Data was compiled for calibration of the Stream Network Temperature Model.

Chinook Salmon Spawning Distribution

Direct observation of spawning was continued for the 1988-1989 season. Spawning activity was high in the upper river between Junction City and Lewiston. Middle river habitats on the Big Bar to Cedar Flat reach were again heavily used, concurring with 1988 results.

Juvenile Populations

Snorkel observations of rearing chinook at five sites showed populations comparable to the past three years. There was no evidence that the high May flows flushed natural chinook from the upper river.

Habitat Requirements for Juvenile Chinook

In the Spring of 1989 we delineated habitat cells along five transects in our Cemetery study site and made snorkel observations along each transect in order to determine if juvenile chinook salmon were using these cells in proportion to the suitability given them by the IFIM HABTAT program. We found that juvenile chinook salmon densities correlated with cell joint preference factors provided by HABTAT. Based on a regression analysis of observed juvenile chinook salmon densities and cell joint preference factors, habitat cells with a joint preference factor of 1.0 should contain 0.48 juvenile chinook salmon per square foot.

Juvenile Salmonid Growth

Growth of juvenile chinook and coho salmon, and steelhead trout were evaluated for all fish captured since the study began. Mean forklength data was examined by analysis of variance for chinook and coho salmon. Year classes were examined for variation, as well as sites within one year class. All three species showed no significant difference in mean forklength or instantaneous growth over the study period.

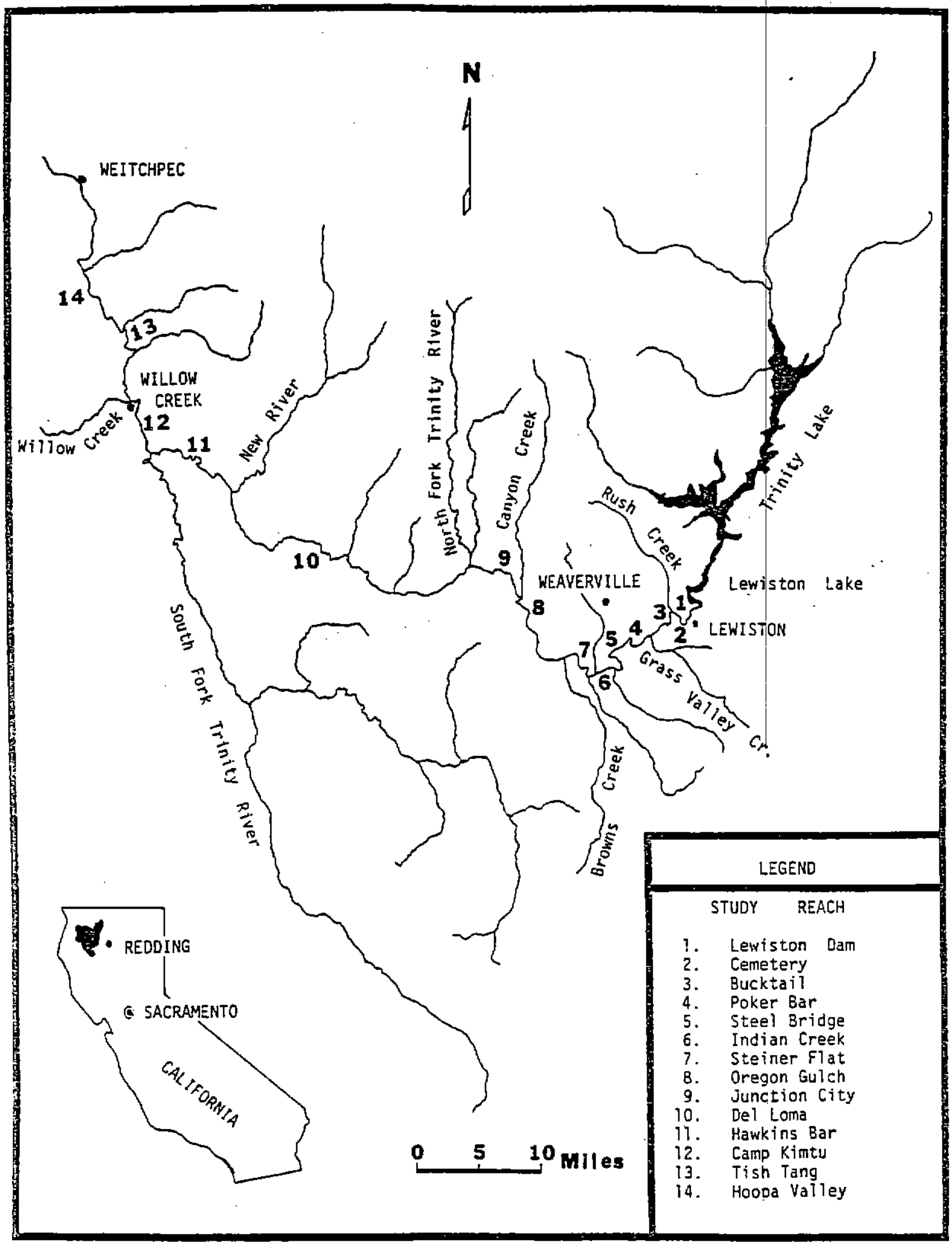

Figure 1. Trinity River Basin with Study Site Locations.

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INTRODUCTION

The Trinity River watershed drains approximately 2,965 square miles in Trinity and Humboldt Counties of northwestern California (Figure 1).

The Trinity River Division of California's Central Valley Project, operated by the U.S. Bureau of Reclamation, is the only major water development project in the basin and serves to export water from the Trinity River to the Central Valley of California. The keystones to this project are Lewiston Dam, at river mile 110, and Trinity Dam just upstream. The former represents the upstream limits of anadromous salmonid migration in the basin. As mitigation for upstream losses the Trinity River hatchery was constructed at the base of Lewiston Dam. In addition, minimum downstream flows were to be provided to maintain fish resources. These efforts, however, were not sufficient to sustain fish populations. Both salmon and steelhead trout populations continued to decline, in some stocks as much as 90 percent of former levels.

In December of 1980 the Fish and Wildlife Service and the Bureau of Reclamation reached an agreement to increase releases to the Trinity River below Lewiston Dam to aid in the rehabilitation of the anadromous fishery resources. The agreement was approved by the Secretary of Interior in January 1981. The basic points of the agreement are: 1) the Bureau of Reclamation will maintain releases at Lewiston Dam at 340,000 acre-feet annually in normal years; 2) the Fish and Wildlife Service will conduct a 12-year study to evaluate the effectiveness of the increased flows; 3) the Bureau of Reclamation will maintain an interim release of 287,000 acre-feet annually in normal years until such time as the Service prepares a detailed plan of study; 4) releases will be incrementally increased to 340,000 acre- feet as habitat and watershed restoration measures are implemented; 5) in dry-years, releases will be 220,000 acre-feet and in critically dry years 140,000 acre-feet; 6) dry and critically dry years will be based on forecasted Shasta Reservoir inflow; and, 7) at the end of the 12-year study the Service is to report to the Secretary, describing the effectiveness of the improved flows and any other habitat rehabilitation measures (e.g. those contained in the Trinity River Basin Fish and Wildlife Management Program) in restoring fish populations and habitat below Lewiston Dam.

As directed by the Secretary the Fish and Wildlife Service completed a Plan of Study for the Trinity River Flow Evaluation in December 1983. Subsequently, Department of Interior funding was provided through the Bureau of Reclamation and field work initiating the 12-year evaluation program began in January 1985 (Fiscal Year 1985).

The study focuses on the mainstem Trinity River from Lewiston Dam to its confluence with the Klamath River at Weitchpec. Its goal is to monitor the rehabilitation of fishery habitat in the

Trinity River below Lewiston Dam. The intent of the study is that: 1) it be conducted by utilizing current scientific methodologies; 2) it be flexible to meet changing fishery resource conditions; 3) it be closely coordinated with other studies and resource management agencies; and 4) it be reported on, by providing timely data analysis at regular intervals and at the conclusion of the study. Under the current schedule, field studies will be completed in 1995, with a final report to the Secretary by September 30, 1996.

The general study plan consists of 6 major tasks. These tasks and their objectives are:

Task 1. Annual Study Plan Review and Modification.

Objective: To assure that the study plan reflects current findings and data.

Task 2. Habitat Preference Criteria Development.

Objective: To develop habitat preference criteria quantifying depths, velocities, substrates, and cover requirements for chinook and coho salmon and steelhead trout spawning, incubation, rearing, holding, and migration. Other factors, such as water quality and temperature will be considered under Task 3.

Task 3. Determination of Habitat Availability and Needs.

Objective A: To determine the amount of salmon and steelhead trout habitat available in the Trinity River downstream of Lewiston Dam under various flow conditions and levels of habitat rehabilitation or through other resource management actions (e.g. the Trinity River Basin Fish and Wildlife Management Program);

Objective B: To determine the amount of habitat required for each freshwater lifestage of salmon and steelhead trout, to sustain those portions of the fish populations in the Trinity Basin that were historically dependent on the Trinity River downstream of Lewiston Dam.

Task 4. Determination of Fish Population Characteristics and Life History Relationships.

Objective A: To determine the relative levels of successful use by fish populations of available habitat in the Trinity River downstream of Lewiston Dam, including spawning success and the subsequent survival and growth of juveniles.

Objective B: To determine which habitat factors may be limiting the restoration of fish populations.

Task 5. Study Coordination.

Objective: To develop and maintain coordination with other study and resource management agencies in the Trinity River Basin to maximize effective use of available information (and to avoid duplication of effort).

Task 6. Reports (Progress, Findings, and Recommendations).

Objective A: To report on the analysis of information developed from field investigations (Tasks 2, 3, and 4) and on relevant information from other studies which have a bearing on the levels of fishery resource rehabilitation achieved in the Trinity River between Lewiston and Weitchpec.

Objective B: To develop recommendations to the Secretary and to other resource management agencies concerning future management options and needs.

Trinity River Flow Evaluation Program activities, methods, and results, primarily between September 1987 and October 1988, are described in the following sections.

The final section on program planning, direction, and coordination describes the focus of study efforts planned for 1990, and beyond. Of serious concern has been the drought conditions experienced over the past six years. Certainly, such a series of events were not anticipated at the outset of the 12-year Flow Evaluation effort. The extent that these conditions have influenced efforts to evaluate the effectiveness of the 1981 Secretarial Decision or habitat restoration activities must be evaluated and will be an important consideration in developing future study objectives. Continued drought conditions, with the accompanying reduction in available water supplies to the Trinity River, may seriously hamper efforts to complete the Trinity River Flow Evaluation, within the time-frame established in the plan of study. This possibility will also need to be considered in developing future study plans.

II. HABITAT AVAILABILITY AND NEEDS

1989 MAIN-STEM HABITAT MEASUREMENTS

In 1985 and 1986 we carried out main-stem salmonid habitat studies based on Instream Flow Incremental Methodology estimates of hydraulic conditions at Lewiston Dam releases from 350 to 800 cfs. Preliminary analysis, presented in our 1988 annual report, showed that salmonid rearing Weighted Usable Area (WUA, an index of available habitat) generally decreases with increases in flow. We simulated conditions at flows only slightly above the highest flow we measured, because it was apparent that at somewhat higher flows the existing river banks would be overtopped in many places, causing radically different stage/discharge relationships and habitat patterns. Any habitat estimate based on extrapolation of our data to higher flows would probably be wrong. So in 1989 we studied a Lewiston Dam release of 2000 cfs to obtain an accurate estimate of high-flow habitat.

METHODS:

To date, we have based habitat estimates on IFG-4, a PHABSIM computer program that allows simulation of unmeasured flows. This technique is necessary in short-term studies where a range of flows over several orders of magnitude must be quickly evaluated.

During 1989 we limited measurement at some transects to portions of the channel that provide fish habitat, not gauging high-velocity thalweg areas. We were able to measure conditions at sites from Lewiston to Del Loma in the limited time that high flows were available.

The measured flows presented below are Lewiston releases of 350 and 450 cfs in the summer of 1985, a release of 800 cfs in the summer of 1986, and a release of 2000 cfs in May, 1989.

To define habitat suitability, we used final preference criteria developed in our preference studies (Hampton 1988, appendix E). Earlier annual reports used initial use criteria then under development.

To determine the total habitat availability between Lewiston and Douglas City, WUA estimated at each transect was multiplied by the distance of the river most closely represented by the transect, as described in Section II.2.

RESULTS:

Figures 1 through 4 show WUA estimates based on our four measured flows between Lewiston and Douglas City.

The most striking pattern is for chinook fry (Figure 1). These fish prefer water velocities at or close to zero, and the higher flow increased the habitat available to them by providing extensive areas of slow water in side-channels and backwaters through most of the river.

Chinook juveniles are tolerant of a wider range of velocities, and this is reflected in Figure 2. The habitat opened up by overtopping channelized banks was balanced by a reduction in the large areas of sub-optimal but usable velocities provided by lower flows.

Steelhead fry WUA increased substantially from 350 to 2000 cfs, after an initial drop, following the pattern for chinook fry (Figure 3). Steelhead juvenile WUA decreased with increasing flows because the slow edge areas provided by high discharge did not compensate for lost mid-stream habitat (Figure 4).

Coho fry and juvenile WUA, not pictured, follow the chinook fry pattern, with greater relative increases in available habitat at the highest flows. This is because both life-stages of coho are dependent on slow water.

DISCUSSION:

These results are derived from a fairly simple process:

1) Watch fish and measure the velocities and depths they use.

2) Measure velocities and depths at various flows in the river.

3) Compare the conditions required by fish and the conditions present in the river at various flows, to determine relative levels of suitable fish habitat.

The results indicate that survival within certain critical life-stages would be enhanced by seasonal high flows in the Trinity River. The difference in habitat availability is pronounced for fry chinook, where there is an approximate doubling of suitable area between 350 and 2,000 cfs.

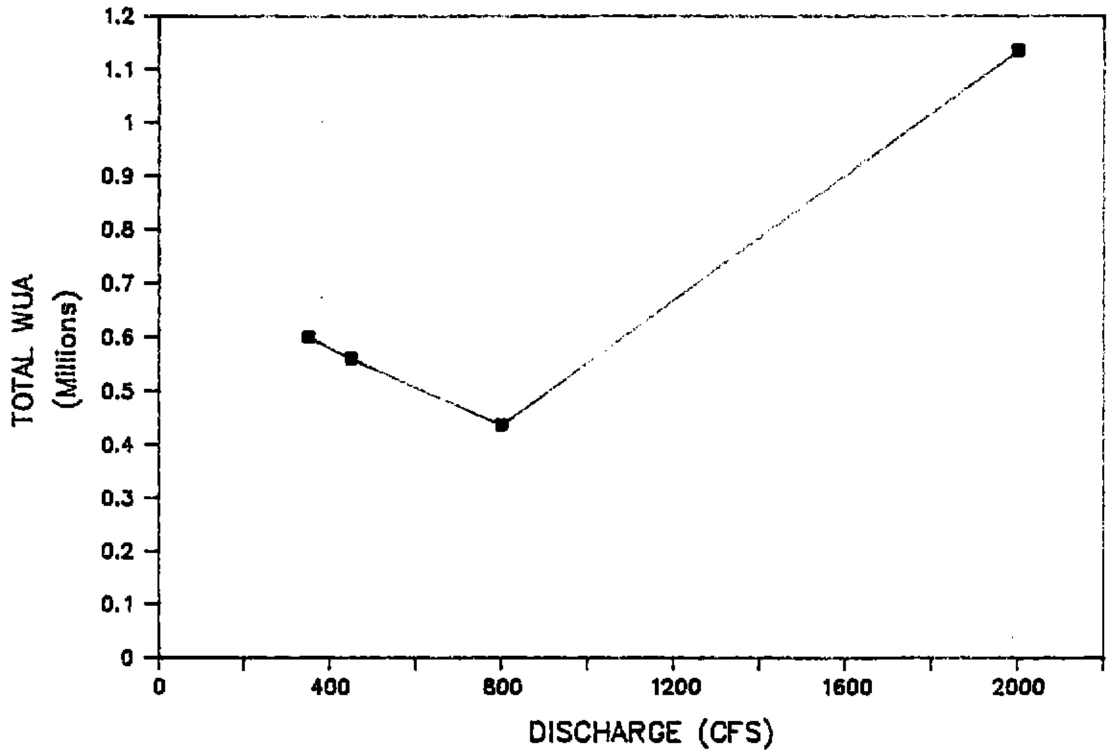


Figure 1. Chinook fry WUA, Lewiston to Douglas City.

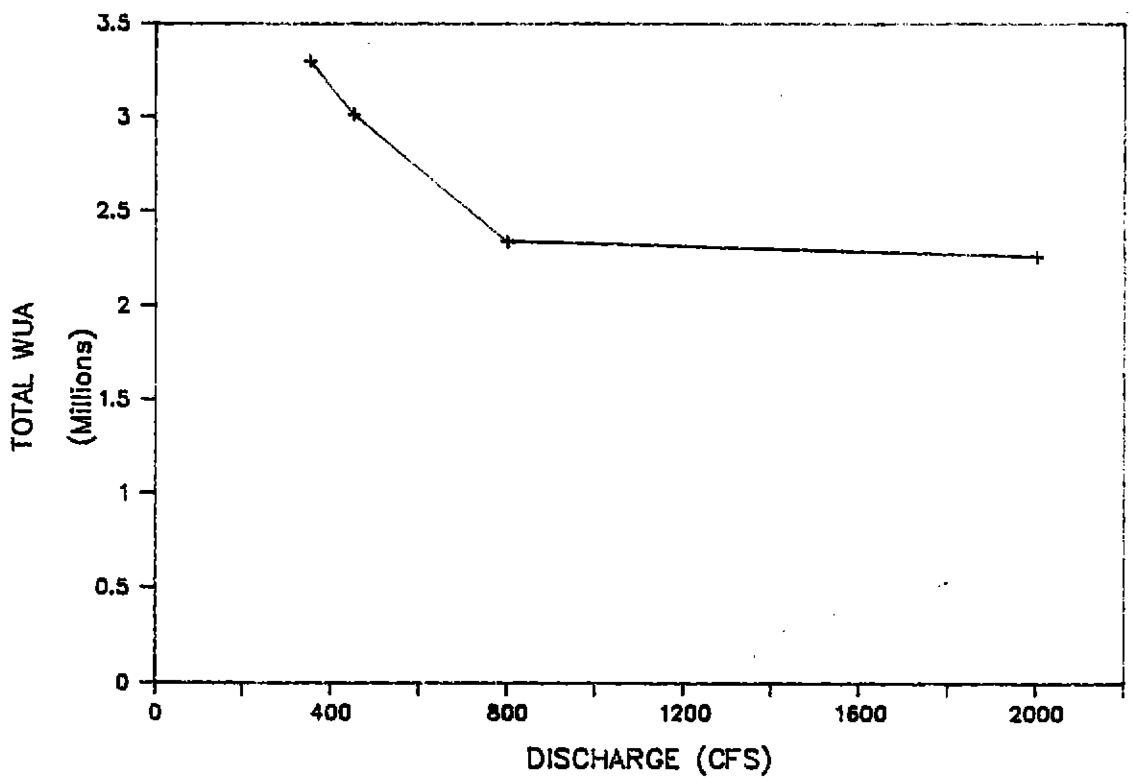


Figure 2. Chinook juvenile WUA, Lewiston to Douglas City.

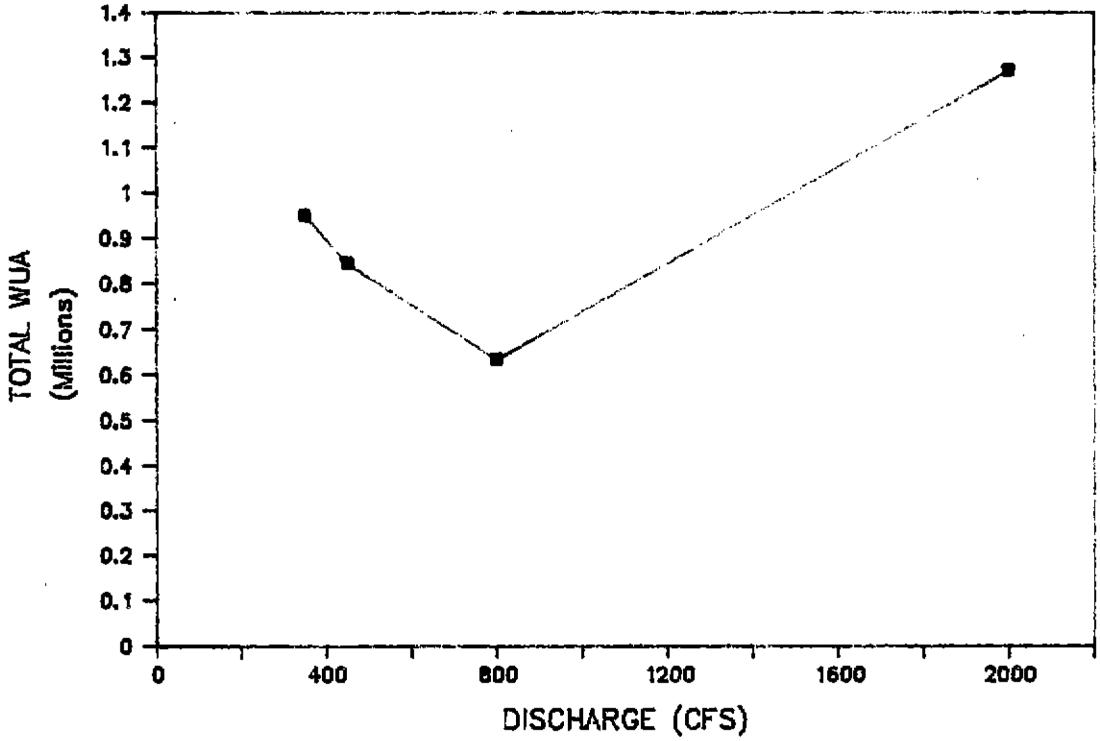


Figure 3. Steelhead fry WUA, Lewiston to Douglas City.

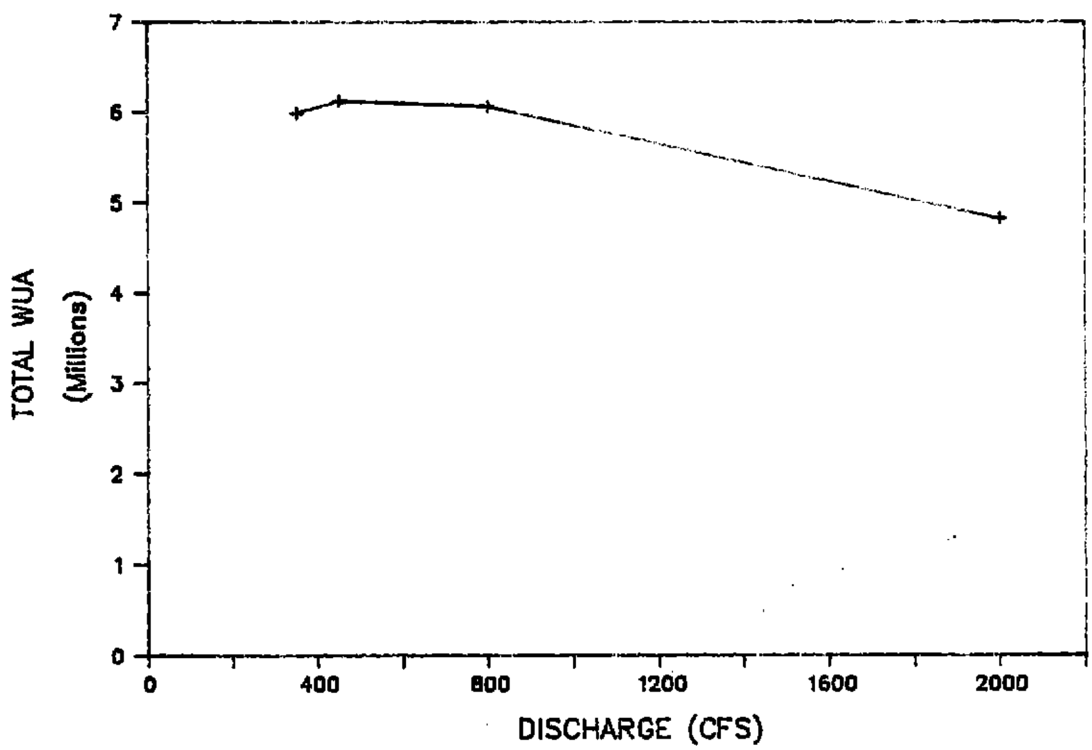


Figure 4. Steelhead juvenile WUA, Lewiston to Douglas City.

Findings:

1. Our mainstem habitat studies to date suggest that water volumes substantially over what is currently allotted may be necessary to meet habitat needs for the Trinity River fishery.

2. A drawback of IFIM studies has been that in each specific case there has only been one of them. Study results have not been confirmed independently, which opens the results to question. With only one study to look at, and no other relevant data, the tendency can be to discuss a study's deficiencies in comparison to a host of alternative studies that could theoretically have produced different results if they had been made.

This could be avoided if interested parties would undertake studies of their own. Independent study results would make it possible to avoid arguments about such elements of habitat estimation as number and location of study sites, computer modeling techniques, transect selection and weighting, computer calibration and flow simulation, and many others. Such studies would be relatively inexpensive, especially if the goal were to provide a check on methods.

The promise of this approach is that future debate on the relationship between instream flows and fishery resources need not be speculative discussions of procedural variations having negligible effect on study results; discussions could be based on reality rather than conjecture.

We encourage parties with a potential interest in validating or invalidating our main-stem habitat estimates undertake independent studies as a means of focusing discussion.

HABITAT MAPPING

We chose our IFIM sites in 1985 based on the representative reach concept. This assumes that it is possible to choose sites within a river reach that represent conditions within a larger segment, because channel characteristics repeat themselves at regular intervals, five to seven times the width of the channel. If a study site ten to fourteen times the channel width is chosen at random it has been assumed to have a good chance of representing segment conditions (USFWS 1982). Practices recommended to improve the representative reach method include various techniques for regularizing or randomizing site selection, thus reducing subjective judgements. Another recently developed approach is to study WUA in representative habitat types such as run, riffle, and pool, and multiply results by the amounts of the various habitat types in a segment. In 1989 we recalculated estimated WUA from Lewiston to Dutch Creek, the lower end of our Steiner Flat site, based on a variation of this second approach.

To reduce disadvantages of static habitat types such as run, riffle, and pool, we mapped the river segments between Lewiston and Dutch Creek according to the characteristics of each transect of the study sites representing the segments. For example, rather than categorizing a length of river in the Steelbridge section as a "run", we would designate it as similar to Steelbridge site Transect 8, based on depth, velocity, bank morphology, and the presence or absence of higher-flow side-channels or potential over-bank slow-water areas. Depending on its similarity to the transect, such a portion of the river should present the flow-dependent habitat characteristics measured there.

RESULTS

Effects of Mapping on WUA Estimates: Results of mapping compared with the extrapolation of representative reach values is shown in Figures 1 through 2, representing the differences in chinook salmon fry in the river from Lewiston to Douglas City, and between Douglas City and Dutch Creek.

The insignificant change in pattern between the estimated WUA based on mapping and the estimate based on representative reaches shows either that our initial study sites are indeed representative, or that flow-related habitat conditions in the Trinity River are consistent enough that variations in the professional judgement that must go into transect selection will not seriously affect an evaluation of overall hydrologic conditions.

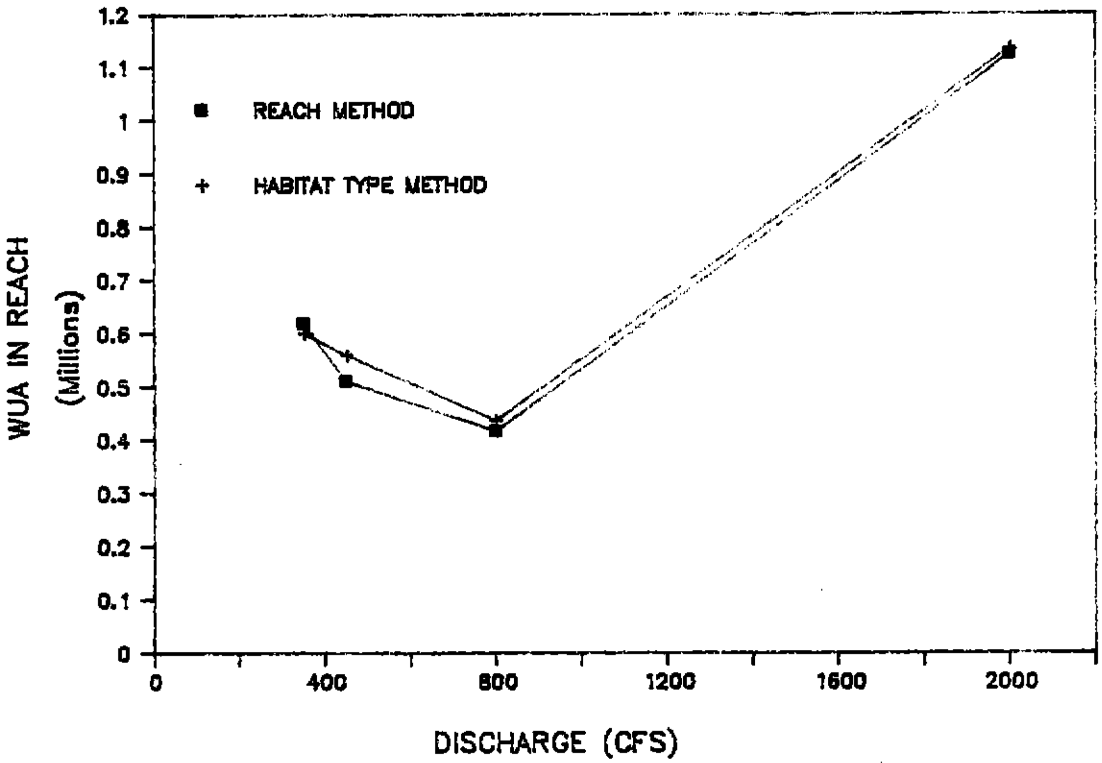


Figure 1. Chinook fry WUA between Lewiston and Douglas City based on reoresentative reach and habitat typing methods.

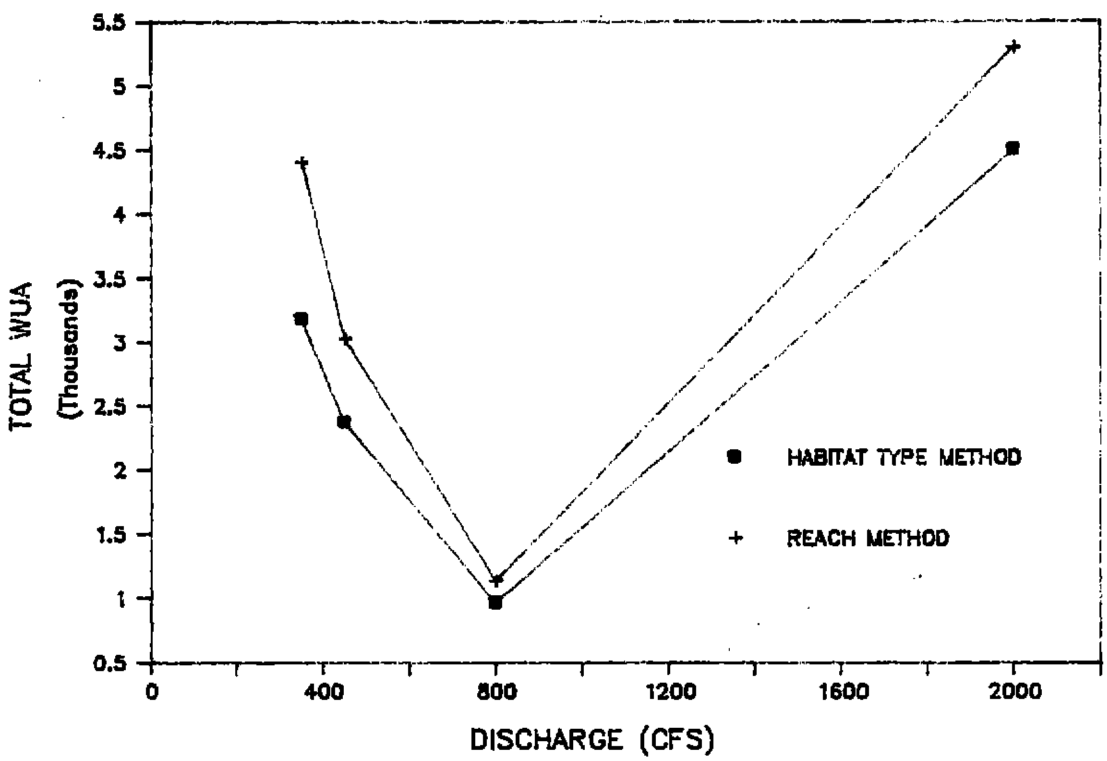


Figure 2. Chinook fry WUA between Douglas City and Dutch Creek based on representative reach and habitat typing methods.

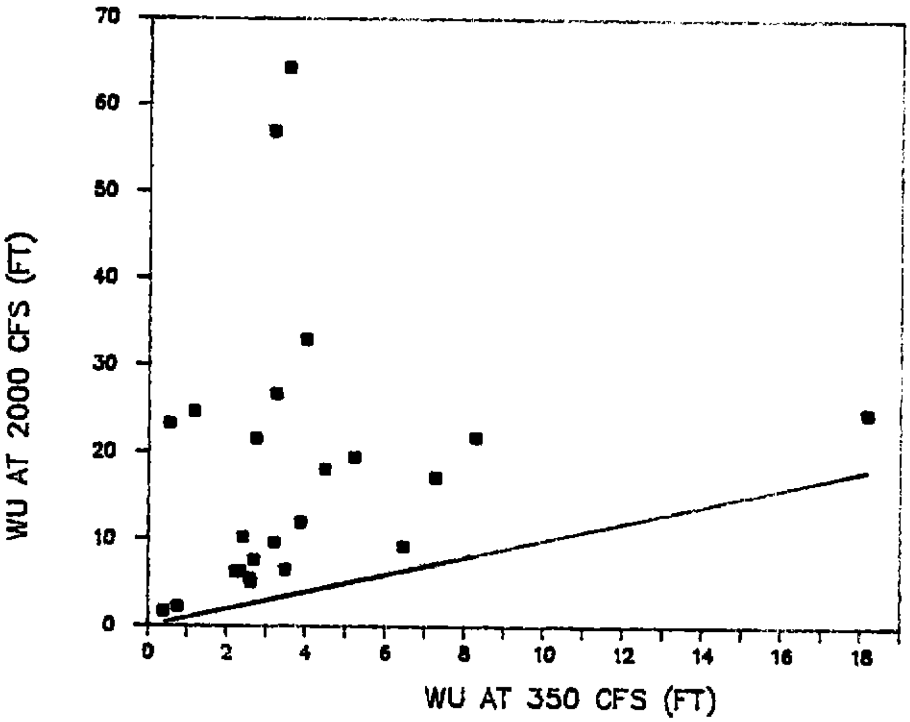


Figure 3. Chinook fry WUA at 350 and 2000 cfs on run transects between Lewiston and Dutch Creek.

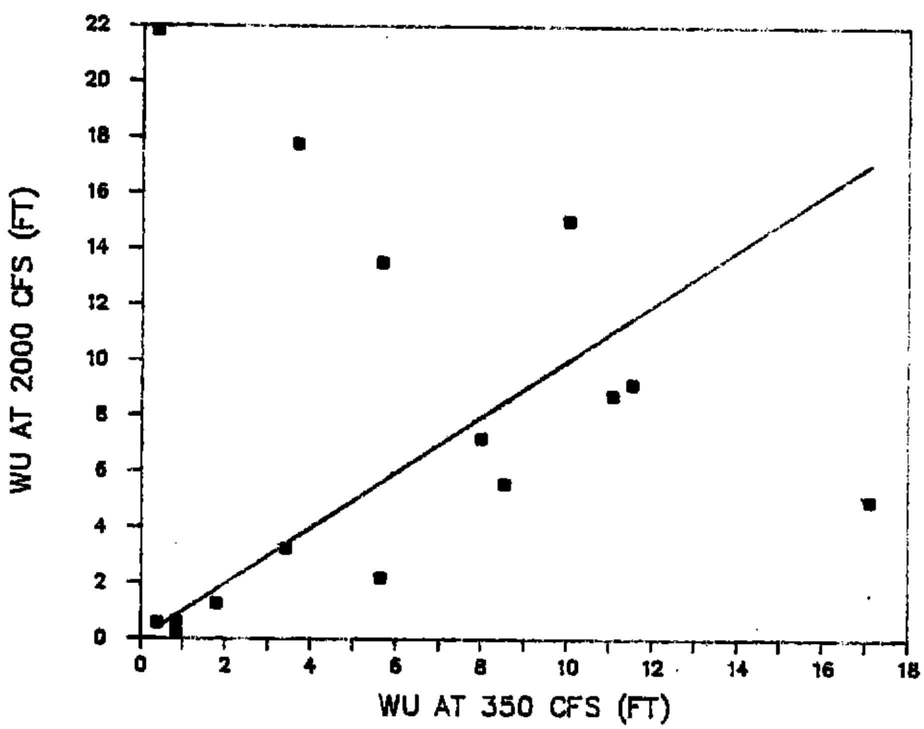


Figure 4. Chinook fry WUA at 350 and 2000 cfs on riffle transects between Lewiston and Dutch Creek.

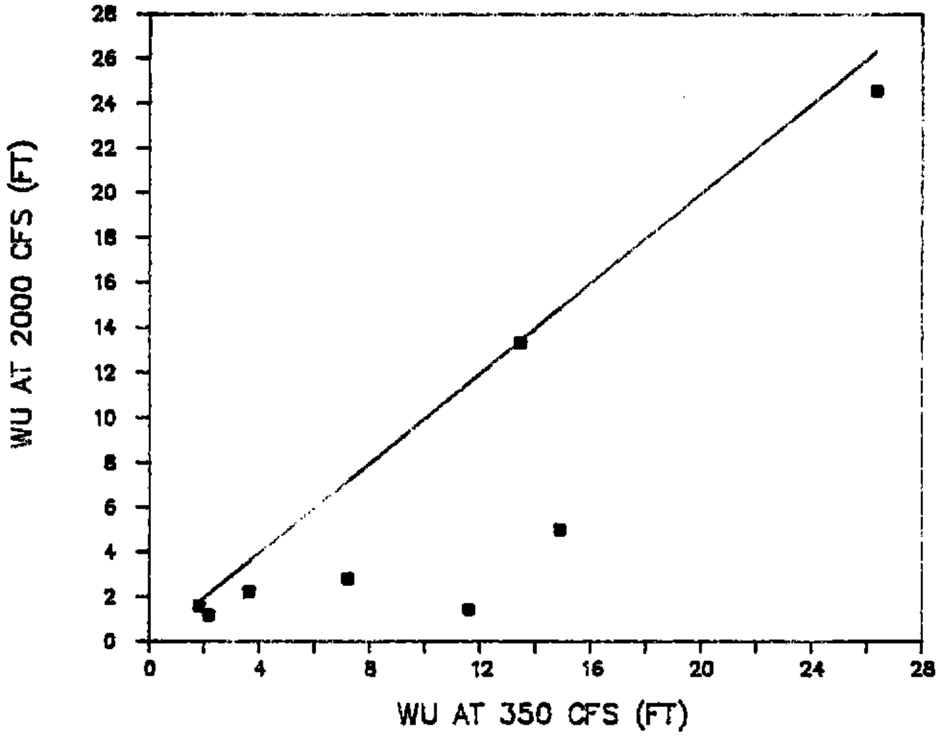


Figure 5. Chinook fry WUA at 350 and 2000 cfs on pool transects between Lewiston and Dutch Creek.

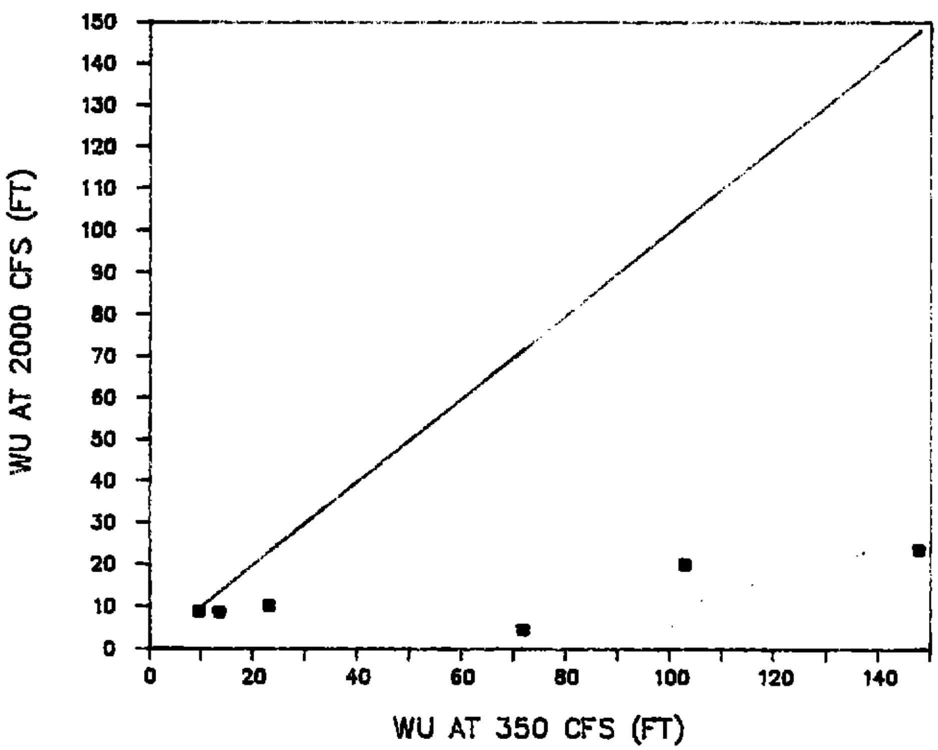


Figure 6. Chinook fry WUA at 350 and 2000 cfs on atypical transects between Lewiston and Dutch Creek.

Characteristcs of Transects Within Habitat Types: For Chinook fry, both methods of determining absolute habitat show a drop in WUA from 350 to around 800 cfs, and an increase between 800 and 2000 cfs. This is the result of development of large areas of low-velocity water where the river overtops the steep banks that are found in run sections or where backwaters form at the tops of riffles.

Figures 3 through 5 show the relationship between chinook fry WUA at 250 and 2000 cfs for individual transects between Lewiston and Dutch Creek that fit the classification of run, riffle, and pool. Figure 6 shows the relationship for atypical transects that are either split by islands with different habitat types in each channel, or are located above Cemetery hole in Lewiston in an area that can be described as marsh or flooded riparian. Each graph includes a line where the ratio is zero, separating transects which show increasing WUA with increasing flow from those showing decreasing WUA.

The run transects all show increasing fry WUA at the highest flow because generally these high discharges overtop the river's channelized banks and create areas of slow water on the pre-project channel. These slow-water areas are wider than the narrow strips that develop at lower flows on the steep, vegetated edges of the low-flow channnel. Typical run transect profiles at Bucktail and Steelbridge are shown in Figures 7 and 8. At Bucktail transect 2 the run evident at 350 and 800 cfs becomes deeper and faster at 2000 cfs, and a slow side-channel develops on the left, providing overall increased rearing habitat at the highest flow. The habitat type that provides the best rearing habitat at high flow does not exist at 350 cfs. At Steelbridge transect 9 two small side-channels develop on the right, and a larger side-channel appears on the left. The feathered bank on the left, one of the few left on the upper river, provides slow-water rearing areas as flow increases.

There is no consistent pattern in riffle transects, because in some cases WUA is reduced as higher water moves uniformly over the steep slopes, and in other cases the riffles form the tops of old side-channels, and extensive back-waters develop at their edges. Figures 9 and 10 show representative riffle transects at Bucktail and Steiner Flat with 350, 800, and 2000 cfs water surface elevations. At Bucktail Transect 9 rearing habitat decreases at higher flows, although an extensive shoal develops on the left. At Steiner Flat Transect 8, a side-channel develops on the left at 2000 cfs, providing extensive rearing habitat that does not exist at 350 or 800 cfs. If either transect were habitat-typed at 350 or 800 cfs, they would clearly be typed as riffles. At 2000 cfs they could be called runs, although the habitat type of biological significance at Steiner Flat Transect 8 is the side-channel.

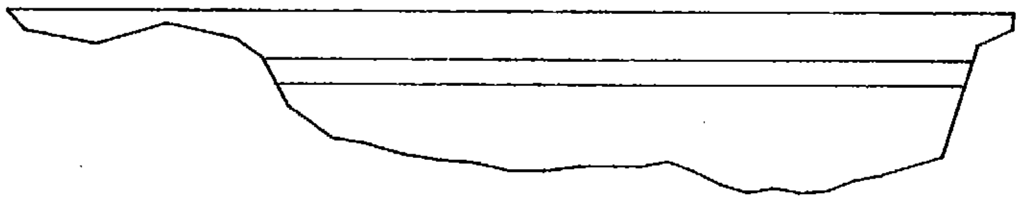


Figure 7. Bucktail transect 2 with 2000, 800, and 350 cfs water surface elevations. Vertical scale multiplied by three.

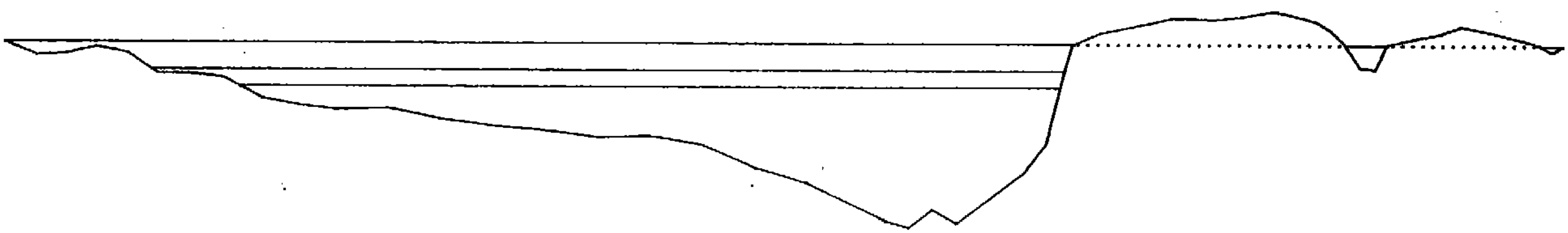


Figure 8. Steelbridge transect 9 with 2000, 800, and 350 cfs water surface elevations. Vertical scale multiplied by three.

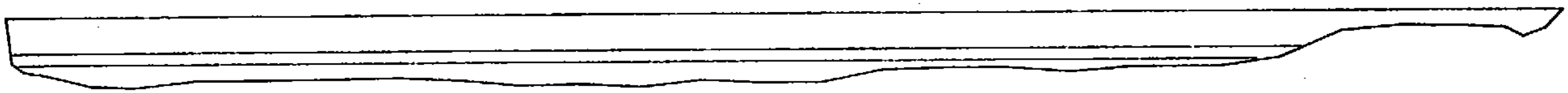


Figure 9. Steiner Flat transect 8 profile with 2000, 800, and 350 cfs warer surface elevations. Vertical scale multiplied by three.

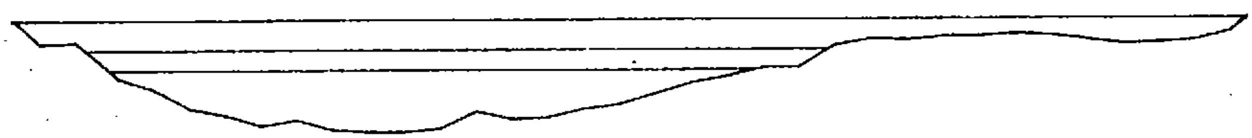


Figure 10. Bucktail transect 9 profile with 2000, 800, and 350 cfs water surface elevations. Vertical scale multiplied by three.

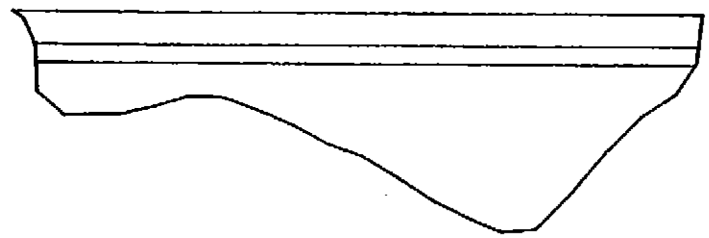


Figure 11. Bucktail transect 7 with 2000, 800, and 350 cfs water surface elevations. Vertical scale multiplied by three.

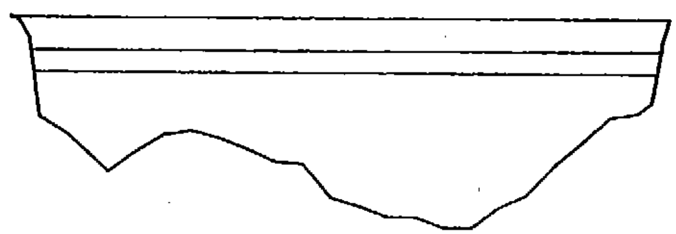


Figure 12. Steiner Flat transect 4 with 2000, 800, and 350 cfs water surface elevations. Vertical scale multiplied by three.

The pool transects all show decreasing fry WUA at higher flows, because slightly higher velocities are capable of moving the large volumes of water through existing pool channels, and there is no overtopping of the banks. Figures 11 and 12 show profiles of pool transects at Bucktail and Steiner Flat with 250, 800, and 2000 cfs water levels. Little new channel area opens up within this range of flows, and the pools become deeper and faster. If the difference between pools and runs is defined by velocity, then these 350 cfs pools would be typed as runs at higher flows.

DISCUSSION

Habitat typing can improve site representativeness to the degree that the habitat types mapped stay constant over the full range of flows and are relevant to fish behavior. For example, fine delineations of habitat type may wash out at high flows when fish are present but map technicians are not; or a habitat type that appears morphologically dominant to biologists standing on the bank may mean little to a fish that stays within a small area of slow water near the stream's edge.

On much of the Trinity River above the North Fork, the major habitat type could be described as "run", so long as flow is no more than about 800 cfs. At a flow of 2000 cfs, these runs become complex combinations of backwaters, bars, shelving riffles, flooded riparian vegetation, and slow edge waters. Side-channels develop, each with its own assortment of habitat types. As flows drop from 800 to 300 cfs, runs tend to become riffles and pocket water, and glides become runs. Fish do not respond to these type names, but rather to microhabitat conditions such as velocity and depth. When considering habitat typing, it must be kept in mind that habitat changes with changes in flow, while mapped type names stay the same. To gain much advantage from habitat typing, we would have to assign types over the range of flows we examine, and develop a patchwork of habitat types changing with flow, especially in the river below Dutch Creek.

However, these data suggest that for describing critical slow-water habitat in the Trinity River, the PHABSIM transect extrapolation procedures provide a robust modeling technique. Most of the river has been molded into a run by project flows, and run transects show a consistent pattern; results from any set of transects, which would necessarily be placed preominantly in run areas, would present a picture similar to the one presented here.

HABITAT AVAILABILITY IN CONSTRUCTED SIDE-CHANNELS

INTRODUCTION

During 1987 and 1988 the Trinity River Flow Evaluation Program conducted several investigations on natural and constructed side-channels located along the upper Trinity River between Lewiston and Douglas City. The results of these investigations indicated that side-channels increase rearing habitat for fry and juvenile salmonids. When compared to the main stem Trinity River, fry rearing habitat nearly doubled in some side-channels. When side-channel habitat gains for fry chinook salmon were compared to main stem fry chinook salmon habitat, side-channels produced from nine to one hundred forty five times more habitat per cubic foot of flow (USFWS 1987, USFWS 1988).

Winter habitat requirements studies, presented in our 1988 annual report, indicated that over-wintering habitat for juvenile steelhead trout may be the key factor limiting smolt production in the Trinity River. Side-channel habitats that provide slow water velocities and clean cobble substrates provide optimum winter habitat for juvenile steelhead trout.

Based on these findings, Trinity River Flow Evaluation staff recommended the construction of additional side-channels to the Trinity as an effective means of increasing fry and juvenile salmonid habitat in the Trinity River to the Trinity River Restoration Program.

Subsequently, the Trinity River Restoration Program constructed three additional side-channels along the Trinity River upstream of Grass Valley Creek during the summer of 1988. The Bureau of Land Management also constructed a side-channel further down river just upstream of the community of Steiner Flat.

The purpose of our 1989 studies was to evaluate and quantify the habitat gains provided by each side-channel for fry and juvenile trout and salmon.

STUDY SITES

The four constructed side-channels investigated in 1989 are: 1) The Cemetery side-channel; 2) the Rush Creek side-channel; 3) the Bucktail side-channel; and 4) the Steiner Flat side-channel. Figure 1 shows the location of each. Habitat delineations for each side-channel were made in coordination with the Trinity River Restoration Program.

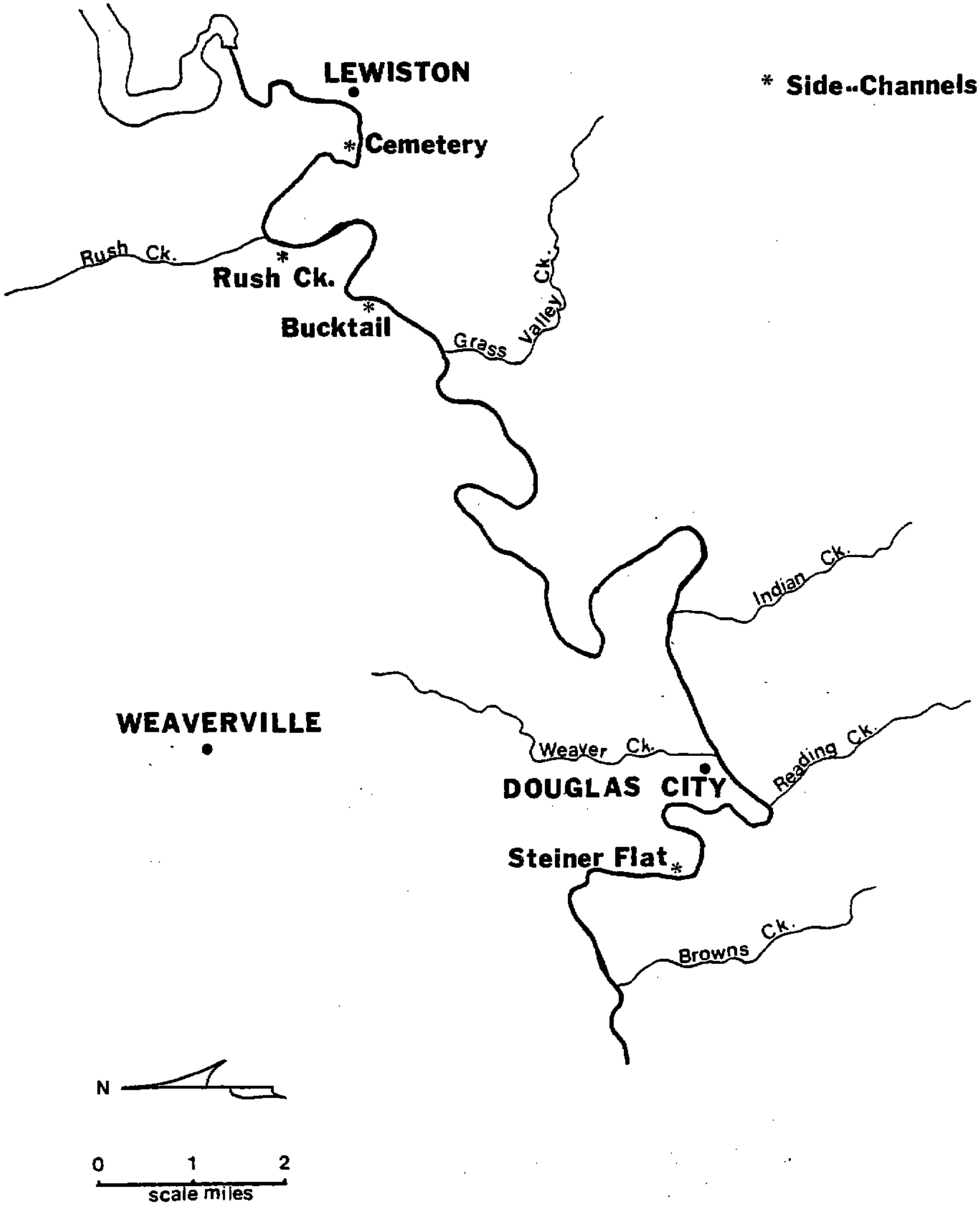


Figure 1. Location of the four side-channels constructed along the upper Trinity River in the summer of 1988.

Cemetery Side-Channel: The Cemetery side-channel is located downstream of the Old Lewiston Bridge at river mile 109. The entrance to the side-channel is located just above the gabion at artificial riffle C along the rivers right bank. The side-channel has a total length of 1037 feet. From the entrance to the side-channel, for a distance 110 feet, flowing perpendicular to the Trinity River, the channel was excavated and is void of riparian vegetation. Below this section the side-channel turns parallel to the Trinity River and flows for 215 feet through a natural channel that conveyed water during flood flows before the side-channel was constructed. Riparian vegetation is present along both banks and small amounts of woody debris are present in the channel. The remaining 657 feet of the side-channel had to be excavated several feet through the historic flood plain in order to lower the bed elevation to an acceptable level. As a result, the channel configuration is trapezoidal, with steep banks, and no riparian vegetation. The side-channel ends as it enters the duck ponds that are adjacent to Cemetery Hole.

Three habitat types were identified within the side-channel as follows:

1) Run - low gradient reach with slow water velocities and shallow to moderate depths. Substrates are mostly composed of sand and silt with some small areas of cobbles and gravel.

2) Riffle - low gradient reach with moderate velocities in shallow water. Substrates contain cobble and gravel with varying amounts of sand.

3) Channelized - excavated reach with moderate gradient, steep banks, and trapezoidal shaped channel. Substrates contain cobbles with large amounts of sand.

Within the side-channel, 292 linear feet were identified as run habitat, 88 linear feet as riffle habitat, and 657 linear feet as channelized habitat. Run and riffle habitat types are dispersed within the upper 380 feet of the side-channel. Two transects were selected to represent run habitats, one in the excavated section at the upper end of the side-channel where no riparian vegetation is present, and a second, in the natural section of the side-channel with riparian vegetation. One transect was placed to represent riffle habitat in the short riffle that forms the transition between run habitat and channelized habitat approximately 347 feet from the beginning of the side-channel. The entire lower 657 feet of the side-channel is composed of channelized habitat and two transects were established across the channel to represent this habitat type.

Rush Creek Side-Channel: The Rush Creek side-channel begins at river mile 107.5 just downstream from the mouth of Rush Creek on the right bank. The side-channel is approximately 3085 feet long, the majority of which flows through an historic river channel. The side-channel ends just above the Salt Flat Bridge where it merges with a small natural side-channel and beaver pond. A total of six habitat types were identified within the side-channel as follows:

1) Channelized - Excavated low gradient reach with steep banks, trapezoidal shaped channel with cobble and gravel substrates embedded in varying degrees of sand. No riparian vegetation present along either bank.

2) Braided run - Low gradient braided channels around riparian vegetation with gently sloping banks along one or both banks of the channel. Substrates generally composed of sand and silt with some cobbles.

3) Duck ponds - Large still water ponds of varying width with depths of up to 12 feet used by resident waterfowl. Substrates are composed of silt, sand and detritus. Various species of submergent and emergent aquatic vegetation.

4) Run/feather bar - Wide slow run in shallow water with a feathered bar along the left bank. Substrates primarily composed of cobbles highly embedded in sand.

5) "W" shaped channel - Two narrow runs with moderate velocities separated by a wide sand bar. Substrates composed of sand.

6) Riffle/pool - Moderate gradient riffles separated by small pools, backwaters and pocket water.

In order to bring water into the historic river channel the upper 570 feet of the side-channel had to be excavated. The habitat here is channelized and is similar to the excavated channelized section in the Cemetery side-channel. The channel is trapezoidal with steep banks. The habitat is a long monotypic run with cobble and sand comprising the majority of the substrate. One IFIM transect was placed in this area, and represents approximately 18 percent of total length of the side-channel.

At the end of the channelized section the side-channel enters the historic river channel, which now defines the side-channels hydraulic characteristics. At this point the side-channel habitat changes to a slow run with some minor braiding around clumps of riparian vegetation. A feathered cobble bar is present along the left bank while the right bank flows parallel to a steep natural bank. The substrate is primarily sand and silt with sparse areas of gravel and cobble along the left bank where the cobble bar begins. This habitat continues for 275 feet and represents approximately 9 percent of the side-channels total length. One IFIM transect was placed in this habitat.

The majority of the side-channel, 46 percent of its length, is composed of a series of duck ponds that appear to have been formed by gold mining operations. A SCUBA survey of the largest pond present in the side-channel found depths in excess of 10 feet with a maximum depth of 12 feet. The ponds contain various species of submergent and emergent aquatic vegetation common to lentic habitats. Large alders, willows, and cottonwoods are present within the riparian community as is himalaya berry and wild blackberry. The substrates are composed of detritus, silt, and sand. Because of the limitations of modeling these still water habitat types with IFIM, only one transect was placed in the upper most pond in the side-channel. This transect is probably representative of about one third of all the ponds present. The habitat across this transect is about 40 feet wide and 3.5 feet deep, with mean column water velocities less than 0.5 feet/second. The habitat is more similar to a slough or deep slow run than to the larger ponds that constitute the majority of this reach. When considering the habitat outputs from transect 3 the reader should keep these subtle habitat differences in mind. Because of the limited suitability of these duck pond habitats for young chinook salmon and steelhead trout they were not included in the habitat simulations for these two species.

Between two of the side-channel ponds the habitat changes to a broad slow run with a feathered bar along the left bank. The bar is primarily composed of cobbles that are highly embedded in sand. The riparian is predominantly composed of willows, which, in some areas are present across the entire channel. This habitat represents 6 percent of the side-channels total length and two IFIM transects were placed here.

Below this broad slow run the habitat changes slightly as the channel configuration becomes "W" shaped, forming two main channels along each bank with a shallow sand bar across the middle. Emergent aquatic plants are present across the center sand bar, while willows, alders, and berries are present along each bank. This habitat comprises approximately 6 percent of the side-channels total length and is represented by one IFIM transect.

The final habitat segment is located at the end of the side-channel below the last duck pond. In this area the gradient increases significantly to form a series of riffles with some small backwaters and pocket water. The channel also braids considerably with several small channels that exit the duck pond upstream. For modeling purposes one transect was placed on the largest of these channels. This area represents roughly 15 percent of the side-channels total length.

Bucktail Side-Channel: The Bucktail side-channel is located just upstream of the Browns Mountain Road Bridge at river mile 105. Before side-channel construction, this site provided salmonid habitat at river flows in excess of 550 cubic feet per second when the channel became inundated (USFWS, 1987). The Trinity River Restoration Program lowered the existing bed elevation throughout the channel in order to provide habitat at river flows as low as 150 cubic feet per second. The side-channel has a total length of 541 feet and was partitioned into two habitat types as follows:

1) Run/riffle - Low to moderate gradient run-riffle sequences with cobble and gravel substrates embedded in approximately 50% sand.

2) Pool - Relatively deep water area with moderate velocities entering across the left bank and a large backwater present along the right bank. Substrates range from sand to cobble and small boulders.

The side-channel was divided into three segments with the upper and lower segments composed of run-riffle habitat types. There is no riparian vegetation present along the entire channel with the exception of a few willows that are offset from the right bank several feet. One IFIM transect was placed in the upper and lower segments. The upper segment represents 50 percent of the side-channels total length and the lower segment represents 30 percent of the total length.

A large pool and backwater are present in the center of the side-channel. The left bank is formed by a steep bank of loose cobble and gravel substrates. Sand has settled out in a small backwater located on the left edge. Across the right half of the pool cobbles with varying degrees of sand are present. As you proceed across the right bank there is a bench with several small boulders and large cobbles. At higher flows a large backwater forms along the right half of the pool. One IFIM transect was placed across this pool which represents 20 percent of the side-channels total length.

Steiner Flat Side-Channel: The Steiner Flat side-channel is located on Bureau of Land Management (BLM) land just upriver of the small community of Steiner Flat at river mile 90. The side-channel was constructed by the BLM across a large river bar on the right bank of the Trinity River. The BLM designed the side-channel and BLM personal were responsible for its construction. Because of the physical characteristics of the site a large amount of material had to be excavated to obtain suitable bed elevations for the side-channel. Although the side-channel has extremely high banks, characteristic of the channelized sections in both the Cemetery and Rush Creek side-channels, the heavy equipment operators managed to create some hydraulic diversity by constructing islands, some small point deflectors, and several hydraulic controls to increase diversity. The habitat flow relationship however, is still limited by the side-channels steep banks. The side-channel is 2044 feet long and has been partitioned into four major habitat types as follows:

1) Run - Shallow low gradient reach with slow water velocities. Substrates composed of cobbles, gravel, and sand.

2) Run/riffle - Short moderate gradient riffles separated by low gradient runs with moderate water velocities.

3) Slow run - Low gradient, moderate depth reach with slow water velocities. Substrates composed of sand.

4) Riffle - Moderate gradient reach with shallow water and high water velocities. Substrates composed of gravel and bedrock.

The upper reach is typical of the run habitats common to the main stem Trinity River but on a smaller scale. Riparian vegetation is present along both banks for the first 279 feet, after which the channel enters the open bar located beyond the riparian belt present along the main stem. The channel continues as a run for an additional 181 feet before transition to the next habitat type. The total length of this run habitat is 460 feet, which, comprises 23 percent of the side-channels total length. One IFIM transect was selected to represent this habitat type.

The majority of the side-channel habitat is formed by a series of short riffles cascading over hydraulic controls that separate runs of various lengths. These habitats have steep banks and are void of riparian vegetation with the exception of an occasional willow or redbud that was intentionally left during side-channel construction. These habitats provide 46 percent of total side-channel length. Because of small variations within this habitat three IFIM transects were selected to accurately represent the entire habitat.

The run-riffle habitat is divided into two separate reaches by one long slow run habitat that is approximately 518 feet in length and represents 25 percent of the side-channels total length. One IFIM transect was placed to represent this habitat type.

The lower 117 feet of the side-channel is a shallow riffle over gravel substrates that is cut between two steep ledges. The right bank is formed by shale bedrock and the left bank is bedrock with sand across the upper layer that is held in place by a network of roots from riparian vegetation. One transect was placed here and represents 6 percent of the side-channels total length.

METHODS

Salmonid habitat estimates were made for each side-channel using the U.S. Fish & Wildlife Service's, Instream Flow Incremental Methodology (IFIM). Field data collection and computer simulations followed the procedures recommended by the U.S. Fish & Wildlife Service's, Aquatic Systems Branch of the National Ecology Research Center (Bovee, 1982; Bovee and Milhouse, 1978; Milhouse, Wegner, and Waddle, 1984; Trihey and Wegner, 1981).

Water surface elevations and transect profiles were measured with a spirit level and leveling rod from established benchmarks with an assumed elevation of 100.00 feet. Mean column water velocities and total depths were measured with a Price AA current meter and top setting wading rod.

Substrates were described visually using the Brusven Substrate Index (Brusven, 1977). The index is composed of a three digit number which describes the dominant and subdominant substrate and the percent embeddedness of the dominant substrate in fines. The size categories that we used with the Brusven Index are presented in Table 1.

Table 1. Substrate classification used with the Brusven Substrate Index for habitat simulations within the IFIM.

Substrate Type	Particle Size	Code
Fines	< 4mm	0
Small Gravel	4 - 25mm	1
Medium Gravel	25 - 50mm	2
Large Gravel	50 - 75mm	3
Small Cobble	75 - 150mm	4
Medium Cobble	150 - 225mm	5
Large Cobble	225 - 300mm	6
Small Boulder	300 - 600mm	7
Large Boulder	> 600mm	8
Bedrock		9

Cover was visually described using a two digit index. The first digit of the index identified the major cover type present and the second digit gave a quality rating to the predominant cover type as poor, fair, good, or excellent, based on professional opinion. Table 2 presents the cover type classifications that were used.

Table 3 presents Trinity River and side-channel discharges that were used for IFIM analysis. Field data collection discharges are denoted by an asteric.

The habitat preference criteria used in the PHABSIM model were developed on the Trinity River through direct observation techniques by our office and are presented by Hampton (1988). The steelhead trout and coho salmon over-wintering suitability criteria are presented in our 1988 annual report (USFWS, 1988).

Table 2. Cover type classifications used in the PHABSIM model of the IFIM for the side-channel habitat simulations.

Cover type and description	Code
No Cover - Gravel less than 75mm or any larger material which is embedded to the extent that no cover is available.	0
Cobble - 75 - 300mm cobbles clear of fines.	1
Boulders - 300mm and larger.	2
Small Woody Debris - Brush and limbs less than 9 inches in diameter.	3
Large Woody Debris - Logs and root wads.	4
Undercut Bank - Undercut at least 0.5 feet.	5
Overhanging Vegetation - Within 1.5 feet of water surface.	6
Aquatic Vegetation - Emergent and submergent plants.	7

Table 3. Trinity River and side-channel discharges (cubic feet per second) that were used for IFIM analysis.

Cemetery		Rush Creek		Bucktail		Steiner Flat	
Trinity	SC	Trinity	SC	Trinity	SC	Trinity	SC
50	1	50	2	50	2	175	5
100	3	100	5	100	6	283	10
150	6	150	7	150	10	375	15
200	8	200	9	200	15	455	20
300	* 14	300	* 13	300	* 26	600	30
500	24	500	20	500	52	680	* 36
800	* 44	800	* 29	800	* 98	790	45
1028	60	1100	41	1500	* 231	965	60
1500	* 94	1500	* 57	1700	273	1290	* 92
1700	111	1700	61	2000	340	1550	120
2000	135	2000	71			1810	* 151
2175	150	2894	100			1965	170
						2200	200

* denotes field data collection discharges

Habitat utilization criteria rather than preference criteria were used in the habitat simulations for fry steelhead trout. Habitat preference criteria have not been developed for fry steelhead trout because we do not have enough microhabitat use observations to develop accurate preference criteria. In future years we plan to collect additional data in order to construct habitat preference criteria. The utilization criteria that were used in the side-channel habitat simulations may be viewed in Appendix A of our habitat preference criteria report (Hampton, 1988).

RESULTS

The habitat estimates for each side-channel are presented as the total side-channel weighted useable area (WUA). Whereas, the habitat estimates for individual transects are presented as the WUA per thousand linear feet of side-channel. Presenting the results in this fashion allows for easy comparison between habitat transects from all side-channels without requiring corrections for differing habitat lengths.

Cemetery Side-Channel

Chinook Salmon - The Cemetery side-channel provides between 870 to 2171 square feet of fry chinook salmon WUA and between 3055 and 6066 square feet of juvenile chinook salmon WUA (Figure 2). The greatest amount of fry habitat was provided by low side-channel discharges (1 cfs). As discharges increased fry habitat decreased until a discharge of 60 cfs was reached. As discharges increased beyond 60 cfs, to 125 cfs, fry habitat increased gradually until a total of 971 square feet of WUA were available. Fry habitat began to decrease again when discharges started to exceed 125 cfs.

The natural run habitat represented by transect 2 provided the greatest amount of habitat and the most stable habitat-flow relationship for fry and juvenile chinook salmon (Figure 4). In the channelized sections, represented by transects 3 and 4, habitat decreased with increasing flow, and the total amount of habitat available is considerably less than that provided by the natural run habitat (Figures 5 and 6).

The physical characteristics of the channelized sections, steep sloping banks and narrow confined channel, limit the potential amount of fry and juvenile chinook salmon habitat that can be achieved with increased flow. As flows increase in these habitats the wetted surface area increases only slightly. Therefore, water velocities must increase in order to allow more water to pass through a channel of nearly equal volume. Since fry salmonids require slow water microhabitats to rear in, their habitat decreases when water velocities are forced to increase do to physical channel characteristics that are present in these sections. In this situation fry and juvenile chinook salmon habitat is limited to extreme edges of the channel where slow water habitat is still available.

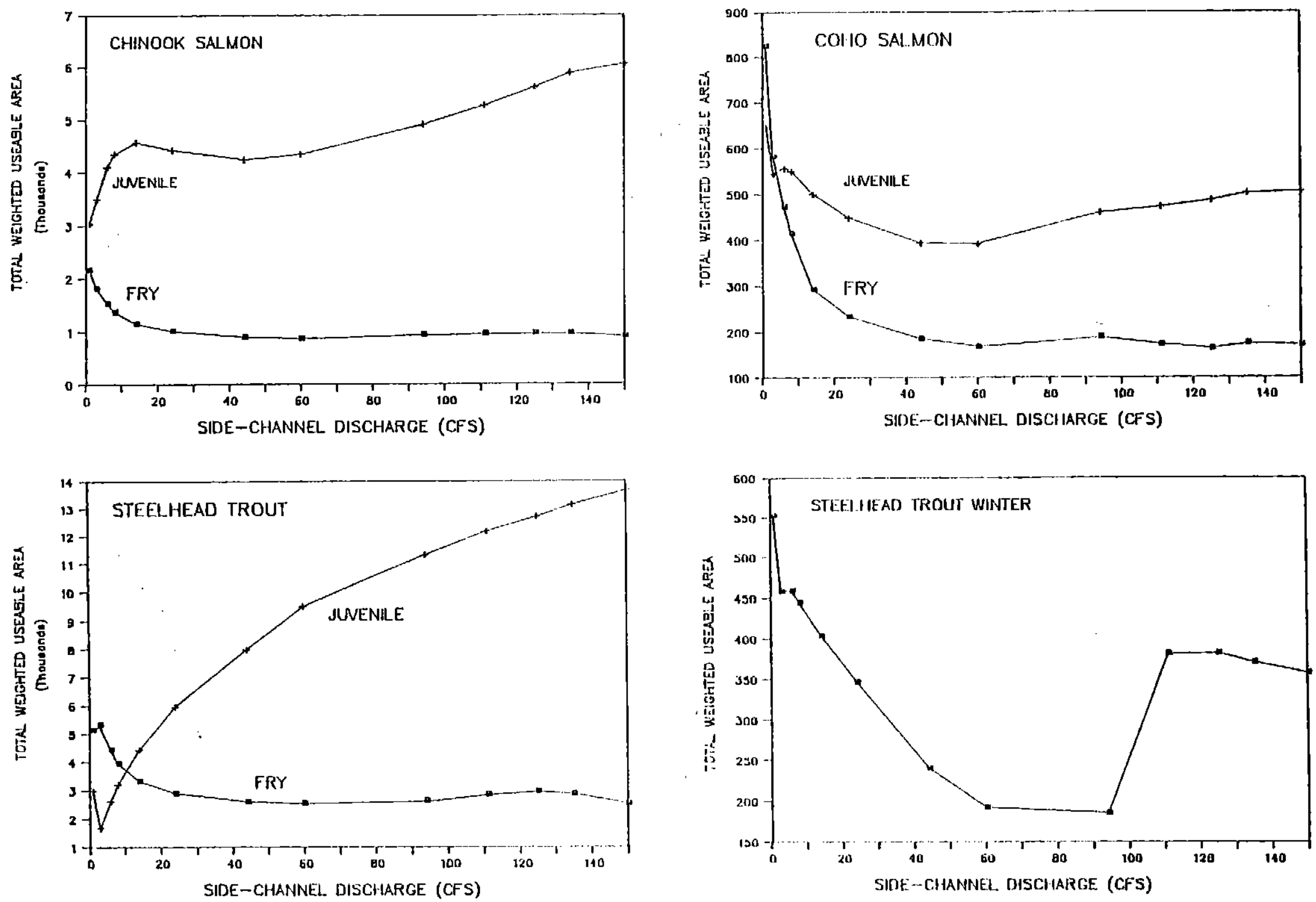


Figure 2. Total weighted usable area (WUA) for fry and juvenile anadromous salmonids available in the Cemetery side-channel, 1989.

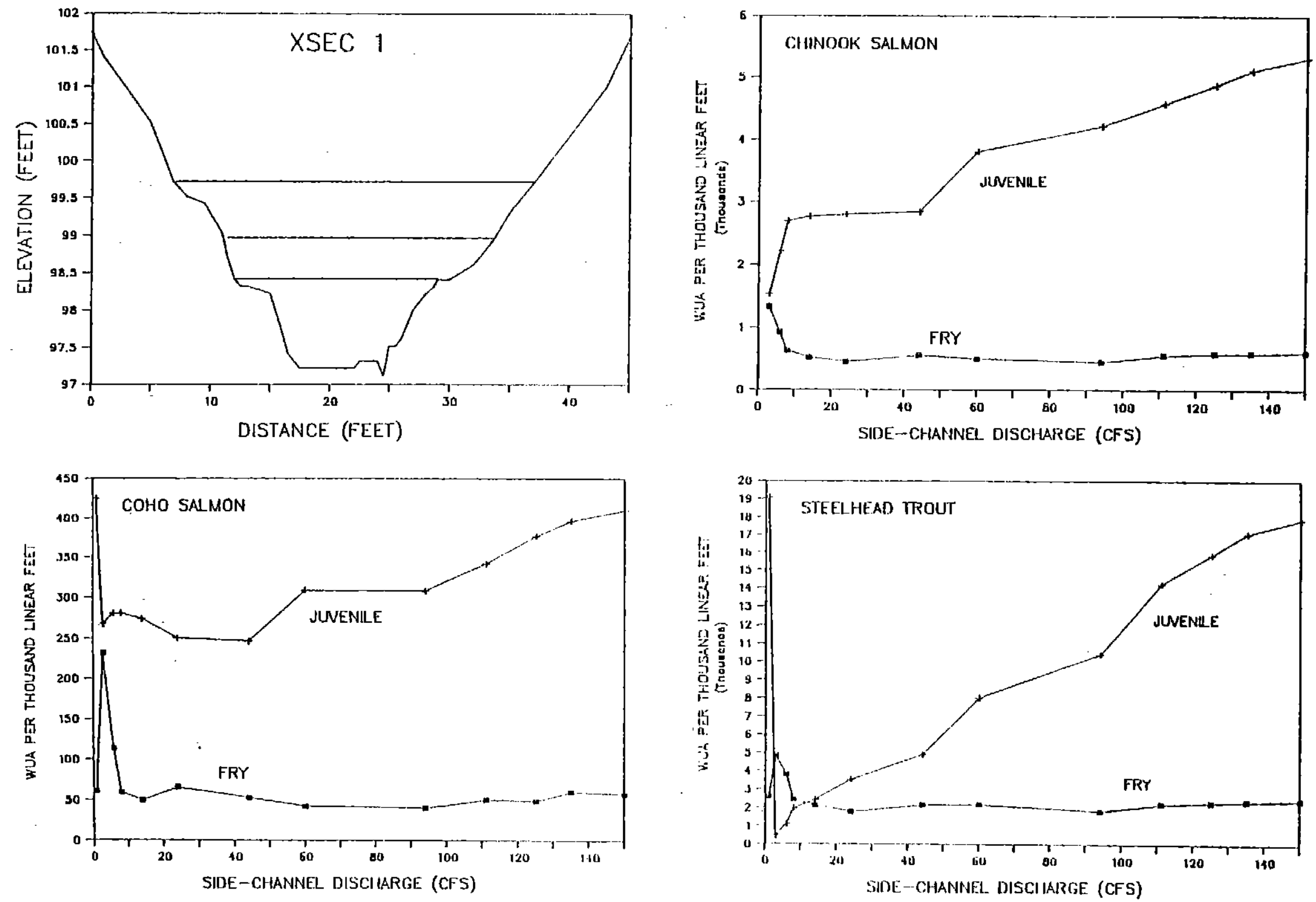


Figure 3. Profile of transect 1 in the Cemetery side-channel and the amount of weighted usable area (square feet/thousand linear feet) provided by transect 1 for fry and juvenile anadromous salmonids.

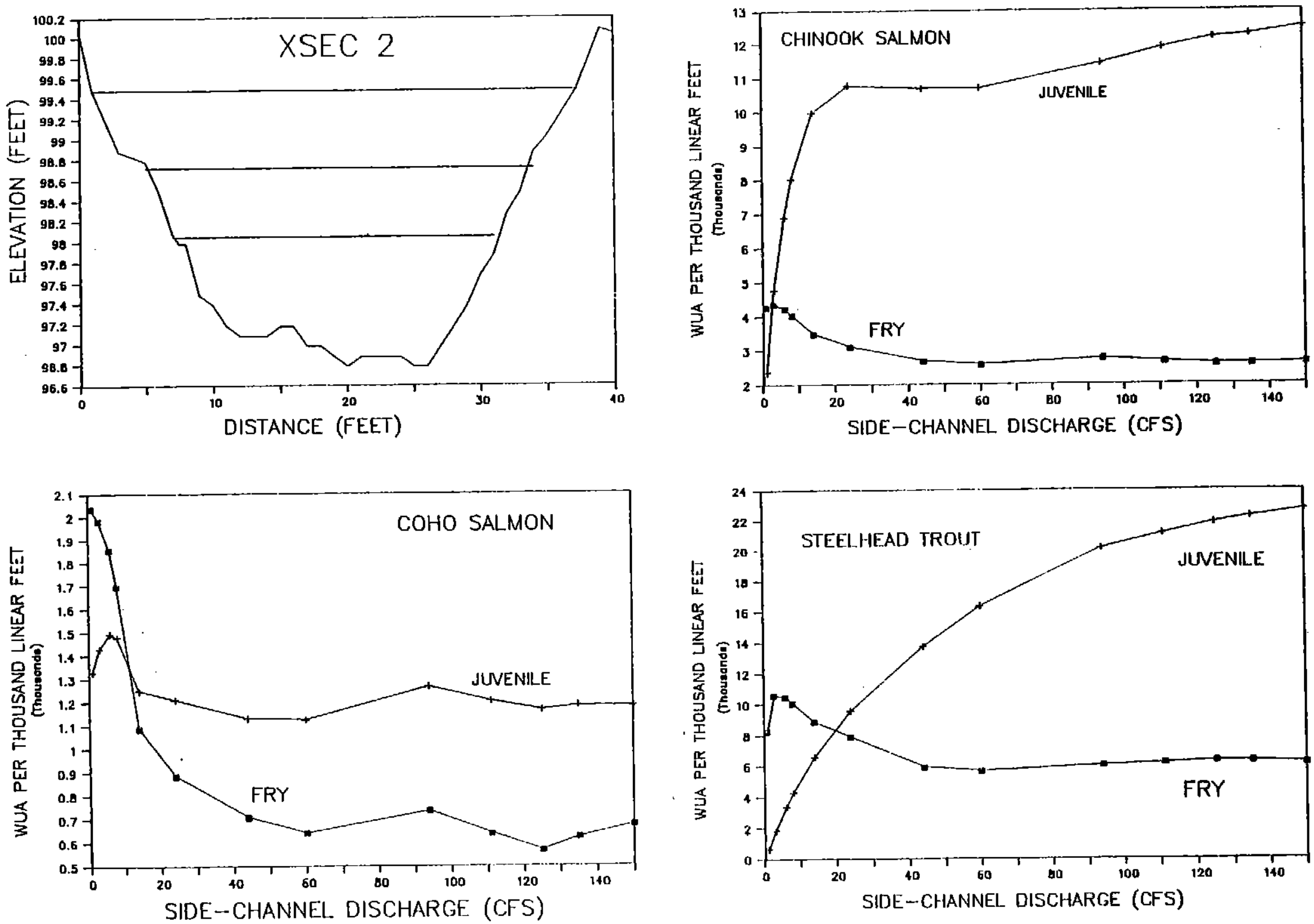


Figure 4. Profile of transect 2 in the Cemetery side-channel and the amount of weighted usable area (square feet/thousand linear feet) provided by transect 2 for fry and juvenile anadromous salmonids.

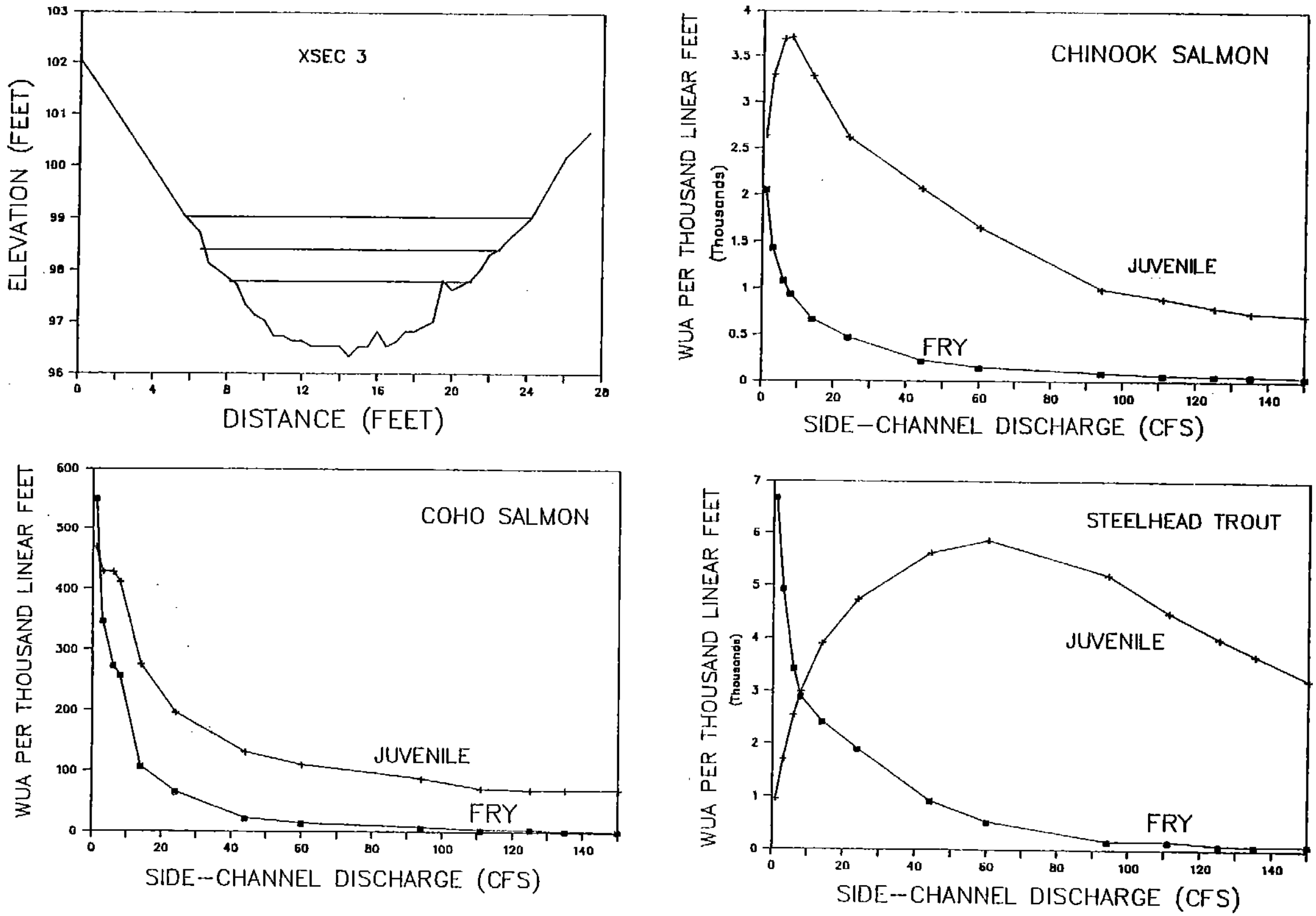


Figure 5. Profile of transect 3 in the Cemetery side-channel and the amount of weighted usable area (square feet/thousand linear feet) provided by transect 3 for fry and juvenile anadromous salmonids.

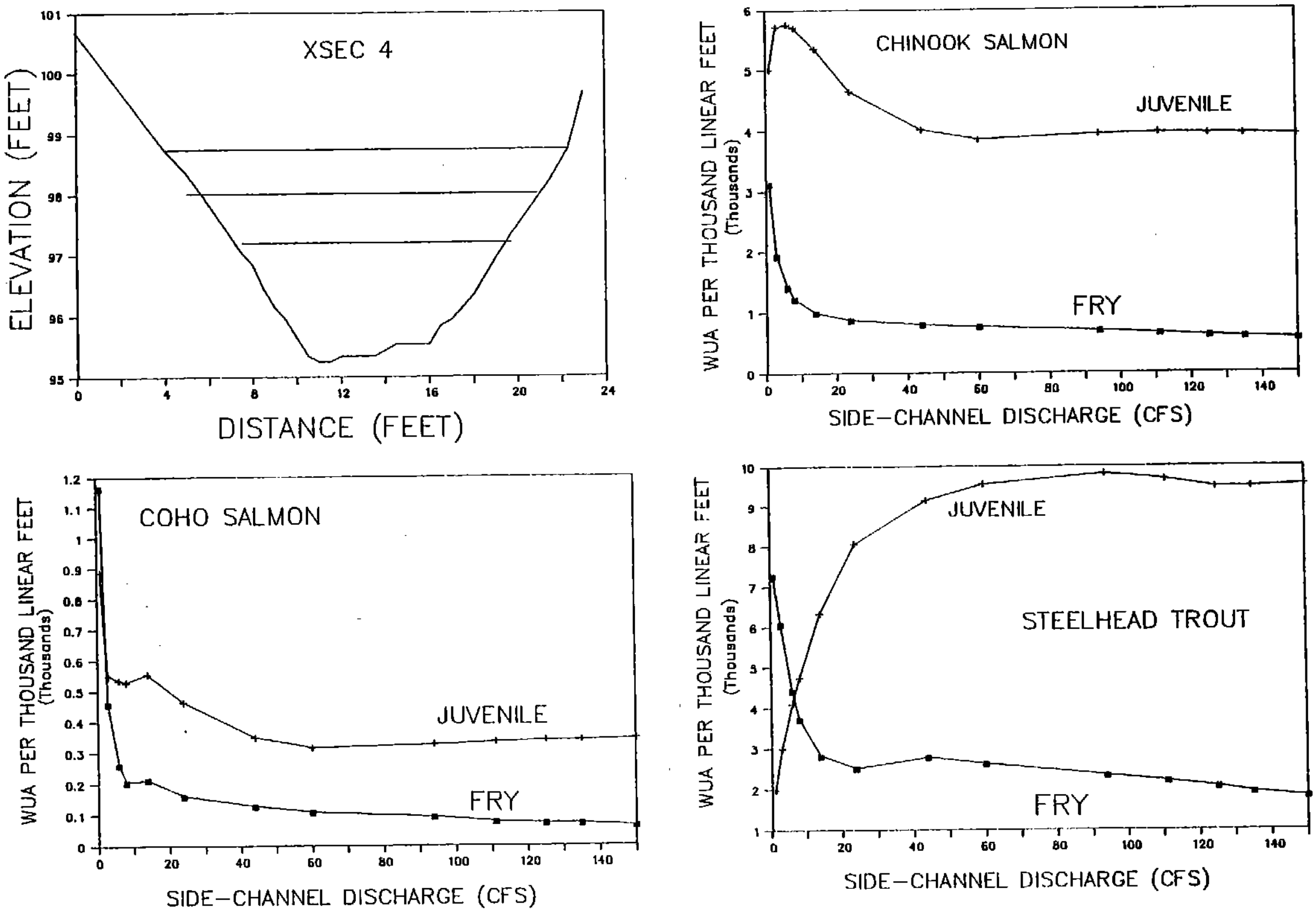


Figure 6. Profile of transect 4 in the Cemetery side-channel and the amount of weighted usable area (square feet/thousand linear feet) provided by transect 4 for fry and juvenile anadromous salmonids.

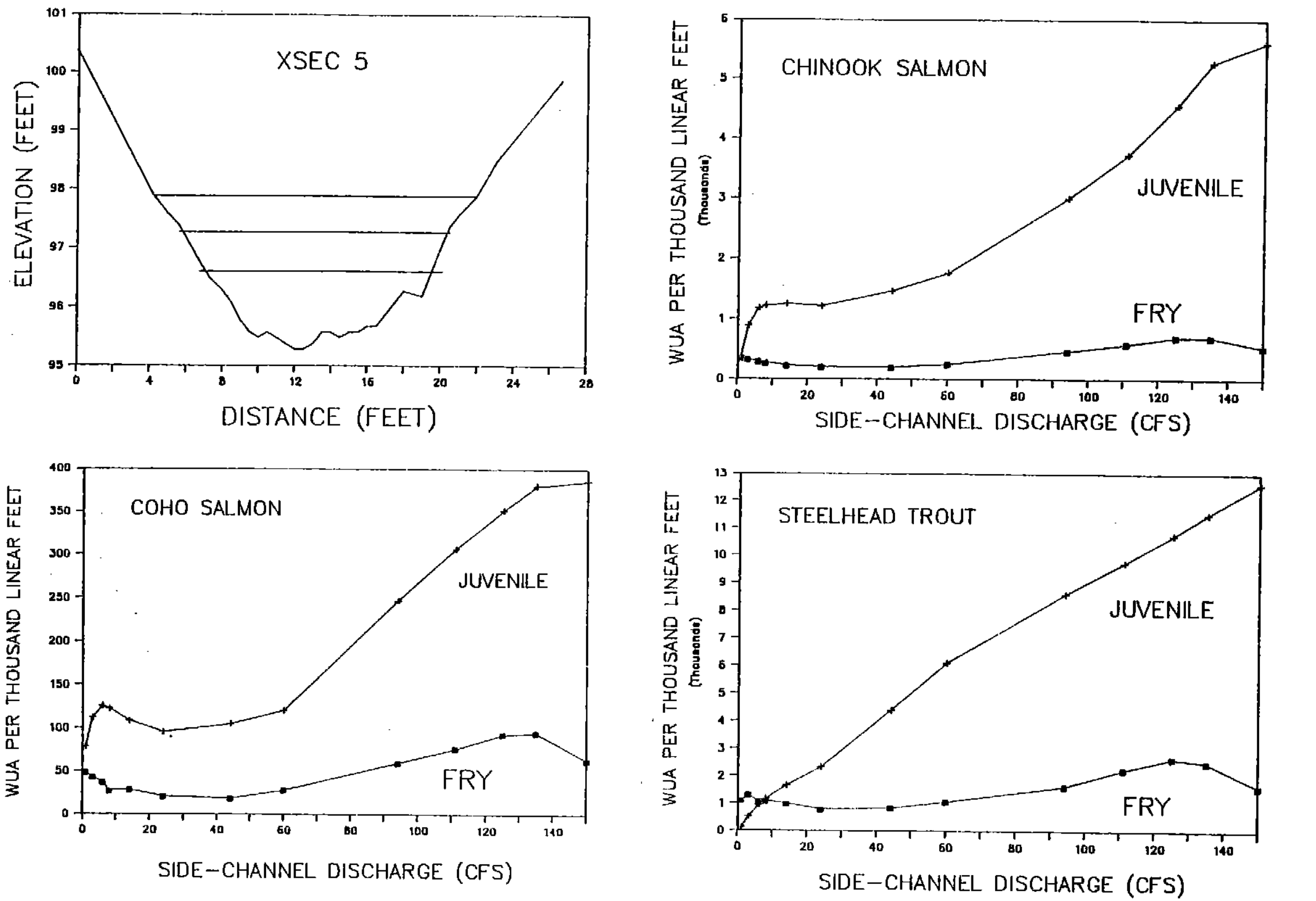


Figure 7. Profile of transect 5 in the Cemetery side-channel and the amount of weighted usable area (square feet/thousand linear feet) provided by transect 5 for fry and juvenile anadromous salmonids.

Habitat increased with flow across transect 5, which also represents channelized habitat. However, the total available habitat is still considerably less than that provided by the natural run habitat (Figure 7). The increase in fry and juvenile habitat that occurs at transect 5 when flows exceed 60 cfs is caused by two physical features of the channel at this location. First, slightly downstream of transect 5 the side-channel makes a bend to the left. At higher flows this bend in the channel begins to act as a hydraulic control, causing water to back up slightly slowing velocities. Second, there is a slight break in the bank slope of transect 5 that becomes inundated when discharges exceed 50 cfs increasing the transects surface area. The downstream hydraulic control begins to reduce velocities combined with the small increase in surface area across transect 5 causes habitat to increase for both fry and juvenile chinook salmon at higher flows.

Three parameters account for the larger amount of fry and juvenile habitat provided by the natural run habitat. First, the surface area is greater across the natural run habitat providing more opportunities for reduced water velocities. Second, The banks along the natural run habitat are not as steep, thus water is allowed to disperse over a greater area with increasing flow. Third, a backwater and chute provide diversity and help maintain slow water habitats, since high velocity areas tend to stay confined in the chute microhabitat.

A large increase in habitat occurs across transect 1 for juvenile chinook salmon when flows begin to exceed 24 cfs (Figure 3). Transect 1 is located in the excavated run habitat at the upper end of the side-channel. When compared to the channelized habitats located in the lower half of the side-channel, the channel slope and bank slope across transect 1 are much less. The formation of a backwater and the inundation of new habitat along gently sloping banks are responsible for the large gains in juvenile chinook salmon habitat when flows exceed 24 cfs.

<u>Coho Salmon</u> - Fry and juvenile coho salmon prefer microhabitats similar to fry chinook salmon with one exception, juvenile coho salmon prefer still to slow water velocities in deeper water. Backwaters, beaver dams, and slow deep side-channels with abundant cover are typical habitats sought out by young coho salmon in the Trinity River.

The Cemetery side-channel provides none of these described microhabitats. Total habitat estimates for the Cemetery side-channel range between 168 and 825 square feet of WUA for fry coho salmon and between 392 and 648 square feet of WUA for juvenile coho salmon (Figure 2). The natural run habitat represented by transect 2 and the backwater that forms at higher flows across transect 1 provide nearly all of the fry and juvenile coho salmon habitat within the side-channel (Figures 3 and 4).

Steelhead trout - Fry steelhead trout habitat in the Cemetery side-channel ranges between 2530 and 5331 square feet of WUA (Figure 2). The greatest amount of habitat is provided under a side-channel flow of 3 cfs. Habitat then decreases until a flow of 60 cfs is reached, at which point 2541 square feet of fry WUA becomes available. As flows increase beyond 60 cfs habitat gradually increases until a second peak of 2974 square feet of WUA is provided under a discharge of 125 cfs.

Examination of the habitat-flow relationships for each transect reveal that the fry steelhead trout habitat-flow relationship correlates closely with the fry chinook salmon habitat-flow relationship except on a much larger scale. The mean column velocity use criteria for fry steelhead trout incorporates a broader range of suitable velocities than does the velocity preference criteria for fry chinook salmon. This may explain why the habitat estimates for fry steelhead trout are much greater than those estimates for fry chinook salmon, even though their WUA outputs correlate closely.

Juvenile steelhead trout habitat increases with increasing flow from a low of 1688 square feet of WUA under a discharge of 3 cfs to a high of 13,669 square feet of WUA under a discharge of 150 cfs (Figure 2). The greatest amount of habitat for juvenile steelhead trout was provided by transects 1 and 2 which represent the excavated and natural run habitats in the upper half of the side-channel. The habitat-flow relationship for these two habitats never decreased, meaning their full potential habitat was never realized under the simulated discharges. Apparently, the velocities in these habitats never exceeded the suitable velocity range defined by the velocity preference criteria. This may be attributable to the larger surface areas and backwaters that are present in these habitat types.

In the channelized habitats, represented by transects 3 and 4, habitat-flow relationship for juvenile steelhead trout peaks at side-channel discharges of approximately 90 cfs (Figures 5 and 6). As flows begin to exceed 90 cfs, water velocities become to fast to provide suitable habitat.

During the winter months when water temperatures begin to drop below 48 degrees fahrenheit, juvenile steelhead trout shift their microhabitat selection toward protected microhabitats that contain large amounts of clean cobble with water velocities ranging between 0.0 to 1.3 feet/second. Over-wintering habitat for juvenile steelhead trout in the Cemetery side-channel ranges from 185 to 553 square feet of WUA (Figure 2). The absence of clean cobble substrate is the main reason for the extremely low over-wintering habitat estimates in the side-channel.

Rush Creek Side-Channel

Chinook Salmon - Total habitat estimates range between 2762 and 5928 square feet of WUA for fry chinook salmon and between 3711 and 30930 square feet of WUA for juvenile chinook salmon (Figure 8). Total habitat for fry chinook salmon peaks at side-channel discharges of approximately 29 cfs. The run habitats with sand or cobble bars (transects 2 and 5) and the riffle habitat that contained a large bench along the right bank (transect 7) provided the greatest amount of fry chinook salmon habitat per thousand linear feet of side-channel (Figures 10, 13, and 15).

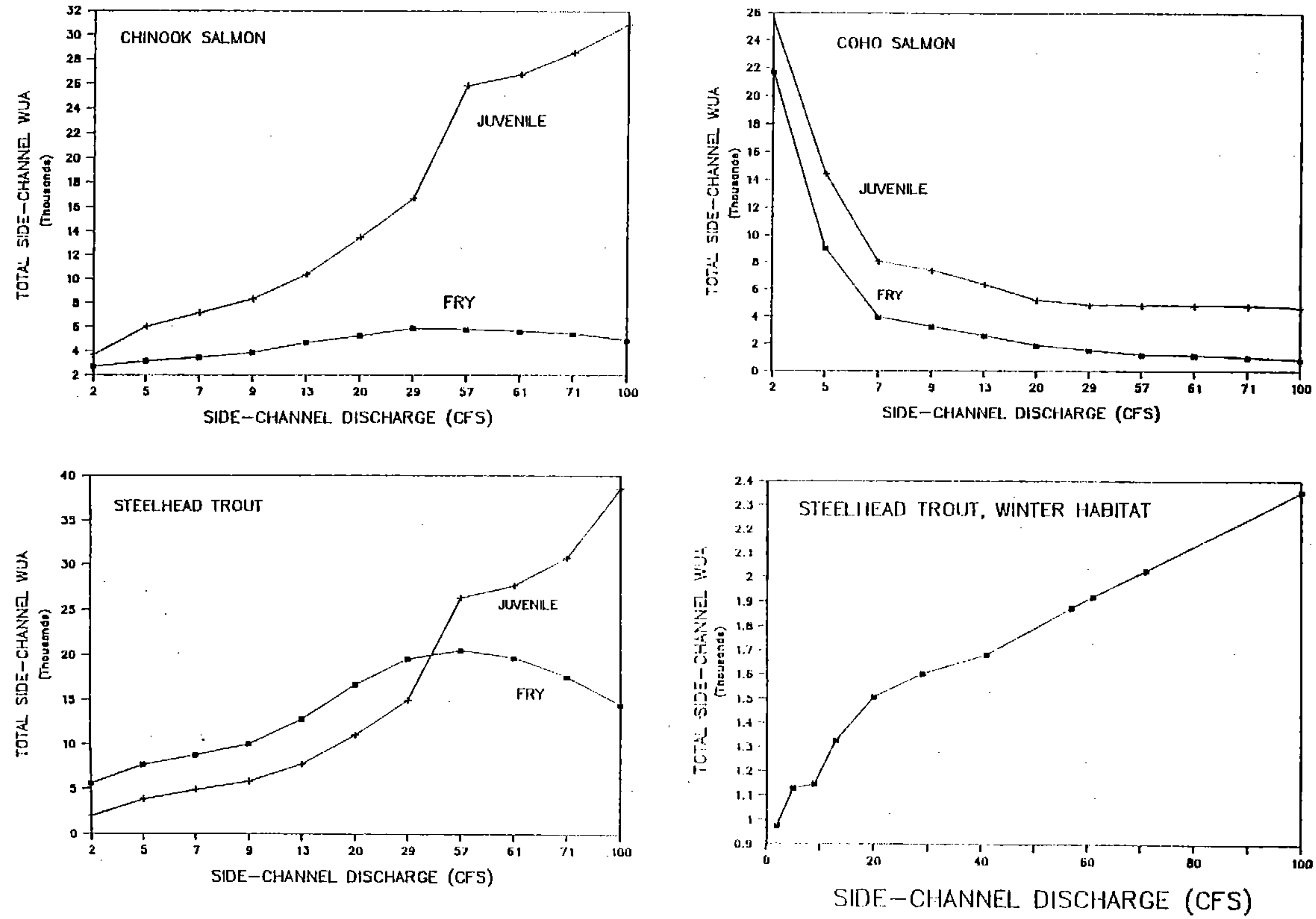
Juvenile chinook salmon habitat in the Rush Creek side-channel increased with flow at all habitats modeled except for the channelized sections represented by transect 1 (Figures 9 through 17). The increases in habitat with flow are most prominent across the run-bar habitats represented by transects 2 and 5 (Figures 10 and 13). Both of these habitats are located along gradual bends in the side-channel and are characterized by a steep bank along the outside bend, where the thalweg is located, and a gently sloping bar along the inside bend. As flows increase in these habitats, thalweg water velocities increase and backwaters or slow water velocity areas develop along the inside bend across newly inundated bars. As a result, the area of slow velocity habitat increases substantially with increased flows, while high water velocity areas are usually confined in the thalweg. The full potential of these habitat areas for providing juvenile chinook salmon habitat cannot be fully realized until higher flows can be obtained and simulated.

<u>Coho Salmon</u> - The majority of habitat for fry and juvenile coho salmon in the Rush Creek side-channel is provided by the duck ponds which are represented by transect 3 (Figure 11). The total habitat output for the side-channel is controlled by the transect 3, duck pond, habitat output. The other habitats provided only minor amounts of fry and juvenile coho salmon habitat.

<u>Steelhead Trout</u> - The greatest amount of fry steelhead trout habitat, over 20548 square feet of WUA, is provided when side-channel discharges range between 30 and 60 cfs. At higher discharges both water velocities and depths become unacceptable for fry steelhead trout (Figures 9 through 15).

The full potential of juvenile steelhead trout habitat was never realized within the range of flows simulated for all habitat types (Figures 9 through 15). The greatest amount of WUA per thousand linear feet was provided by the run-bar habitat represented by transect 2 (Figure 10). The channelized section represented by transect 1 provided the second greatest amount of habitat per thousand linear feet of side-channel, however, it appears that the habitat flow relationship for transect 1 is beginning to level off and may be near optimum at a discharge of just over 70 cfs (Figure 9).

Over-wintering habitat for juvenile steelhead trout also shows a continuous increase in habitat with increasing flows (Figure 8). This increase is mainly the result of the increased availability of cobble substrates along the bar of transect 2.



Figeure 8. Total weighted usable area (WUA) for fry and juvenile anadromous salmonids available in the Rush Creek side-channel, 1989.

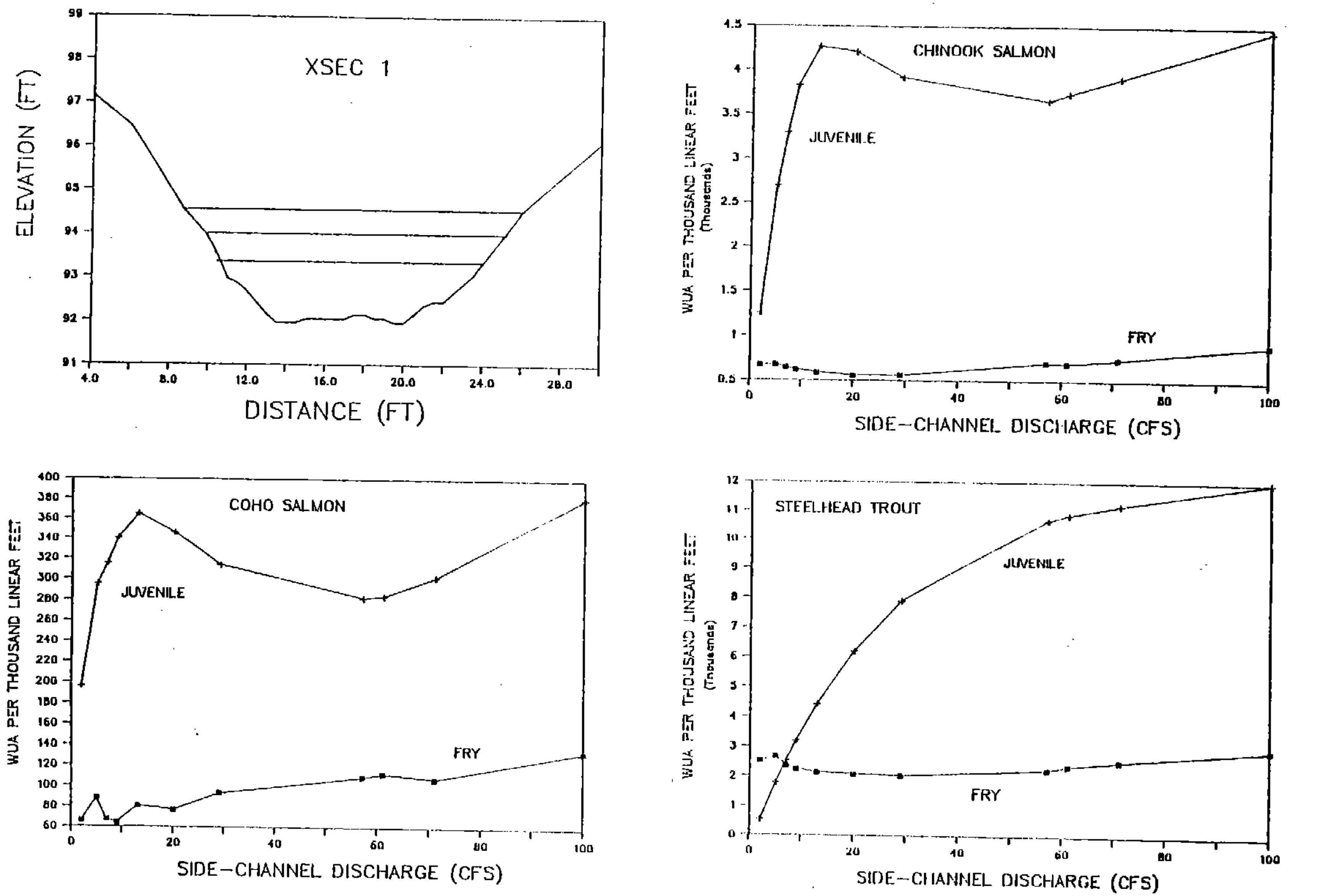


Figure 9. Profile of transect 1 in the Rush Creek side-channel and the amount of weighted usable area (square feet/thousand linear feet) provided by transect 1 for fry and juvenile anadromous salmonids.

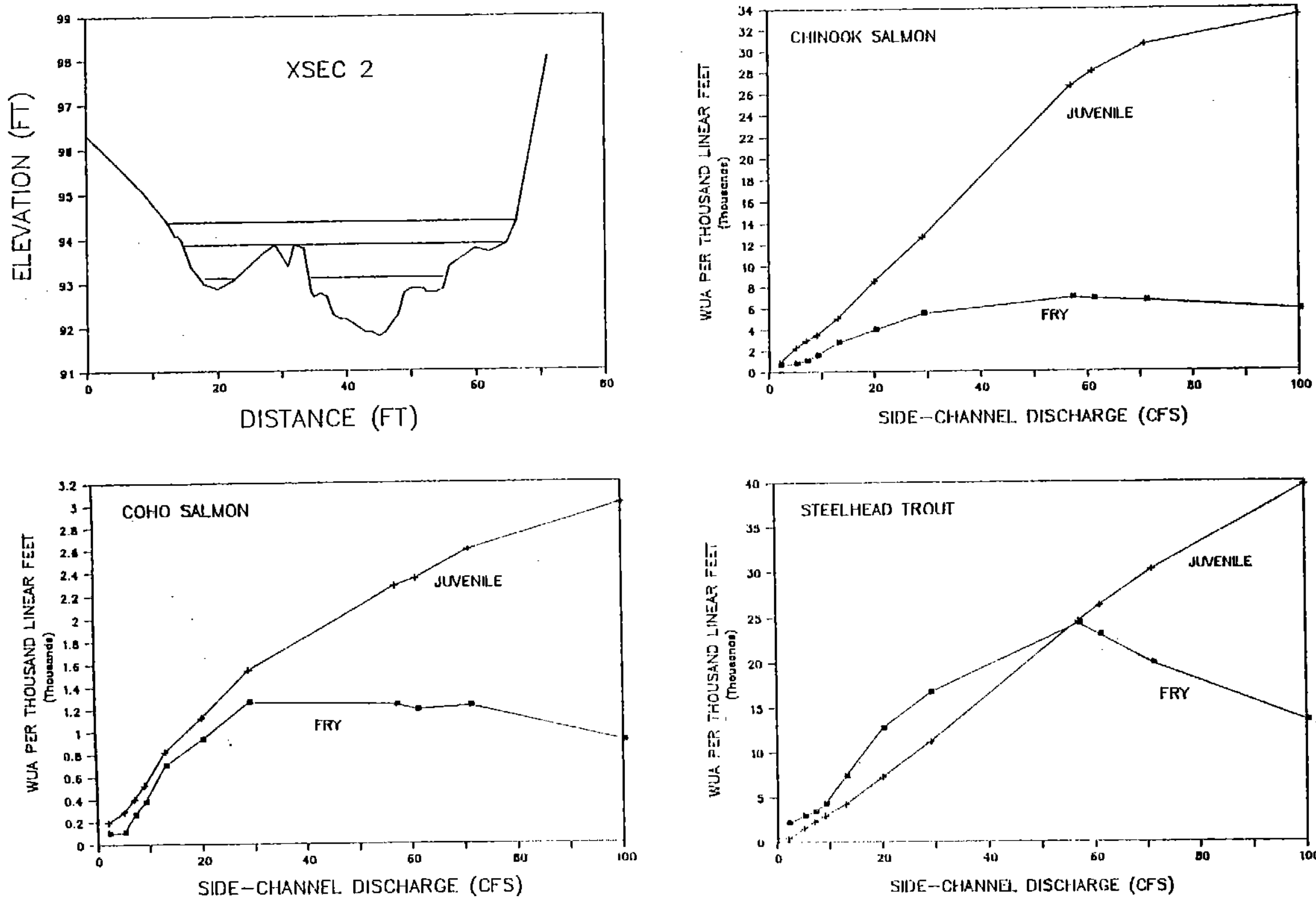
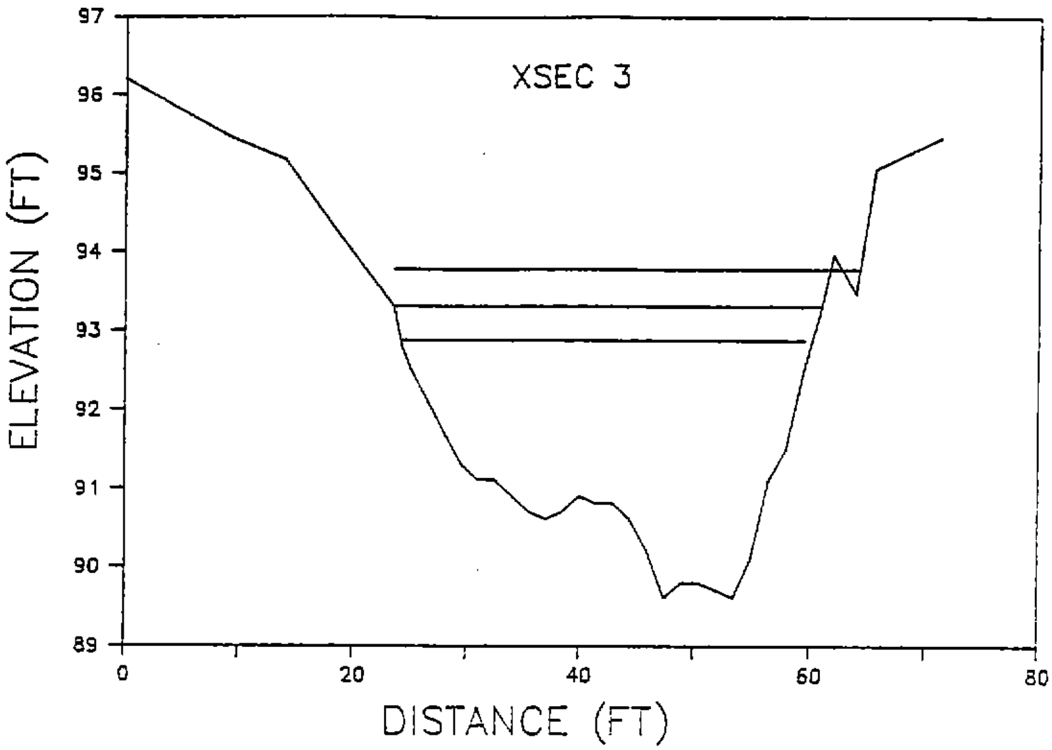


Figure 10. Profile of transect 2 in the Rush Creek side-channel and the amount of weighted usable area (square feet/thousand linear feet) provided by transect 2 for fry and juvenile anadromous salmonids



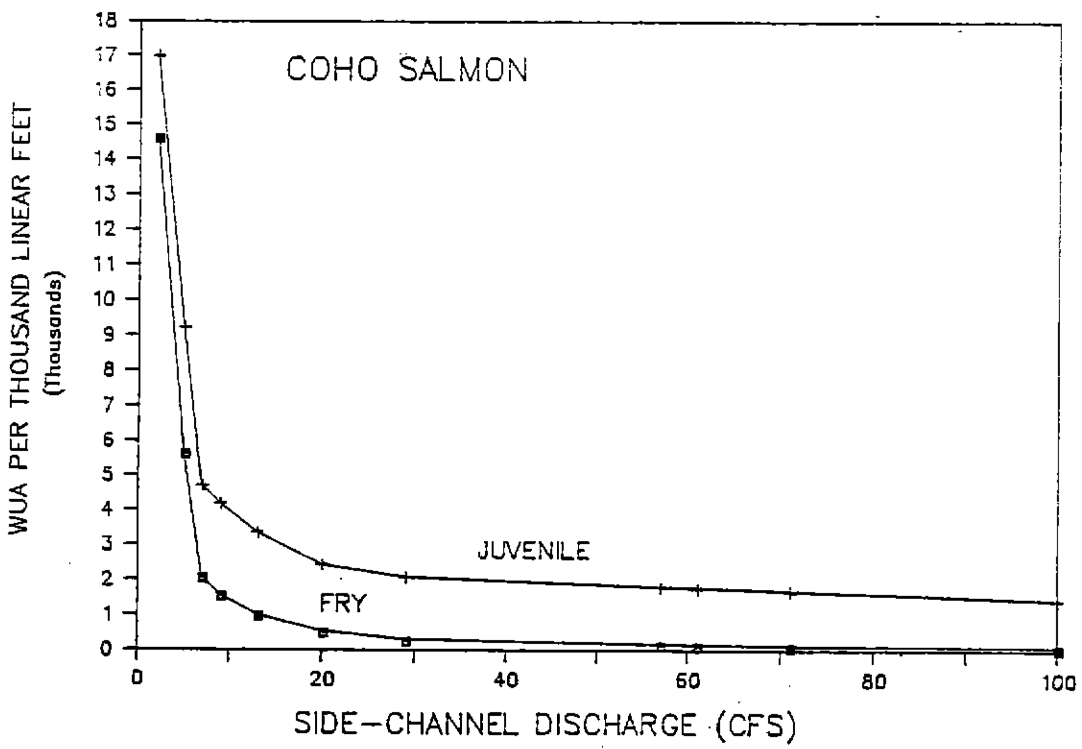


Figure 11. Profile of transect 3 in the Rush Creek side-channel and the amount of weighted usable area (square feet/thousand linear feet) available to fry and juvenile coho salmon.

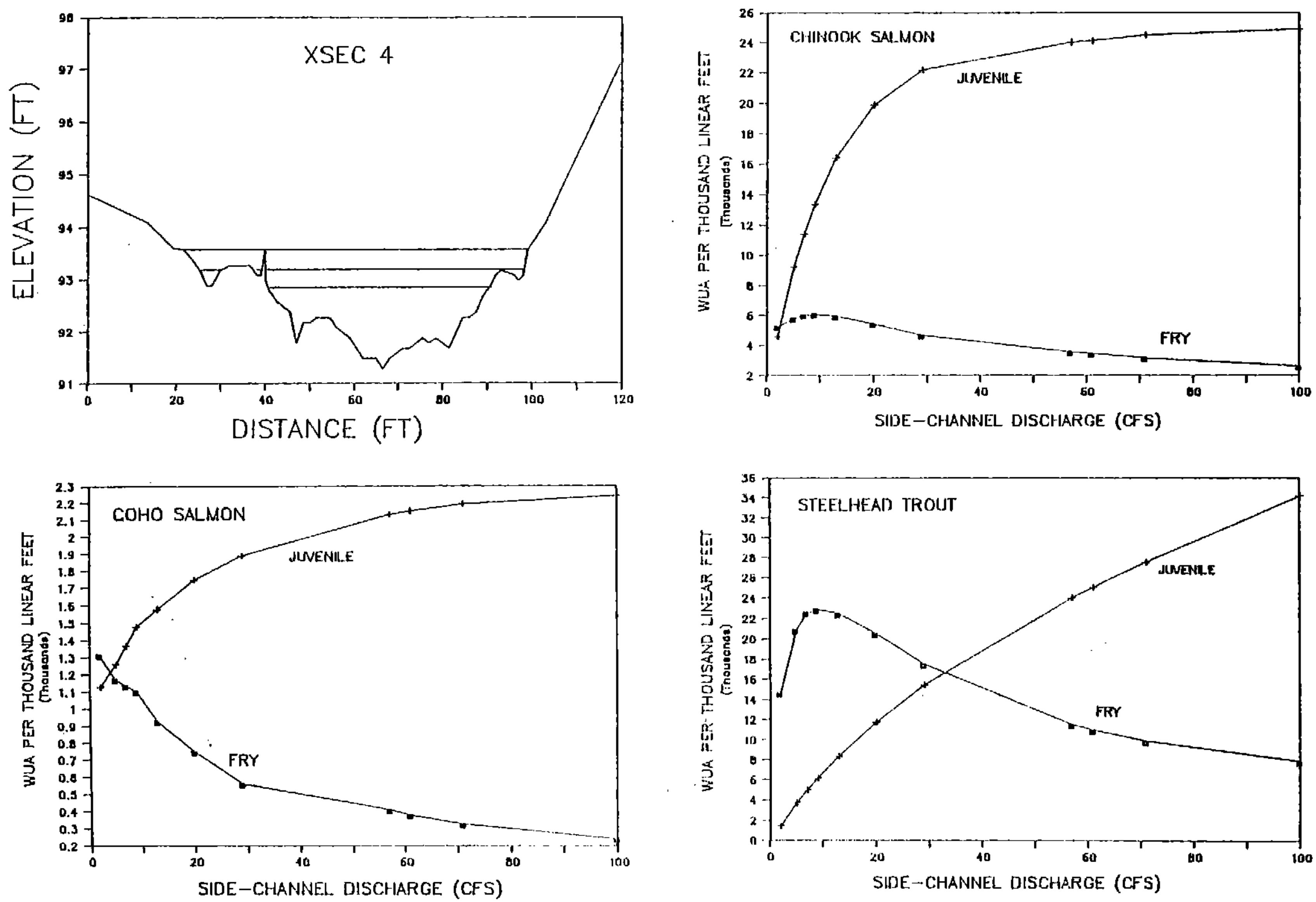


Figure 12. Profile of transect 4 in the Rush Creek side-channel and the amount of weighted usable area (square feet/thousand linear feet) provided by transect 4 for fry and juvenile anadromous salmonids.

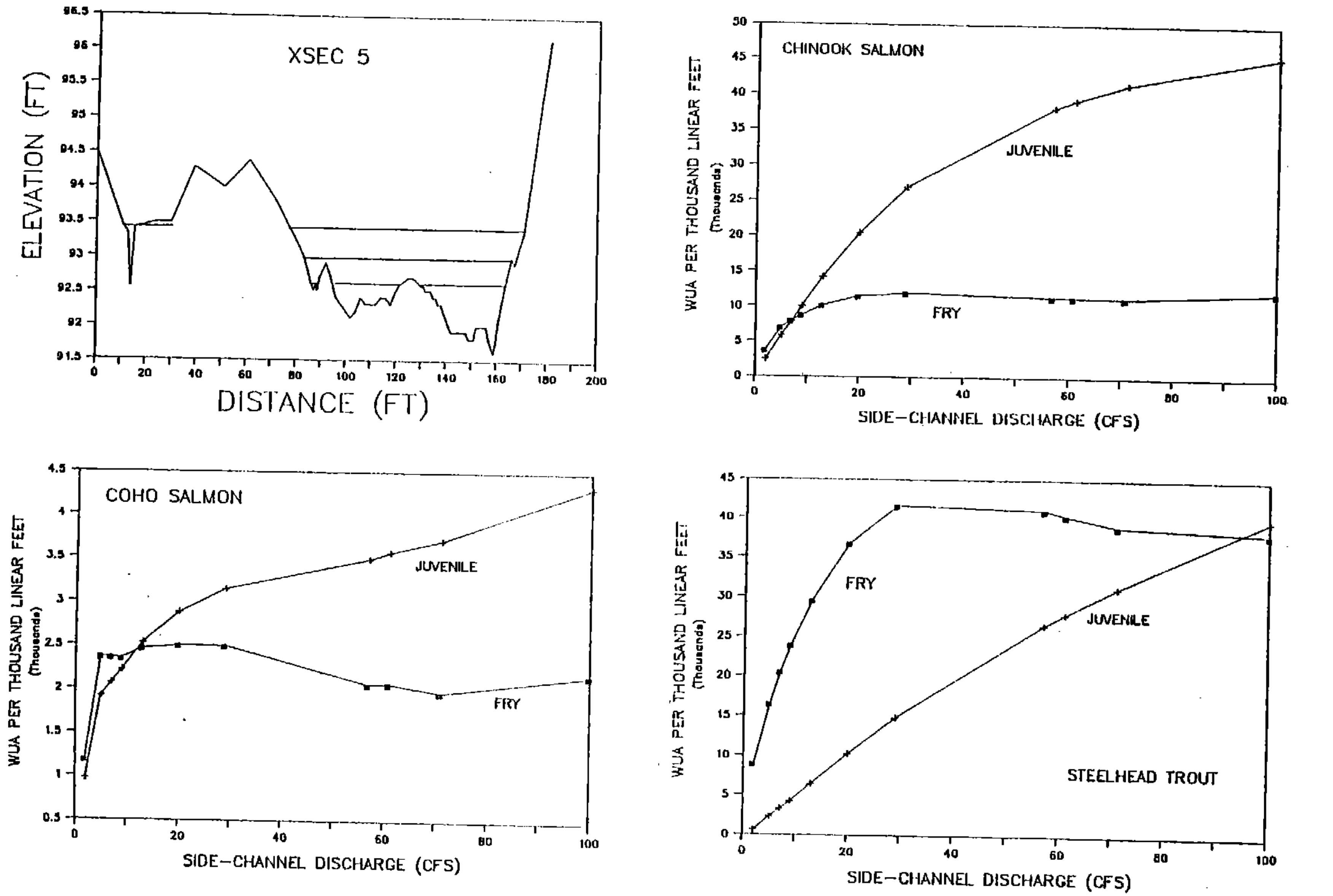


Figure 13. Profile of transect 5 in the Rush Creek side-channel and the amount of weighted usable area (square feet/thousand linear feet) provided by transect 5 for fry and juvenile anadromous salmonids.

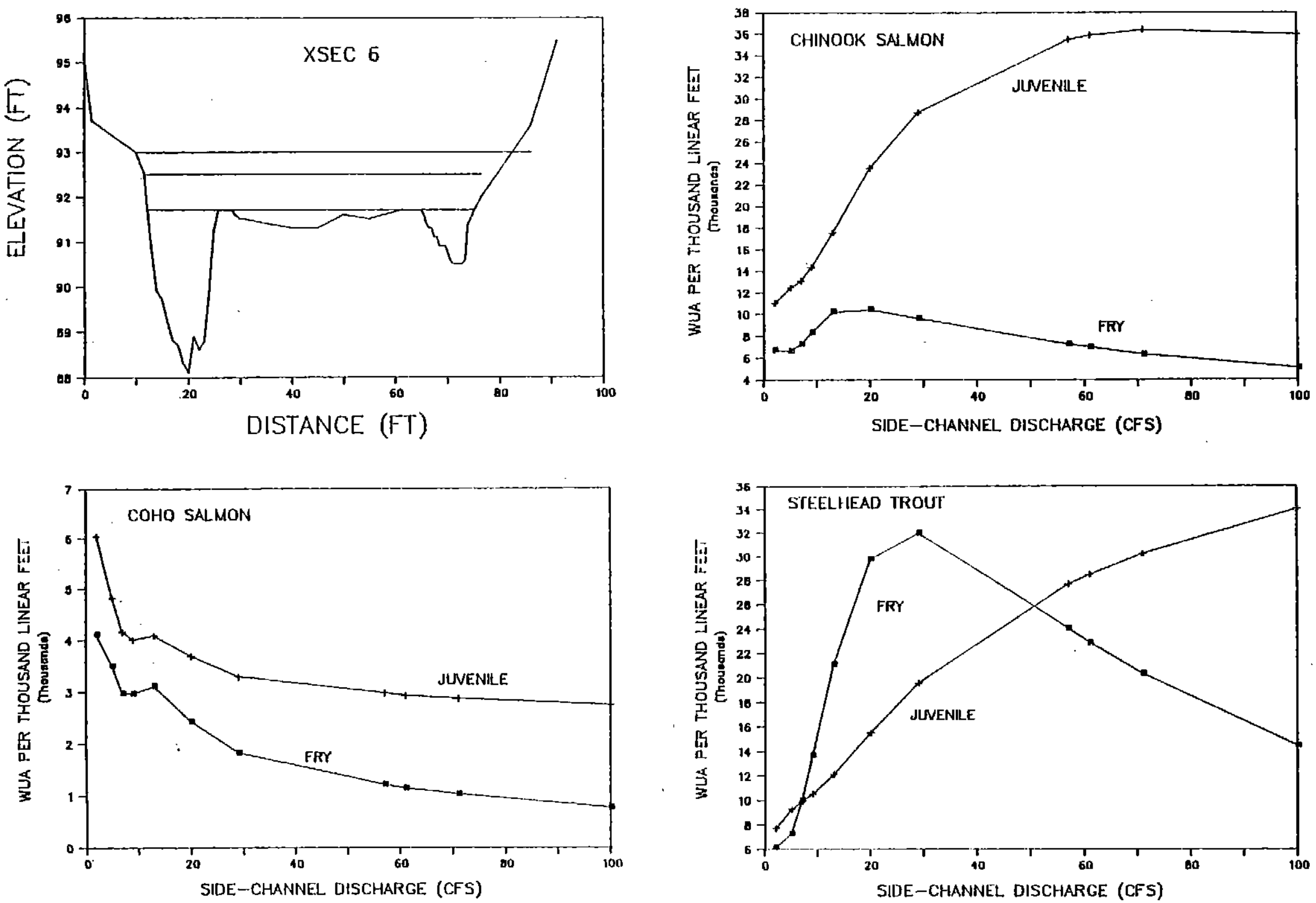


Figure 14. Profile of transect 6 in the Rush Creek side-channel and the amount of weighted usable area (square feet/thousand linear feet) provided by transect 6 for fry and juvenile anadromous salmonids.

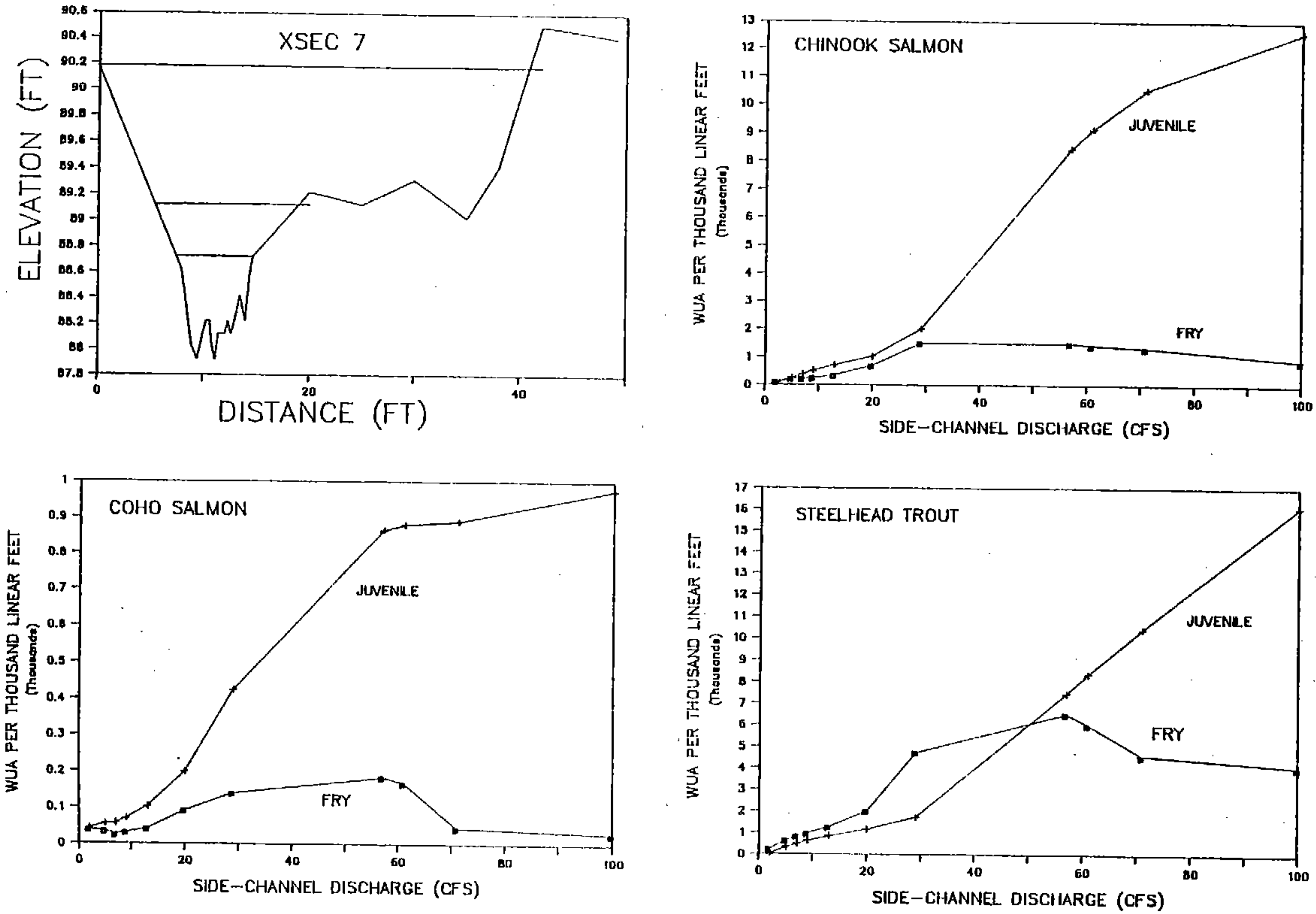


Figure 15. Profile of transect 7 in the Rush Creek side-channel and the amount of weighted usable area (square feet/thousand linear feet) provided by transect 7 for fry and juvenile anadromous salmonids.

Bucktail Side-Channel

Chinook Salmon - Bucktail side-channel provides the best fry chinook salmon habitat flow relationship than any other side-channel constructed along the Trinity River in 1988. The total WUA provided by Bucktail side-channel ranges between 977 and 1,893 square feet (Figure 16). However, the total habitat continues to increase above the range of flows simulated (2 to 340 cfs). The pool habitat represented by transect 2 provides the greatest amount of WUA per thousand linear feet (Figure 18). The presence of both a backwater and a major bench along the right bank compliment each other in maximizing available fry chinook habitat at a side-channel discharge of 30 cfs. Secondary benches are also located along the right bank of the riffle run habitat represented by transect 1 and the left bank of the riffle run habitat represented by transect 3 (Figures 17 and 19). When these benches become inundated during high flows they significantly increase fry chinook salmon habitat throughout the side-channel.

The same physical habitat features that benefited fry chinook salmon habitat also created excellent juvenile chinook salmon habitat. Total juvenile chinook salmon habitat ranged between 1,124 and 10,630 square feet of WUA, and habitat continued to increase with increasing flows. Large gains in habitat occurred when the benches located along each transect became inundated increasing the area of slow water velocity habitats. For example, when the bench located along the right bank of the pool habitat became inundated the habitat width increased by 32 feet, increasing surface area by over 70 percent (Figure 18).

Coho Salmon - The habitat flow relationships for fry and juvenile coho salmon are similar to the habitat flow relationships for chinook salmon but with reduced habitat areas. Total fry coho salmon habitat fluctuated between 208 and 530 square feet of WUA (Figure 16). The greatest amount of habitat is provided at low side-channel discharges less than 6 cfs. Habitat increases slightly when each of the benches first become flooded. The pool habitat provides more fry WUA per thousand linear feet of stream than both the upper and lower run-riffle habitats combined. Fry habitat in the pool peaks at side-channel discharges of 2 and 98 cfs (Figure 18). The second habitat peak is created by the initial flooding of the large bench located along the pools right bank.

The total habitat for juvenile coho salmon ranges between 346 and 1,079 square feet of WUA (Figure 16). The full habitat potential for juvenile coho salmon was not reached under the range of flows simulated. Habitat across the upper and lower run-riffle sections increased with flow, while the habitat provided by the pool began to level off and decrease slightly when the side-channel discharge exceeded 270 cfs.

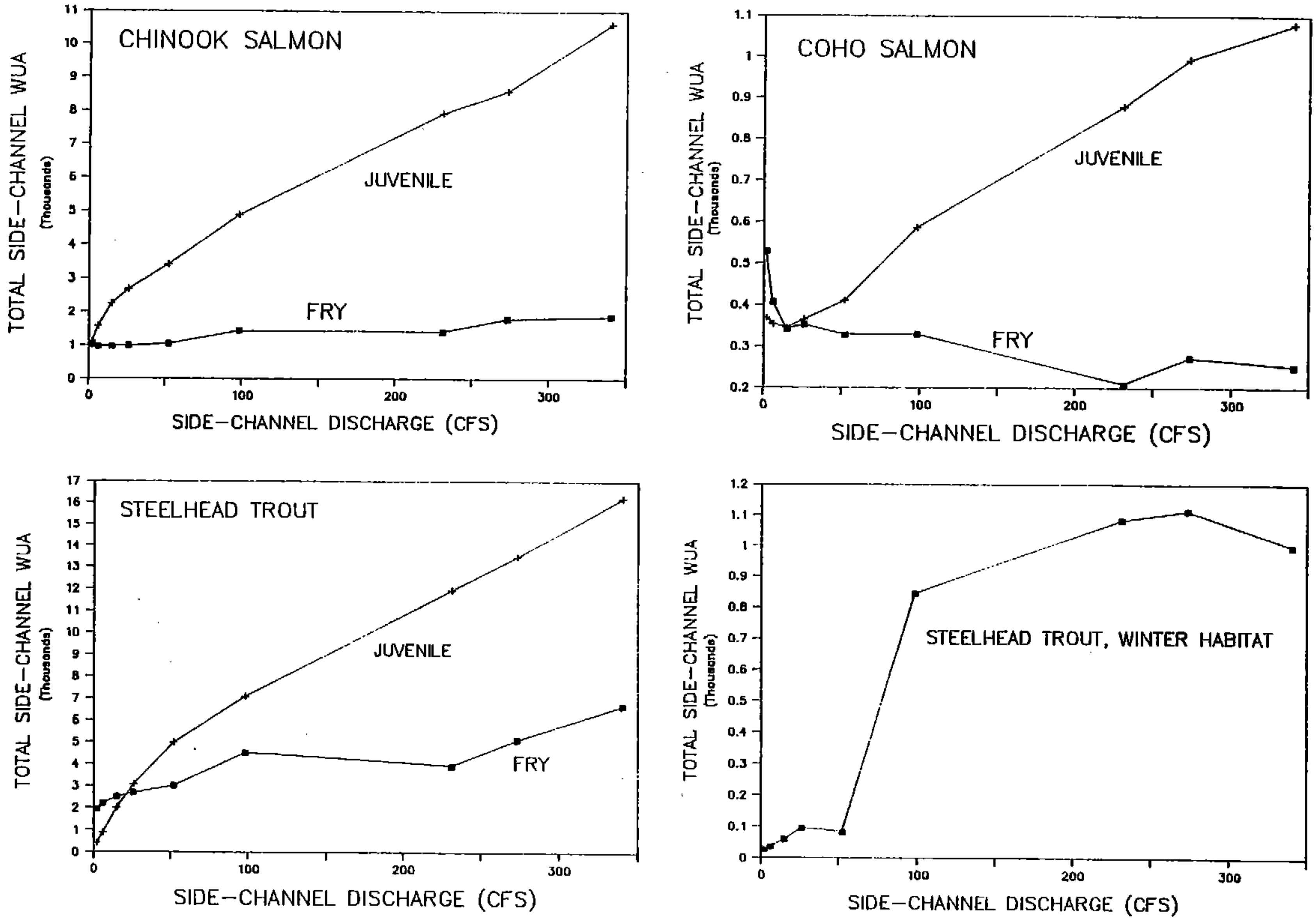


Figure 16. Total weighted usable area (WUA) for fry and juvenile anadromous salmonids available in the Bucktail side-channel, 1988.

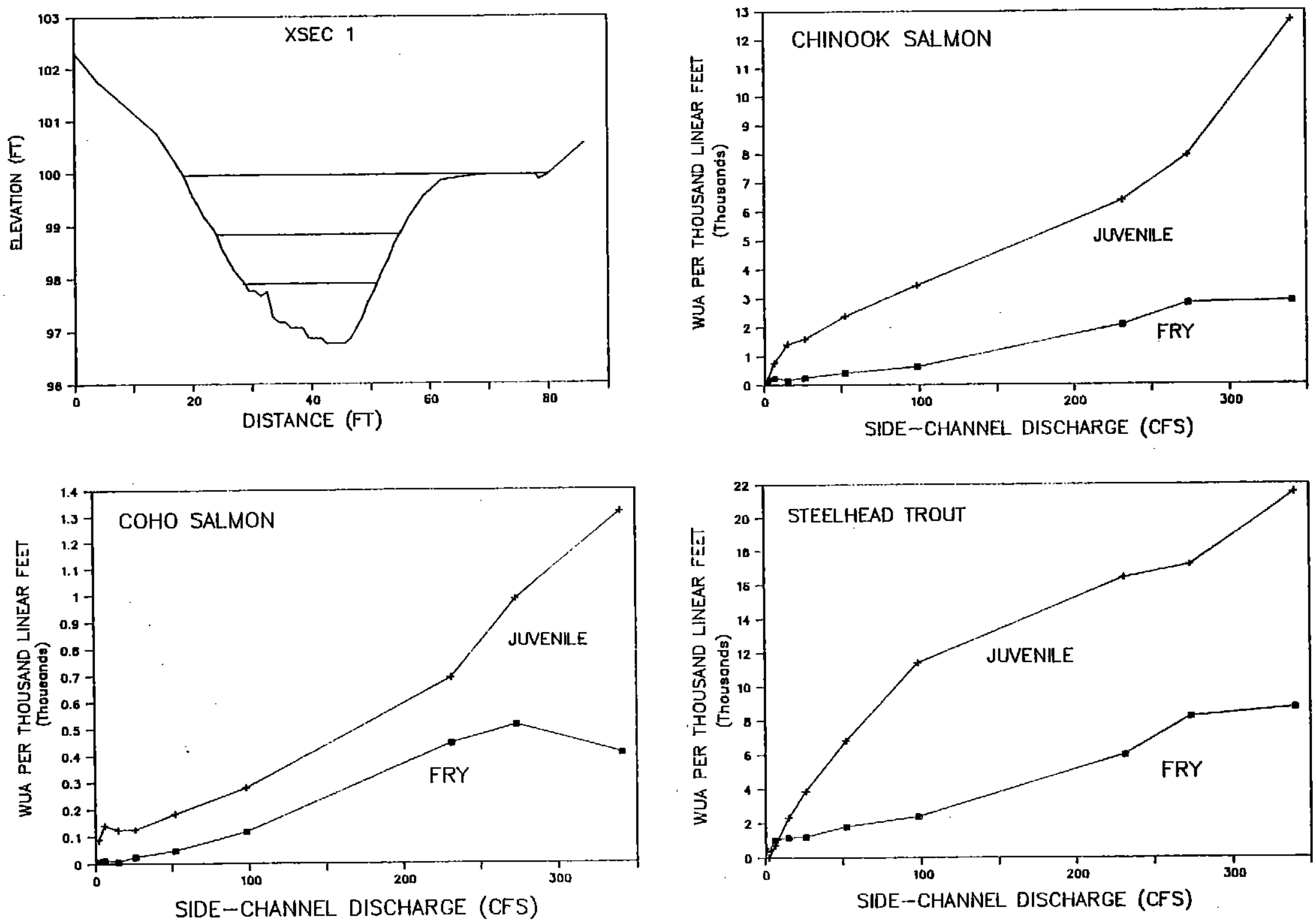


Figure 17. Profile of transect 1 in the Bucktail side-channel and the amount of weighted usable area (square feet/thousand linear feet) provided by transect 1 for fry and juvenile anadromous salmonids.

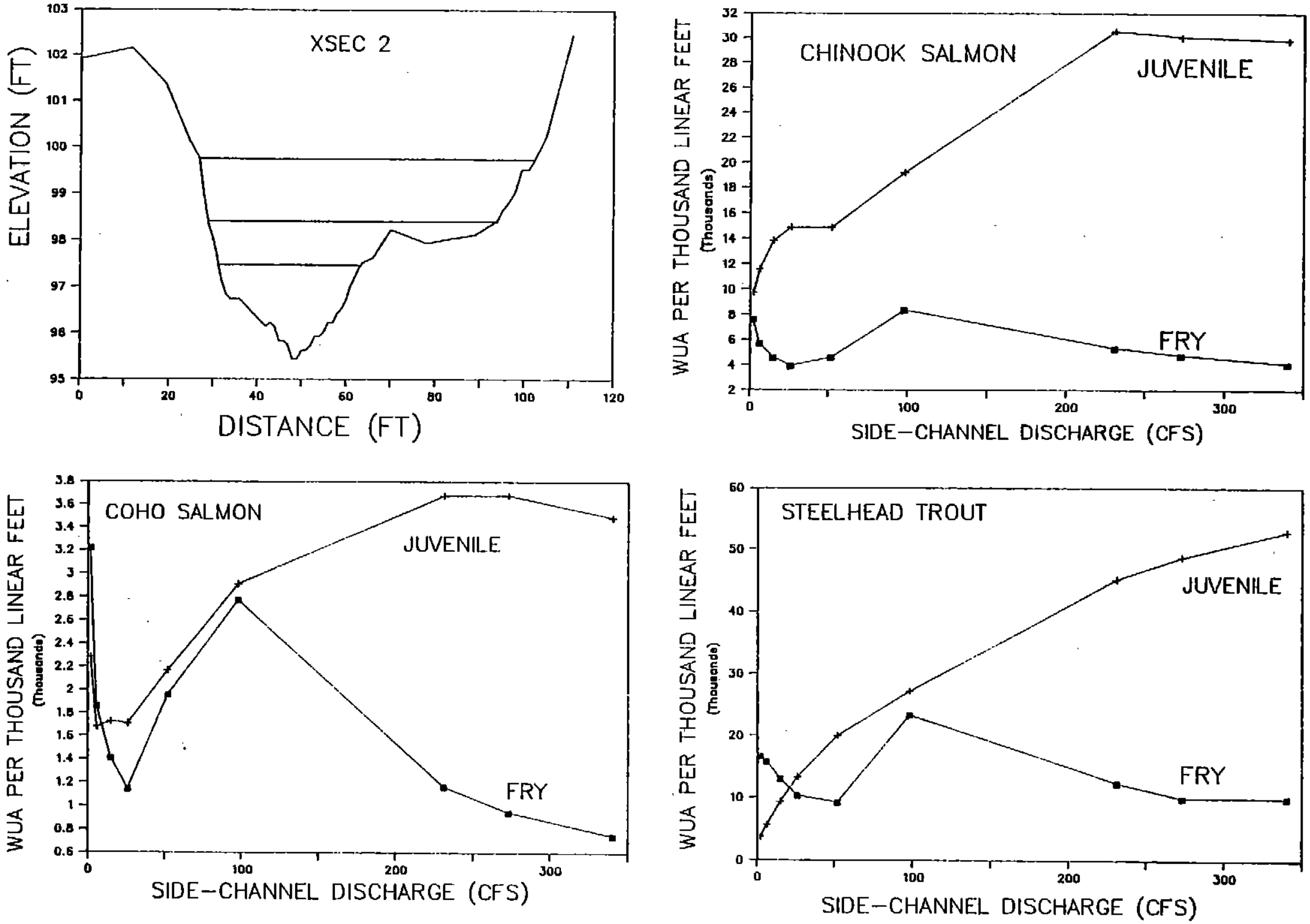


Figure 18. Profile of transect 2 in the Bucktail side-channel and the amount of weighted usable area (square feet/thousand linear feet) provided by transect 2 for fry and juvenile anadromous salmonids.

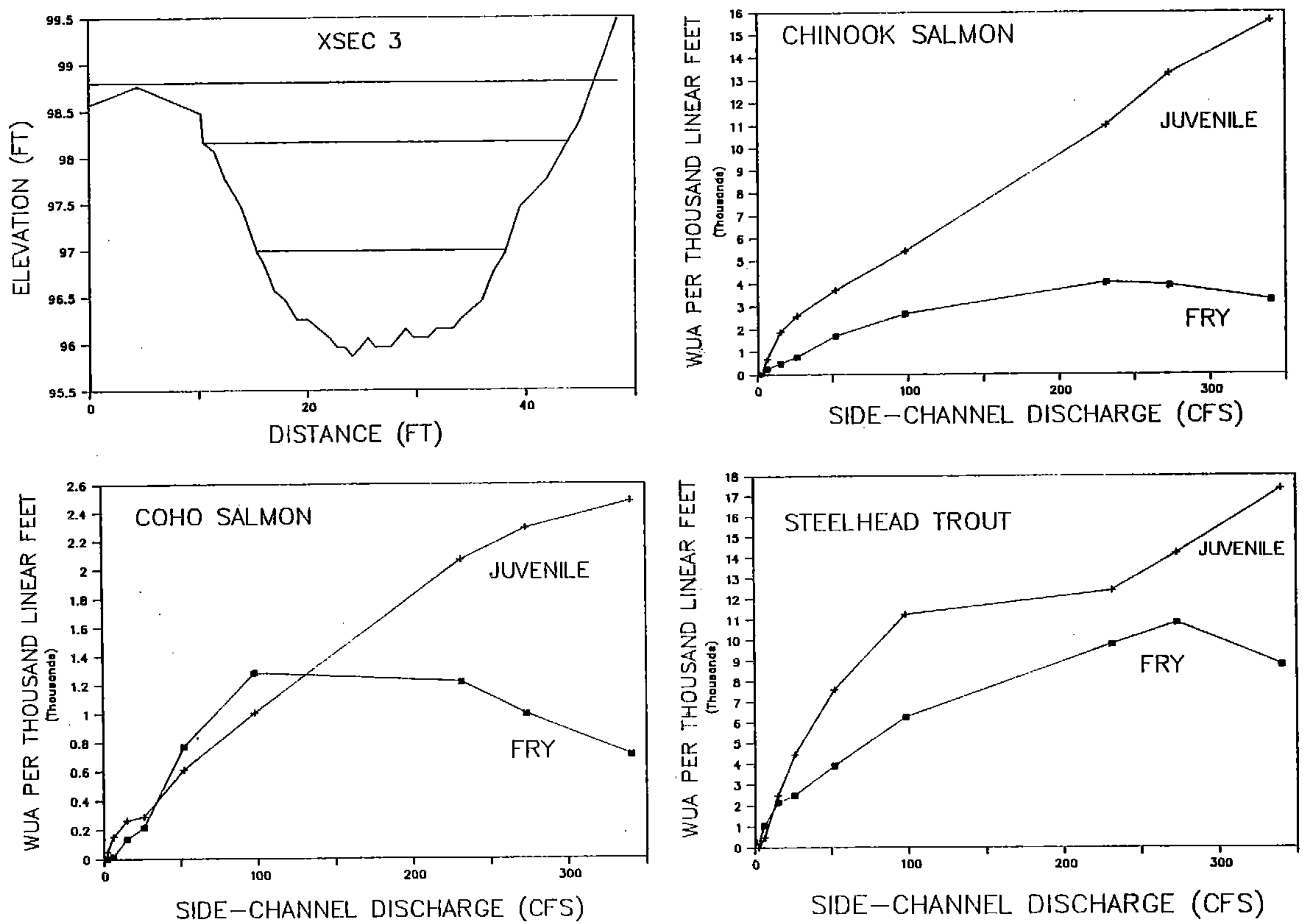


Figure 19. Profile of transect 3 in the Bucktail side-channel and the amount of weighted usable area (square feet/thousand linear feet) provided by transect 3 for fry and juvenile anadromous salmonids.

Steelhead trout - Fry steelhead trout habitat increased with increasing flow in the run-riffle habitats primarily because of the increased habitat area provided by the benches that became flooded at higher discharges. The pool provided nearly twice as much WUA per thousand linear feet of stream as both run-riffle habitats. Fry steelhead trout habitat provided by the pool peaked when the side-channel discharge reached 100 cfs. Juvenile steelhead trout habitat increases throughout all of the simulated discharges. Total juvenile steelhead trout habitat increases from 416 to 10,630 square feet of WUA (Figures 16 through 19).

Over-wintering habitat for juvenile steelhead is nearly nonexistent for flows less than 50 cfs, however, over-wintering habitat increases dramatically as the side-channel flows increase over 90 cfs (Figure 16). At these higher flows small boulders and cobbles that are present along the right bench of the pool become available for juvenile steelhead trout to use as refuge cover.

Steiner Flat Side-Channel

Chinook Salmon - The greatest amount of fry chinook salmon habitat in the Steiner Flat side-channel is provided by low flows. Approximately 6,787 square feet of fry chinook salmon WUA are available under a discharge of 5 cfs (Figure 20). As side-channel flows increase, fry habitat decreases.

Juvenile chinook salmon habitat peaks at 20 cfs when approximately 20,440 square feet of WUA are available. Habitat decreases steadily for flows between 20 and 120 cfs (Figure 20). The habitat flow relationship then stabilizes for discharges over 120 cfs at approximately 10,200 square feet of WUA. The habitat flow relationship for the Steiner Flat side-channel decreases as flows increase because of the steep banks that border nearly the entire length of the side-channel. At lower flows, however, the Steiner Flat side-channel provides the greatest total amount of WUA for juvenile chinook salmon when compared to the other constructed side-channels. Placement of hydraulic controls, creation of islands and point deflectors, to slow water velocities and create backwaters increased habitat over what would have probably been provided otherwise.

Coho Salmon - The two long run habitats, one located at the upper end of the side-channel (transect 1) and the other located in the center of side-channel (transect 4), provide most of the available fry and juvenile coho salmon habitat in the Steiner Flat side-channel (Figure 21 and 24). The best discharges to optimize fry and juvenile coho salmon habitat would range between 140 and 160 cfs. At these discharges over 1,800 square feet of fry coho salmon WUA and 1,500 square feet of juvenile coho salmon WUA are available.

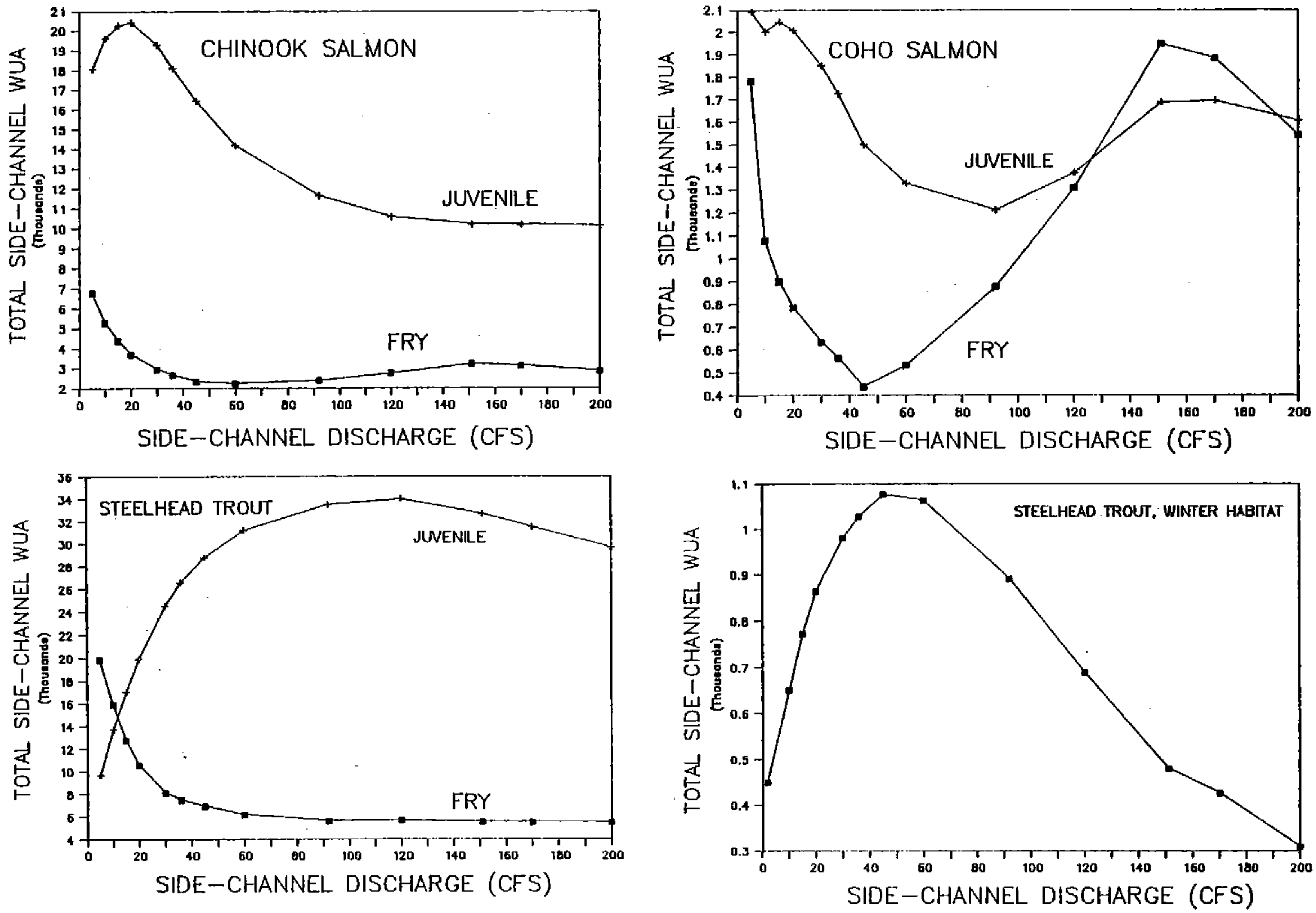


Figure 20. Total weighed usable area (WUA) for fry and juvenile anadromous salmonids available in the Steiner Flat side-channel, 1988.

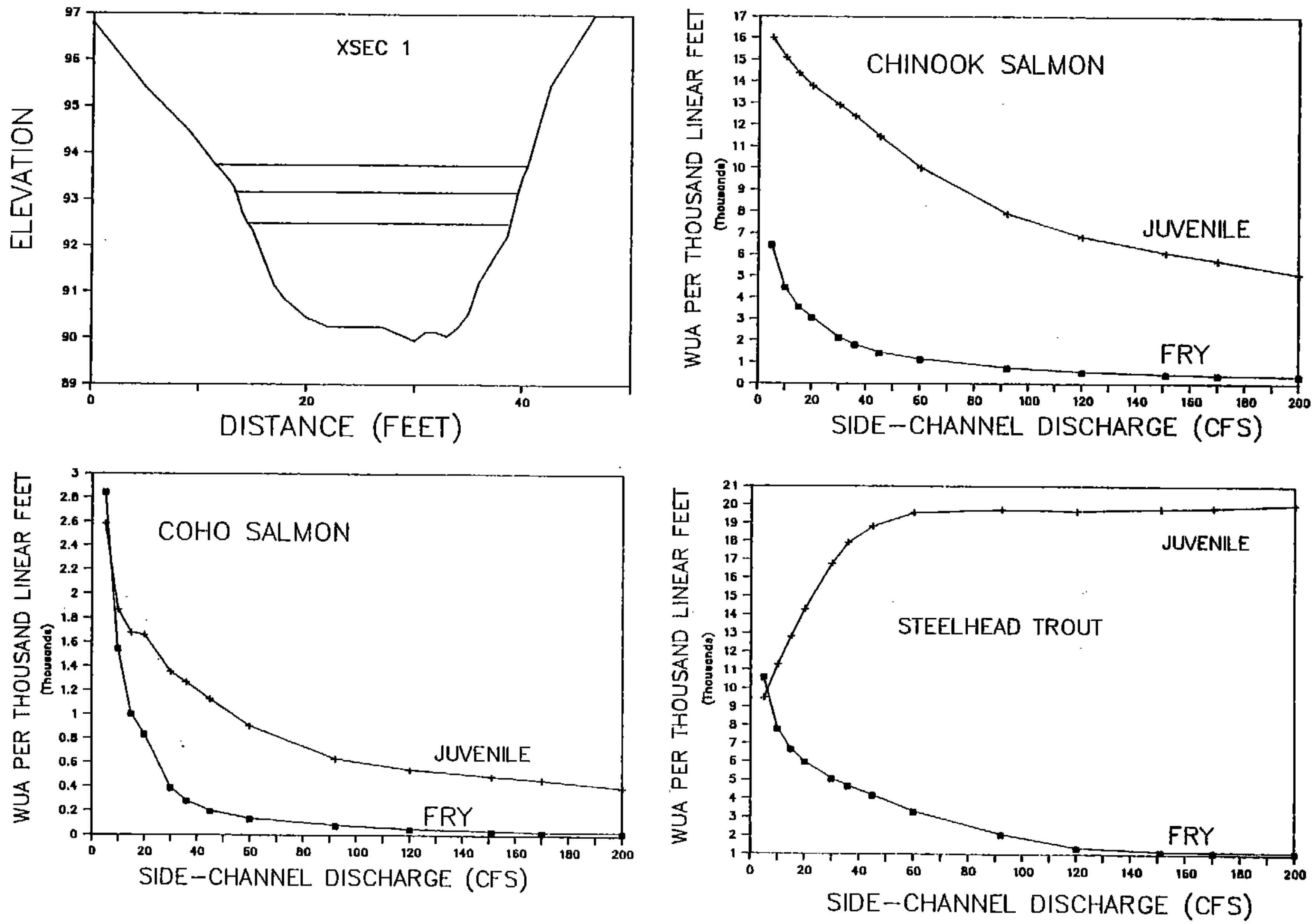


Figure 21. Profile of transect 1 in the Steiner Flat side-channel and the amount of weighted usable area (square feet/thousand linear feet) provided by transect 1 for fry and juvenile anadromous salmonids.

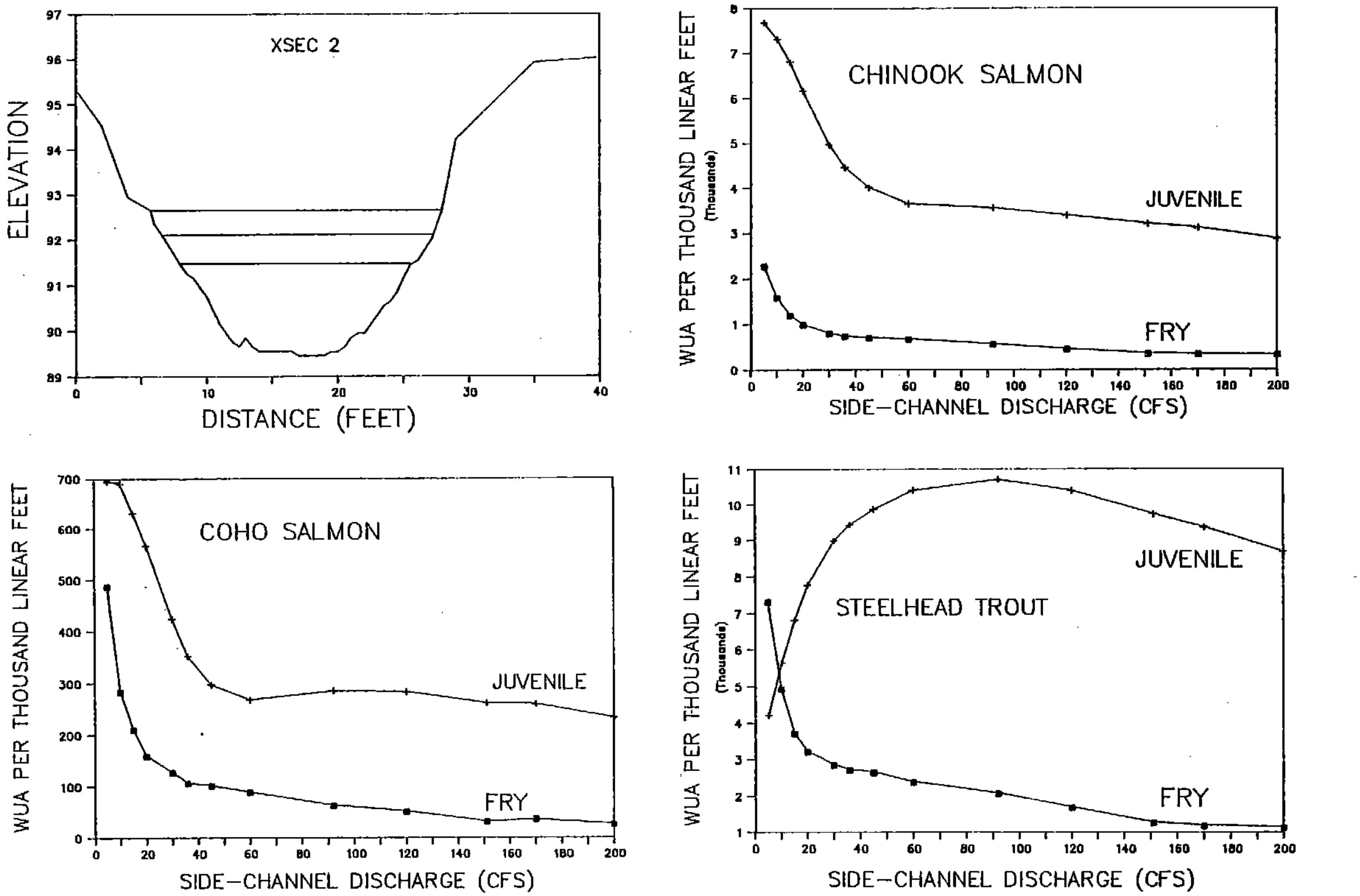


Figure 22. Profile of transect 2 in the Steiner Flat side-channel and the amount of weighted usable area (square feet/thousand linear feet) provided by transect 2 for fry and juvenile anadromous salmonids.

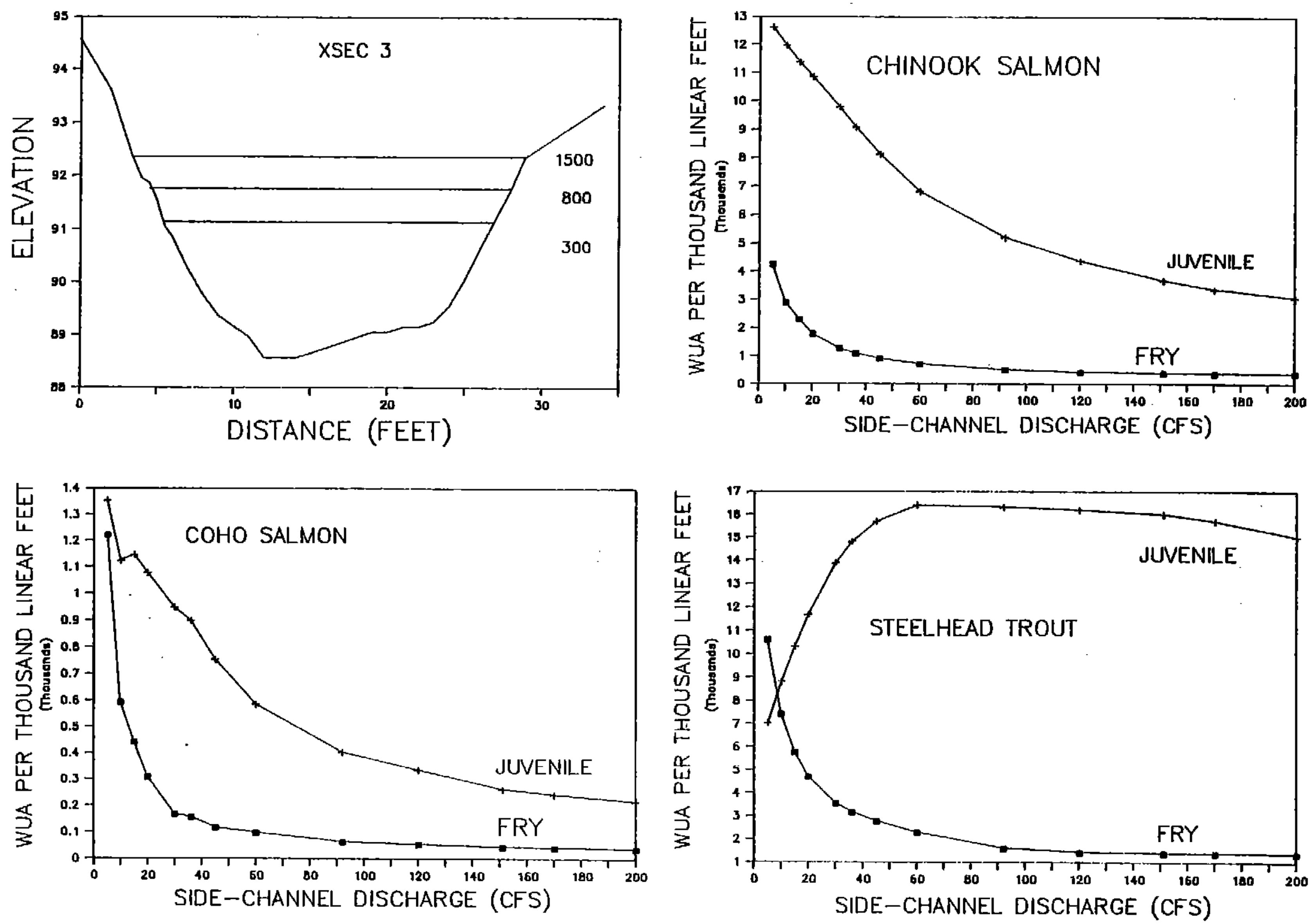


Figure 23. Profile of transect 3 in the Steiner Flat side-channel and the amount of weighted usable area (square feet/thousand linear feet) provided by transect 3 for fry and juvenile anadromous salmonids.

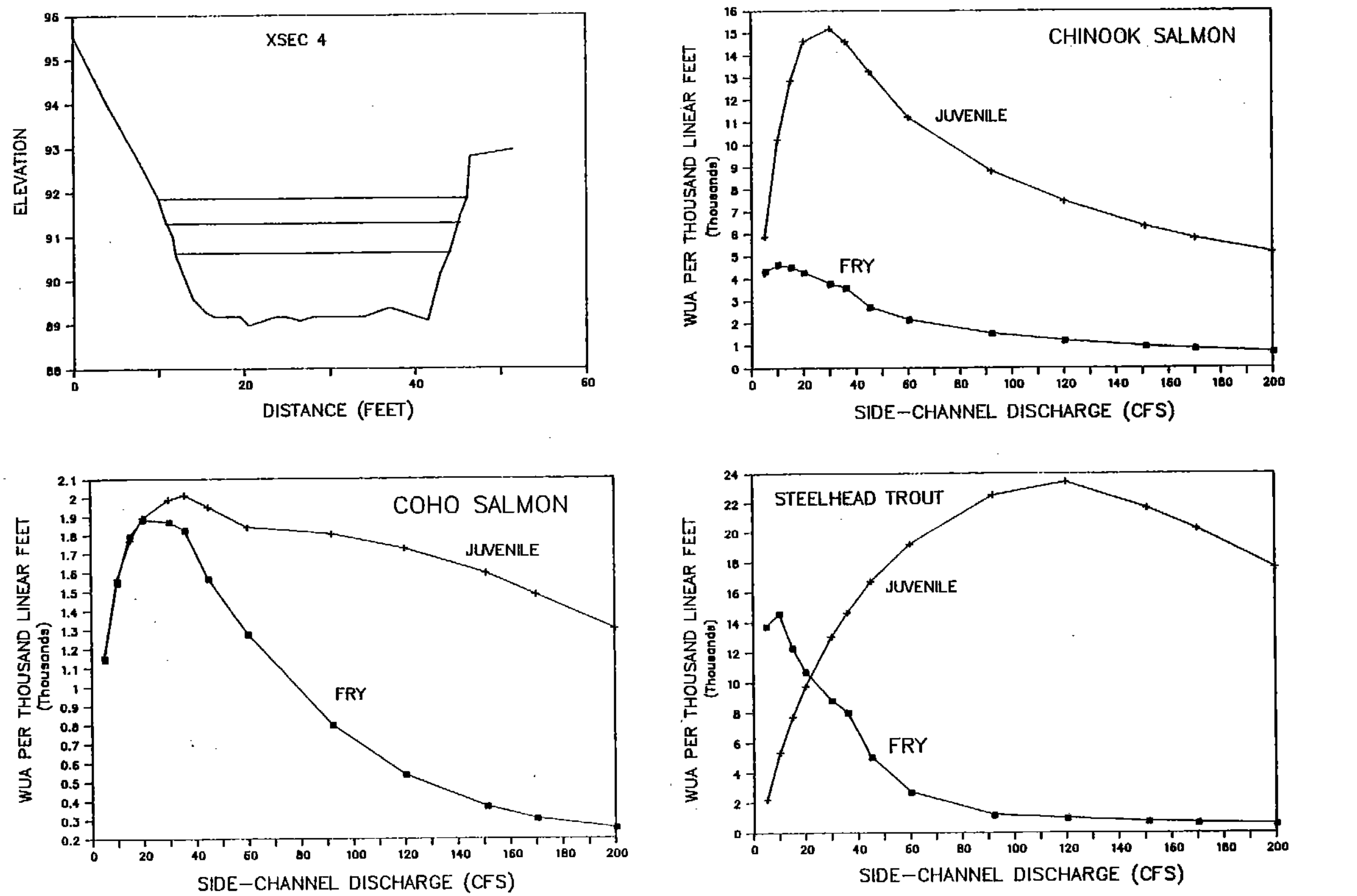


Figure 24. Profile of transect 4 in the Steiner Flat side-channel and the amount of weighted usable area (square feet/thousand linear feet) provided by transect 4 for fry and juvenile anadromous salmonids.

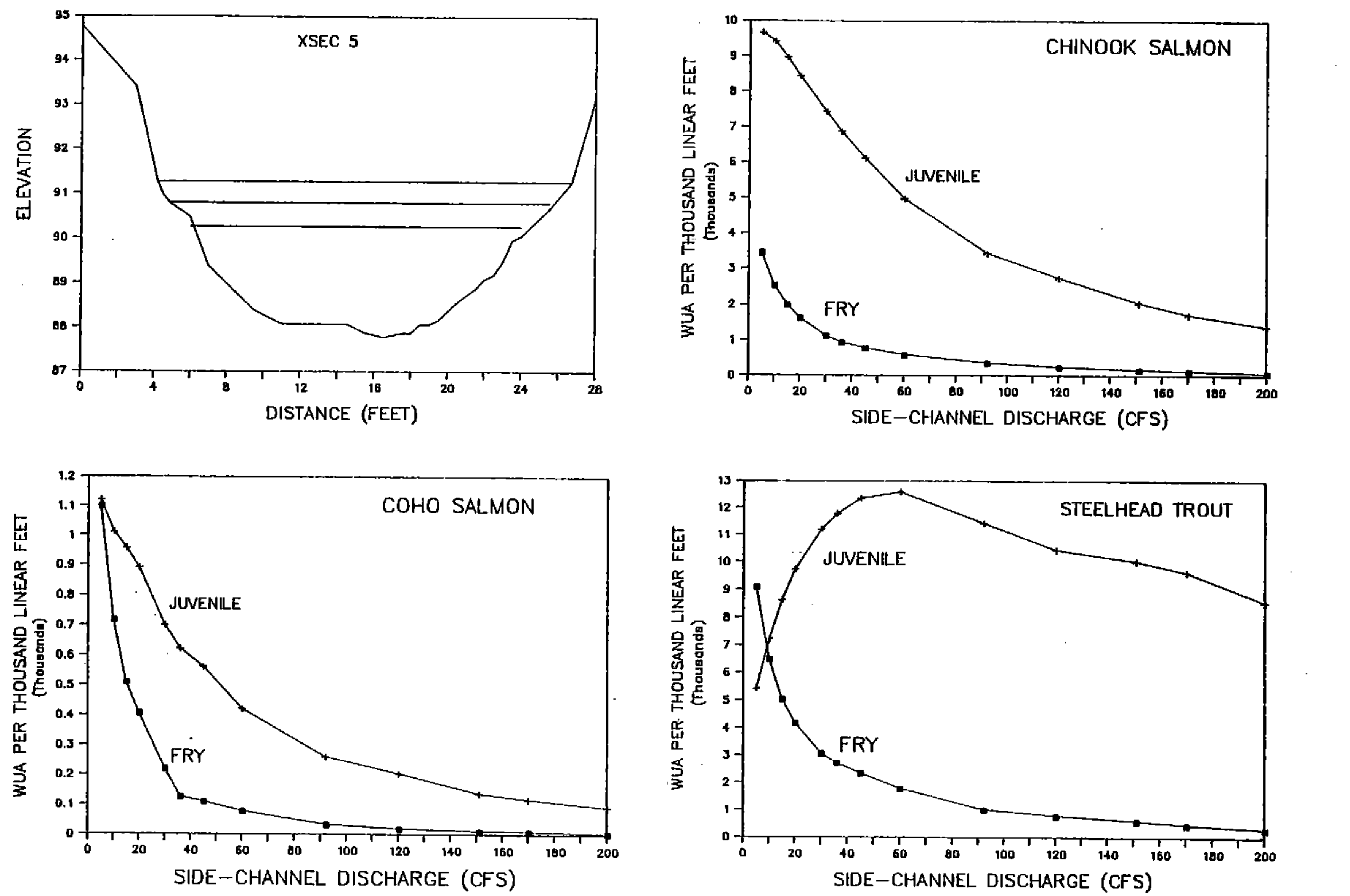


Figure 25. Profile of transect 5 in the Steiner Flat side-channel and the amount of weighted usable area (square feet/thousand linear feet) provided by transect 5 for fry and juvenile anadromous salmonids.

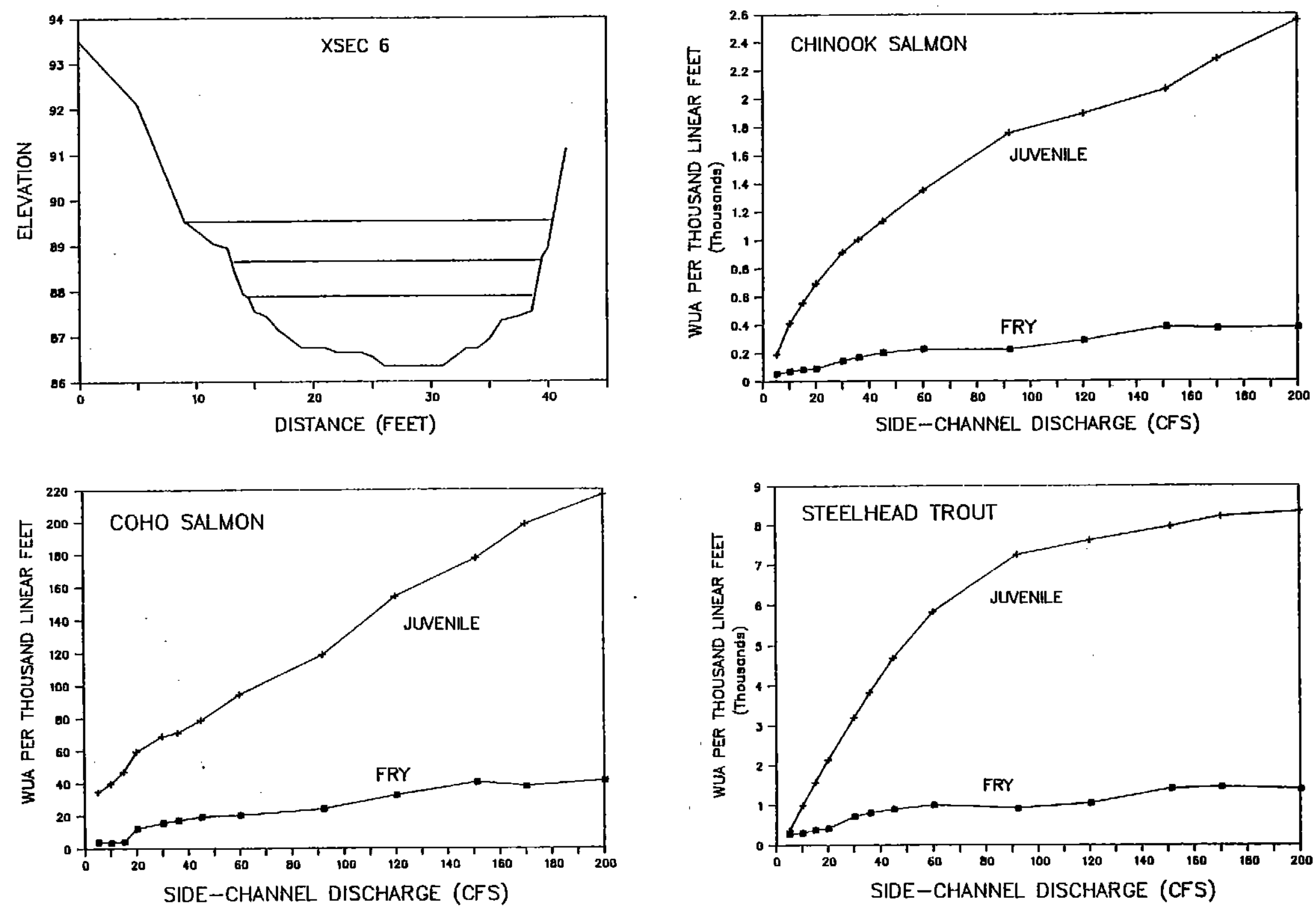


Figure 26. Profile of transect 6 in the Steiner Flat side-channel and the amount of weighted usable area (square feet/thousand linear feet) provide by transect 6 for fry and juvenile anadromous salmonids.

Steelhead Trout - Fry steelhead trout habitat decreases rapidly from 19,896 square feet of WUA to 8,117 square feet of WUA as flows increase from 5 cfs to 30 cfs (Figure 20). As flows begin to exceed 60 cfs the available habitat becomes fairly stable at 5,500 square feet of WUA. At these flow levels all of the fry steelhead trout habitat would be limited to the side-channel margins as midchannel water velocities become to swift.

Juvenile steelhead trout habitat increases with side-channel flow. Maximum juvenile steelhead trout habitat, 34,000 square feet of WUA, is reached at a side-channel discharge of 120 cfs (Figure 20).

Compared to summer rearing habitat estimates, over-wintering habitat for juvenile steelhead trout is extremely limited. Optimum over-wintering under the current habitat conditions occur at discharges between 30 to 60 cfs when just over 1,000 square feet of WUA are available (Figure 20).

DISCUSSION

Habitat Gains

Construction of the four side-channels increased fry chinook salmon habitat by 10,461 square feet of WUA. When fry chinook salmon habitat provided by the upper three side-channels (Cemetery, Rush Creek, and Bucktail) is compared to fry chinook salmon habitat available in the mainstem (300 cfs), between Lewiston and Douglas City, side-channels increase available habitat by 0.11 percent (Table 4). If we assume that 2,000 cfs habitat outputs for the main-stem are representative of pre-project habitat conditions for fry chinook salmon, and Bucktail side-channel is selected as a representative side-channel, then approximately 523 Bucktail type side-channels would be required to produce pre-project habitat conditions under a river discharge of 300 cfs. The construction of 53.6 miles of side-channels along 19 miles of river between Lewiston and Douglas City would be required to meet preproject fry chinook salmon habitat goals. Based on these assumptions, and side-channel habitat conditions as they occurred in the spring 1989, side-channel construction alone will not provide the needed habitat quantities required to rehabilitate the main-stem to pre-project habitat conditions, however, side-channel construction still provides a valuable method of increasing available habitat and should continue.

Table 4. Comparison of fry chinook salmon habitat in the main stem between Lewiston and Douglas City with newly constructed side-channels also located between Lewiston and Douglas City.

SOURCE	DISCHARGE	WUA	DISCHARGE	WUA
Trinity River (Lewiston - DC)	300	628,274	2,000	1,134,740
Side-Channels				
Cemetery	14	1,153	135	967
Rush Creek	13	4,741	71	5,435
Bucktail	26	967	340	1,915
Total		6,861		8,317
Percent habitat gain		0.11%		0.73%

FISH POPULATION ESTIMATES AND WEIGHTED USEABLE AREA

As part of a coordinated effort with our side-channel habitat evaluations, the Trinity River Restoration Program (TRRP) conducted salmonid population sampling within the same habitat reaches that were modeled using IFIM. The goal of this coordinated effort was to develop a relationship between WUA and fish density.

The TRRP developed fry chinook salmon population estimates for each identified habitat reach by using equal-effort-depletion methods (USFWS 1989). Population estimates could not be developed for the pond habitat reach in the Rush Creek side-channel because the reach was to deep to be sampled effectively with backpack electrofishers. Population estimates were also not developed for the run/feathered bar and "W" shaped channel habitat reaches in the Rush Creek side-channel because block nets could not be set.

For the upper three side-channels (Cemetery, Rush Creek, and Bucktail) fry chinook salmon populations correlate well with WUA estimates (Figure 27). However, the Steiner Flat side-channel, which is located further downstream (RM 90), contained the greatest amount of WUA, yet only yielded the second highest fry chinook salmon population estimate. This is probably a factor of its location further down river below the major spawning areas in the upper river below Lewiston. Although the relationship between total side-channel WUA and fry chinook salmon numbers is good, when individual habitat reach WUA estimates are compared

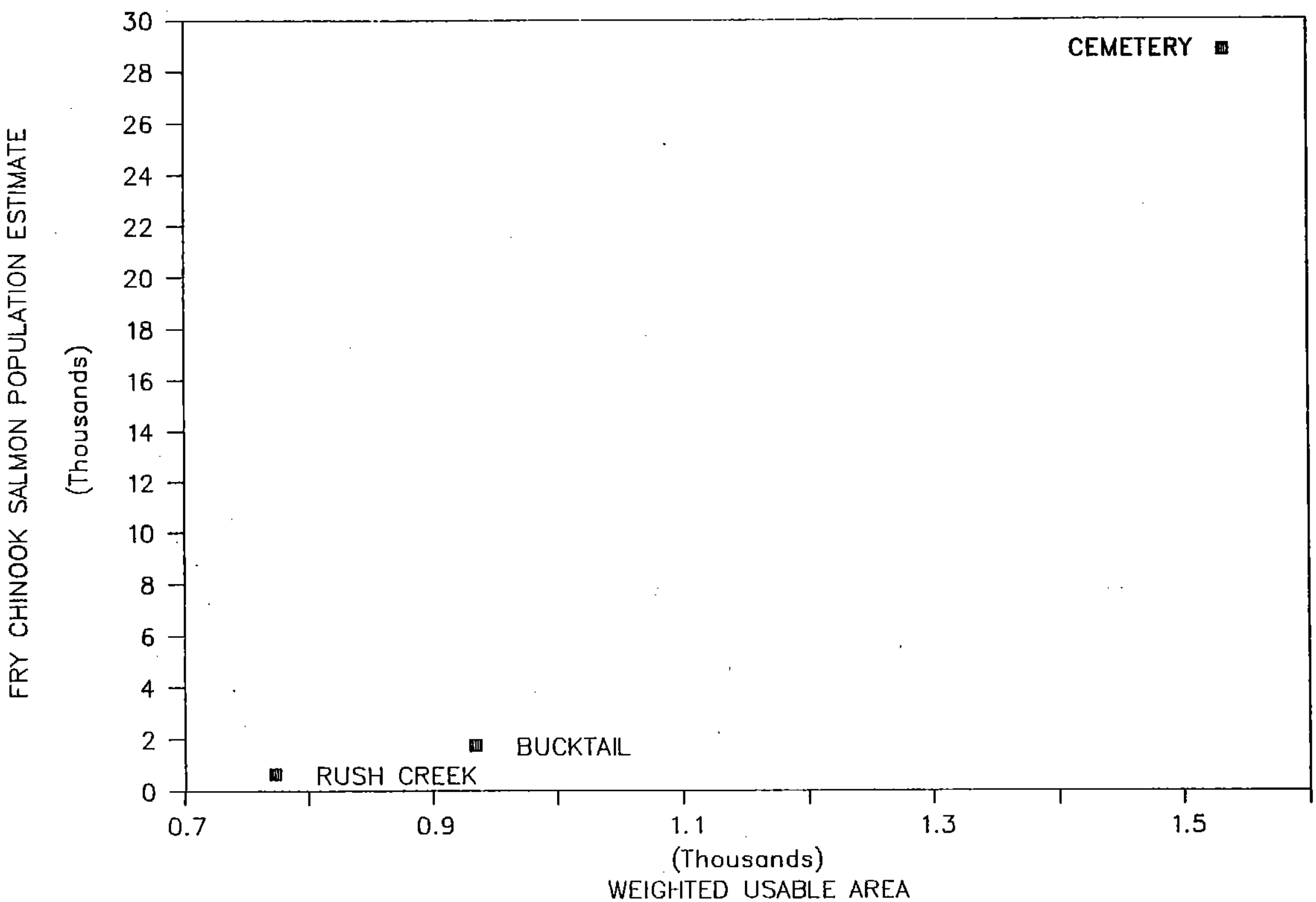


Figure 27. Weighted usable area and fry chinook salmon populations for the three upper river side-channels constructed in 1988.

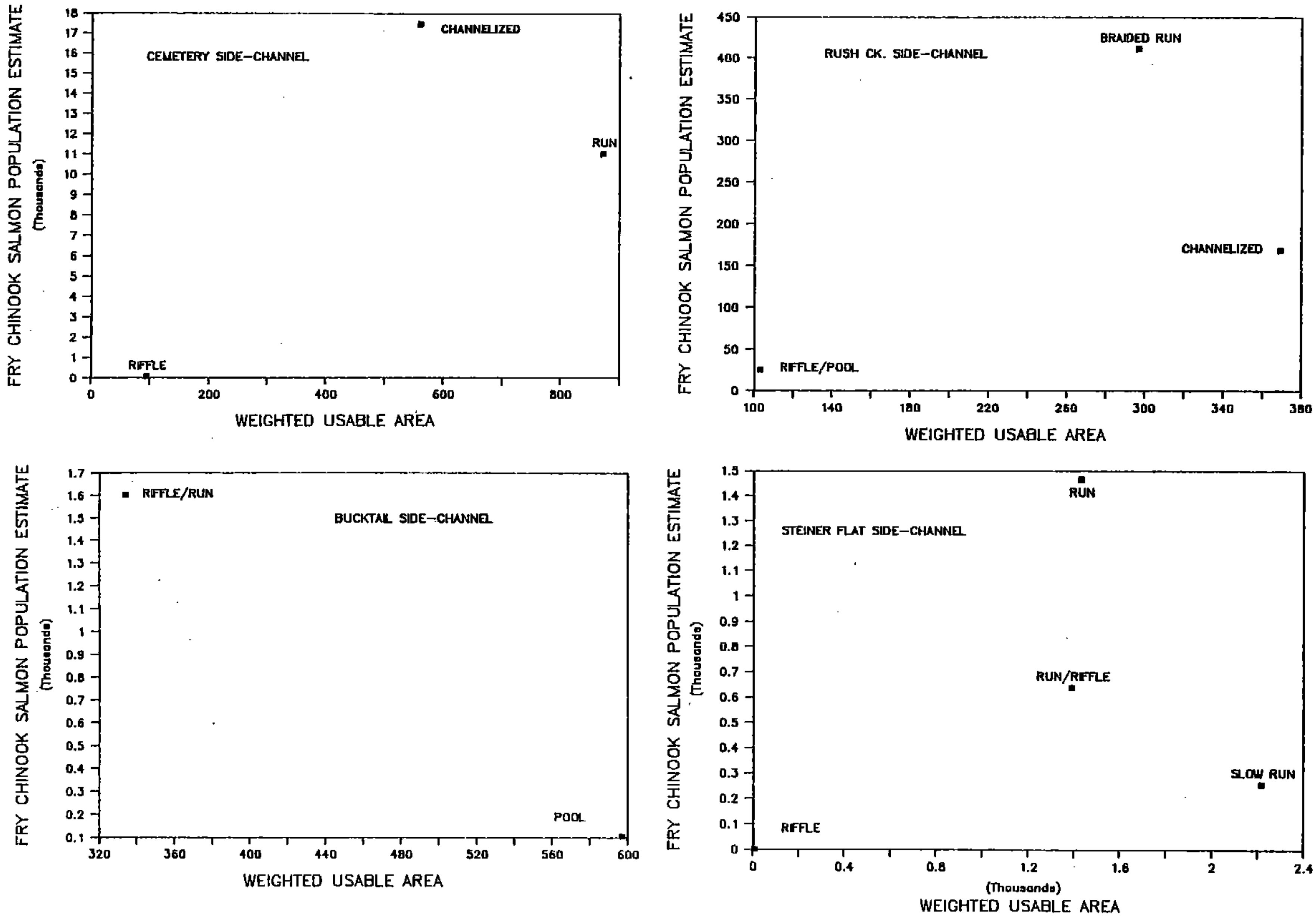


Figure 28. Weighted usable area and fry chinook salmon population estimates for each habitat type in the four constructed side-channels, 1989.

with their corresponding fry chinook salmon population estimates the relationship between WUA and number of fry chinook salmon failed to yield a significant relationship (Figure 28). However, with the exception of the Bucktail side-channel, fry chinook salmon numbers were generally higher in habitat reaches with higher WUA estimates. A comparison between fry chinook salmon population estimates and WUA for each habitat reach during March 1989 is presented in Table 5.

Table 5. March 1989 fry chinook salmon population estimates (95% CI) and weighted usable area predictions for selected habitat reaches within side-channels constructed by the Trinity River Restoration Program and Bureau of Land Management.

Side-Channel (discharge cfs)	Habitat Reach	WUA	Fry Chinook Population Est.
Cemetery (6)	Run	873	11095 (760-22824)
	Riffle	95	135 (105-167)
	Channelized	563	17523 (7895-27151)
Rush Creek (7)	Channelized	370	171 (124-218)
	Braided run	297	413 (371-454)
	Riffle/Pool	104	27 (15-39)
Bucktail (10)	Riffle/Run	335	1608 (1428-1788)
	Pool	598	114 (101-130)
Steiner Flat (20)	Run	1435	1471 (1312-1830)
	Run/Riffle	1393	645 (388-902)
	Slow Run	2221	264 (221-307)
	Riffle	11	7 (6-8)

There are several explanations for the breakdown in the relationship between habitat reach WUA and fry chinook salmon populations. The critical parameters that are used by the HABTAT program for estimating WUA of fry and juvenile chinook salmon are water depth and mean column water velocity. In our juvenile chinook salmon habitat requirements study (section III.3) we found that the highest densities of juvenile chinook salmon were located in habitat cells that were adjacent to high velocity areas or shear velocity zones. To some degree, this same relationship probably exists for fry chinook salmon as well. This would explain the low numbers of fry chinook salmon that were found in the slow run habitat in the Steiner Flat side-channel relative to the habitat reaches present. This habitat reach is monotypic, with slow water velocities and shallow depths. Those two parameters resulted in high WUA estimates, however, the lack of higher water velocities to create some habitat diversity was lacking. This reach is also void of cover (cobbles, brush, etc.) which may have had some influence on the selection of this area by fry chinook, however, even if cover had been available I believe that without some velocity diversity fry chinook salmon numbers would remain at low levels.

In most cases, one or two IFIM transects were sampled to represent each habitat reach. In order to be truly representative of the habitat, transect placement and habitat reach selection is extremely important. Since one or two transects must accurately represent its respective habitat reach, each habitat reach must contain homogeneous habitat. The importance of transect selection is exemplified when you consider the fact that each transect is a measurement of one line perpendicular to the channel that is then extrapolated to represent the entire habitat reach which may be several hundred feet in length. If the habitat reach contains small variations in microhabitat (shear zones or pocket water microhabitats) that attract high numbers of fry salmon, and are not represented by the IFIM transect, the WUA estimates for that habitat reach may not be truly accurate. Selection of fish population sampling sites within each habitat reach, although important, is not as crucial as the transect selection, since fish sampling sites include from 50 to 100 feet of the habitat reach, thus sampling a much greater proportion of the habitat.

It appears that some of the habitat reaches selected for this investigation included some minor microhabitat variations that effected our fish population WUA relationship. Redefinition of habitat reaches based on more specific microhabitats will increase the accuracy of IFIM transect WUA predictions by reducing the habitat diversity that is present in each reach.

During this investigation IFIM transect locations and fish sampling locations, although in the same habitat reaches, were not always overlapping. Therefore, minor differences in microhabitat may have been present in the fish sampling stations that were not adequately represented by the IFIM transects. Selection of IFIM transects within fish sampling stations will reduce the chance of missing critical microhabitats.

In order to improve 1990 side-channel investigations several changes in study design have been incorporated as follows:

1) Redefine habitat reaches to include more specific microhabitat types.

2) Select IFIM transects within fish population sampling stations.

3) Select two habitat reaches for intensive IFIM modeling that will include at least 10 IFIM transects per fish sampling station.

RECOMMENDATIONS

Cemetery Side-Channel

The channelized areas of the Cemetery side-channel account for 63 percent of the side-channels total length, yet provide only limited amounts of habitat for fry and juvenile chinook salmon. The habitat quality in this section could be improved through changes in the channel configuration. Two key physical features are responsible for depressing the potential fry and juvenile chinook salmon habitat: 1) The current channel slope is to steep and lacks any variation that would provide some habitat diversity in the form of changing water depths and velocities, and 2) The trapezoidal shaped channel cross section limits available fry and juvenile chinook salmon habitat to side-channel edges as water velocities increase with discharge.

In order to improve habitat conditions in this section the current channel configuration should be modified in order to increase hydraulic diversity. The channel slope should be altered by constructing hydraulic controls in order to form pool riffle sequences. Construction of meanders in this straight section would also decrease the overall channel slope by increasing the thalweg length. Meanders would provide some velocity diversity as the channel thalweg shifts across channel at the end of each bend. In order to obtain the full habitat potential of meanders the banks located along the inside bends of each meander should be feathered back or formed into a series of benches. These areas will provide valuable slow water habitat for fry and juvenile chinook salmon as side-channel discharges increase.

In swift water areas construction of cobble or boulder wing defectors would increase rearing area by creating velocity shelters near shear velocity zones. These microhabitats are used extensively by juvenile chinook salmon in the main stem.

In order to improve winter habitat for juvenile steelhead trout cobbles should be placed throughout the side-channel concentrating on areas with water velocities less than 1.0 feet/second where sand deposition is unlikely to occur. Cobble placement would also provide rearing cover for fry chinook salmon and juvenile brown trout.

Rush Creek Side-Channel

The upper channelized section of the Rush Creek side-channel represents 34 percent of the available side-channel length for fry and juvenile chinook salmon excluding the duck ponds. The channel slope of this section is less than the channel slope of the Cemetery channelized section. As a result, the available juvenile chinook salmon habitat per unit of water is slightly greater in the Rush Creek channelized section. The habitat could still be improved significantly in this section through channel alterations. In the current channel configuration habitat declines as flows increase and there is no hydraulic diversity. Construction of meanders and hydraulic controls to create run-riffle sequences would increase habitat area at lower side-channel discharges. Feathering banks or construction of benches that become inundated at higher flows would help maintain or possibly increase habitat at higher flows. Since the current channel slope is not to extreme another possible channel alteration might include construction of eddy coves periodically along the channelized slopes. These areas would provide some increased velocity diversity and may also provide some refuge during high flow events.

Fry chinook salmon habitat for the remainder of the side-channel would be optimized with a side-channel discharge between 30 to 60 cfs. Habitat manipulations in the upper channelized section should be made to optimize habitat for discharges in this range. However, before side-channel discharges are increased an evaluation of the effects that these higher flows would have on the waterfowl use of the duck ponds in the side-channel should be considered.

Cobbles should be placed in selected areas of the side-channel in order to increase over-wintering habitat for juvenile steelhead trout and rearing cover for fry chinook salmon.

Bucktail Side-Channel

Large habitat gains occurred in the Bucktail side-channel when benches along the upper run and pool habitats became flooded at higher discharges. In order to increase habitat area during lower flows the elevation of the benches should be lowered. The left banks along each run should also be feathered back in order to improve the habitat values at higher discharges.

Habitat could be improved in the swift water areas of each run by constructing cobble wing deflectors or boulder clusters to create some velocity shelters for feeding salmonids. Wing deflectors should be staggered along each bank in order to cause the thalweg to meander throughout the channel creating several back eddies increasing diversity of water velocities.

Cobble placement throughout the side-channel would benefit over-wintering juvenile steelhead trout as well as provide cover for rearing fry chinook salmon.

Steiner Flat Side-Channel

With the current channel configuration fry and juvenile chinook salmon habitat in the Steiner Flat side-channel is optimum when the side-channel discharge is less than 10 cfs. Because of the number of tributaries that enter the river upstream of Steiner Flat, river flows tend to fluctuate much more than in the upper river sections. Therefore, maintaining low discharge levels in the side-channel to optimize habitat becomes extremely difficult if not impossible especially during the Spring rearing season when runoff is high.

A better alternative to controlling discharges would be to modify the channel shape in order to increase habitat values for higher discharges. The steep banks of the side-channel are responsible for reduced habitat levels for flows in excess of 20 cfs. A reduction in the bank slopes and creation of benches along selected areas of the channel would increase habitat at higher flows by increasing the wetted area and creating slow velocity habitat areas. Another alternative for increasing habitat would be the construction of eddy coves along the steep banks. These areas would be protected from high water velocities and may create additional refuge and feeding areas for young salmon and trout. Several hydraulic controls were placed in the side-channel during its construction and these have helped to improve the available habitat by increasing overall diversity.

Cobble placement would be beneficial to over-wintering steelhead trout and fry chinook salmon.

POST-EVALUATION HABITAT CHANGES

Since the side-channels have only recently been constructed they have yet to be exposed to long term hydraulic energy inputs. Over time we can expect gradual and sometimes major habitat changes to occur. Establishment of riparian vegetation, influences by animal behavior (ie. beavers, spawning salmon) and high flows will all cause habitat changes to some degree until a state of equilibrium is achieved.

The Steiner side-channel has already experienced one high flow during April of 1989 when the side-channel was bank full for several days. After the storm, we observed several areas of the side-channel where substrate materials had been moved. Sand had been scoured slightly from the riffle and swifter run habitats and was deposited in the deep slow run habitats as the flows resided.

Through coordinated efforts with the Trinity River Restoration Project some habitat modifications that have been discussed in this report have already been completed. Modifications to the channelized habitat section of the Cemetery side-channel and the Bucktail side-channel were completed in the late summer of 1989. Cobble placement began in all of the side channels in the fall of 1989 and is continuing at the time of this report. One more additional side-channel was also constructed by the Trinity River Restoration Project in the upper Trinity River just upstream of the Salt Flat Road Bridge along the left bank.

FUTURE EVALUATIONS

Additional IFIM analysis will be conducted in the modified sections of each side-channel and for the new Salt Flat side-channel in 1990 in order to evaluate habitat gains in these areas. Results of these evaluations will be available in our 1990 annual report.

PRELIMINARY ADJACENT-VELOCITY HABITAT CRITERIA

INTRODUCTION

The current habitat preference critieria use focal point mean column velocites to describe microhabitats that are selected by juvenile steelhead trout. Although preference criteria that describe focal point water velocities are critical, alone they do not adequately describe all of the microhabitat parameters that are necessary to feeding juvenile steelhead. Adjacent water velocities, or feeding lane water velocities, may be equally important to rearing steelhead, since these are the water velocities responsible for delivering food items near focal point locations. Use of only focal point water velocities in the Physical Habitat Simulation (PHABSIM) component of the IFIM would favor those river flows that optimize slower focal point water velocities without consideration to feeding lane velocities.

The Instream Flow Incremental Methodology (IFIM) through the HABTAV program has acquired the ability to simulate situations where fish habitat is determined by hydraulic parameters at the fish's location, as well as by velocities near the fish (Pawenska 1985). This program gives the model the ability to consider feeding lane water velocities as well as focal point water velocities when computing the habitat joint preference factor that is used to predict Weighted Useable Area (WUA) for a given target species. In order to use this feature of the model, two additional habitat suitability criteria parameters must be developed. First, the maximum distance that the target species is willing to travel in order to capture prey must be determined, and second, the water velocities present where the prey organism was captured must be described.

METHODS

Habitat use data was collected by snorkel divers who observed feeding juvenile steelhead trout in riffle habitats from below Lewiston Dam downstream to the U.S. Forest Service campground at Tish Tang. The snorkel divers approached each sampling station from a downstream direction in order prevent spooking juvenile trout. Once in the water the two snorkel divers spread out and slowly moved upstream searching for juvenile steelhead trout. When juvenile steelhead trout were spotted the snorkeler would stop and observe for several minutes in order to determine the focal point, and feeding distance. Each target fish must have an established focal point which he defends against other fish or consistently returns to after capturing food items before microhabitat data were collected. Feeding distance was measured as the distance that each fish was willing to travel in order to capture prey items and still return to the same focal point. We quickly found that juvenile steelhead trout will often travel several feet to capture food items and then establish a new focal point close to where the last food item was taken, rather then return back to the previous focal point location.

Large painted washers were used to denote focal points and feeding distances. The orange side of the washer was placed up in order to mark focal point locations and the silver side of the washer was used to denote feeding distances for each target fish. Using washer markers allowed us to make several fish observations before microhabitat data had to be collected. We found large heavy washers worked well because they could easily be carried under our wet suit gloves or sleeves allowing our hands to remain free and yet still be easily accessible. Other markers such as bobbers and sinkers were awkward to carry or tended to tangle and could not be easily concealed.

The following data was collected for each observation:

1. Total depth at focal point (feet).
2. Mean column velocity at focal point (feet/second).
3. Focal point depth or fish depth (feet).
4. Focal point velocity or nose velocity (feet/second).
5. Cover type and quality at focal point.
6. Substrate composition at focal point.
7. Distance traveled to feeding location (feet).
8. Total depth at feeding location (feet).
9. Mean column velocity at feeding location (feet/second).

For a description of the cover and substrate code categories please refer to section XX.X of this report.

Water depths were measured with a top setting wading rod and water velocities were measured with a Price AA current meter.

RESULTS AND DISCUSSION

The following results are strictly preliminary and are only presented with a limited amount of data analysis. The results that are presented in this report are for general information only and therefore caution should be used before these criteria are used elsewhere. To date, 145 microhabitat observations have been made on juvenile steelhead trout in the Trinity River. Final development of HABTAV utilization criteria will be completed next year after additional data collection and will be presented in our 1990 Annual Report.

The majority of our sampling effort was confined to riffle habitats because our sampling efforts in other habitats containing slower water velocities such as pools and deep runs revealed that juvenile steelhead trout tended to roam in search of food items rather than establish focal points. The observed density of juvenile steelhead trout using riffle habitats also appearred to be much greater than in other slow water habitats.

In faster velocity habitats (riffles), juvenile steelhead trout established focal points near roughness elements that created velocity shelters in microhabitats where abundant food items were easily captured in the drift.

Behavioral interactions between juvenile steelhead trout included head down lateral displays, exaggerated swimming motions, and charges that sometimes resulted in nipping. However, these interactions were rarely observed. Generally, juvenile steelhead trout tended to move between focal points spread over a large area with only minimal behavioral interactions between species.

Focal points were usually located near the river bottom in association with cobble and small boulder substrates (Figure 1). focal point water velocities ranged between 0.2 and 4.2 feet/second with velocities between 0.8 and 1.0 feet/second most often used (Figure 2). Mean column water velocities at the focal point and feeding lane water velocities used by juvenile steelhead trout have similar frequency distributions. Feeding lane water velocities most often observed were approximately 1.0 feet/second faster than focal point water velocities. Juvenile steelhead trout traveled up to 6.1 feet to capture prey from a single focal point. The average feeding distance traveled equaled 2.2 feet (Figure 5).

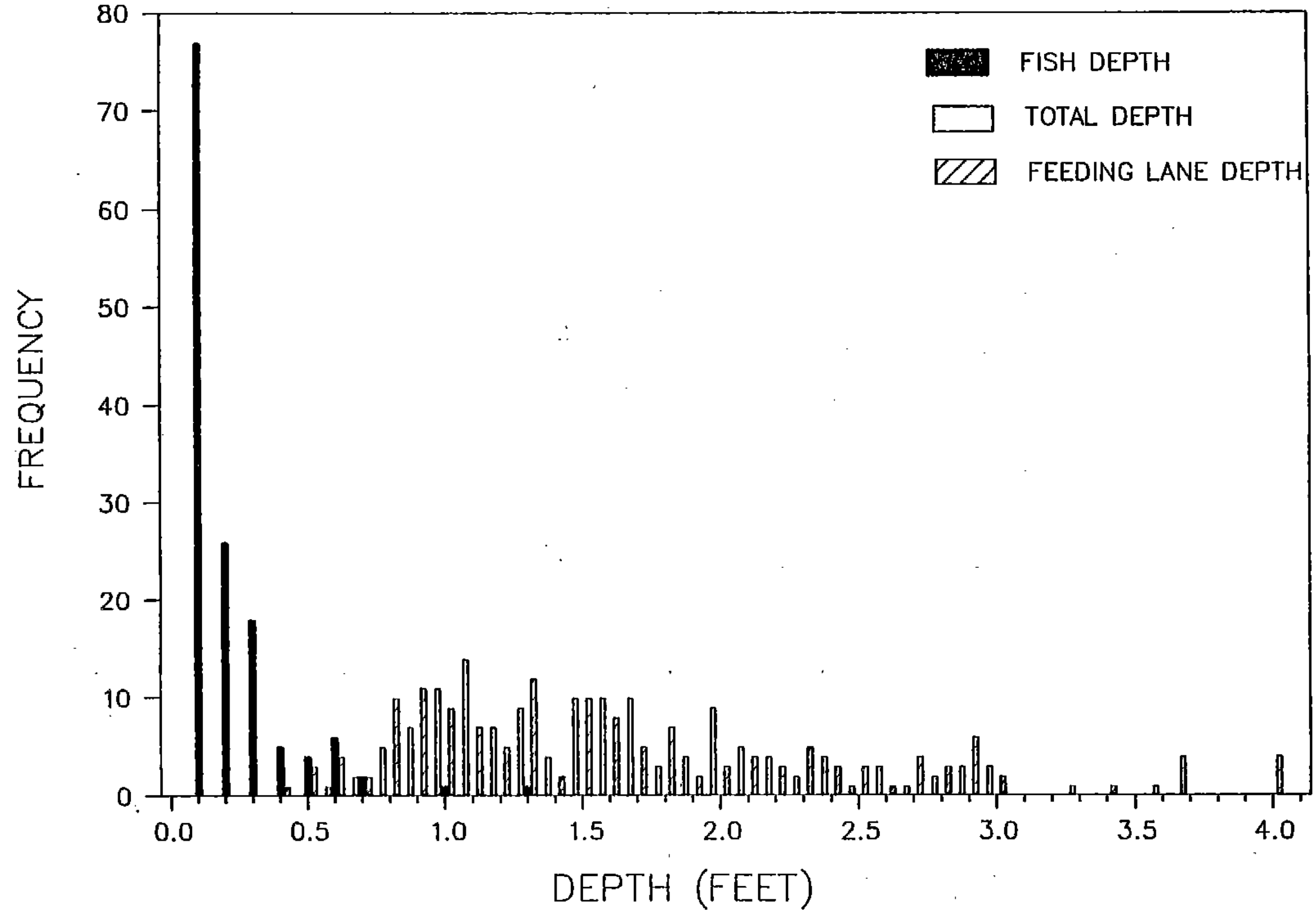


Figure 1. Frequency distributions describing depth of fish, total depths and feeding lane depths used by juvenile steelhead trout in the Trinity River.

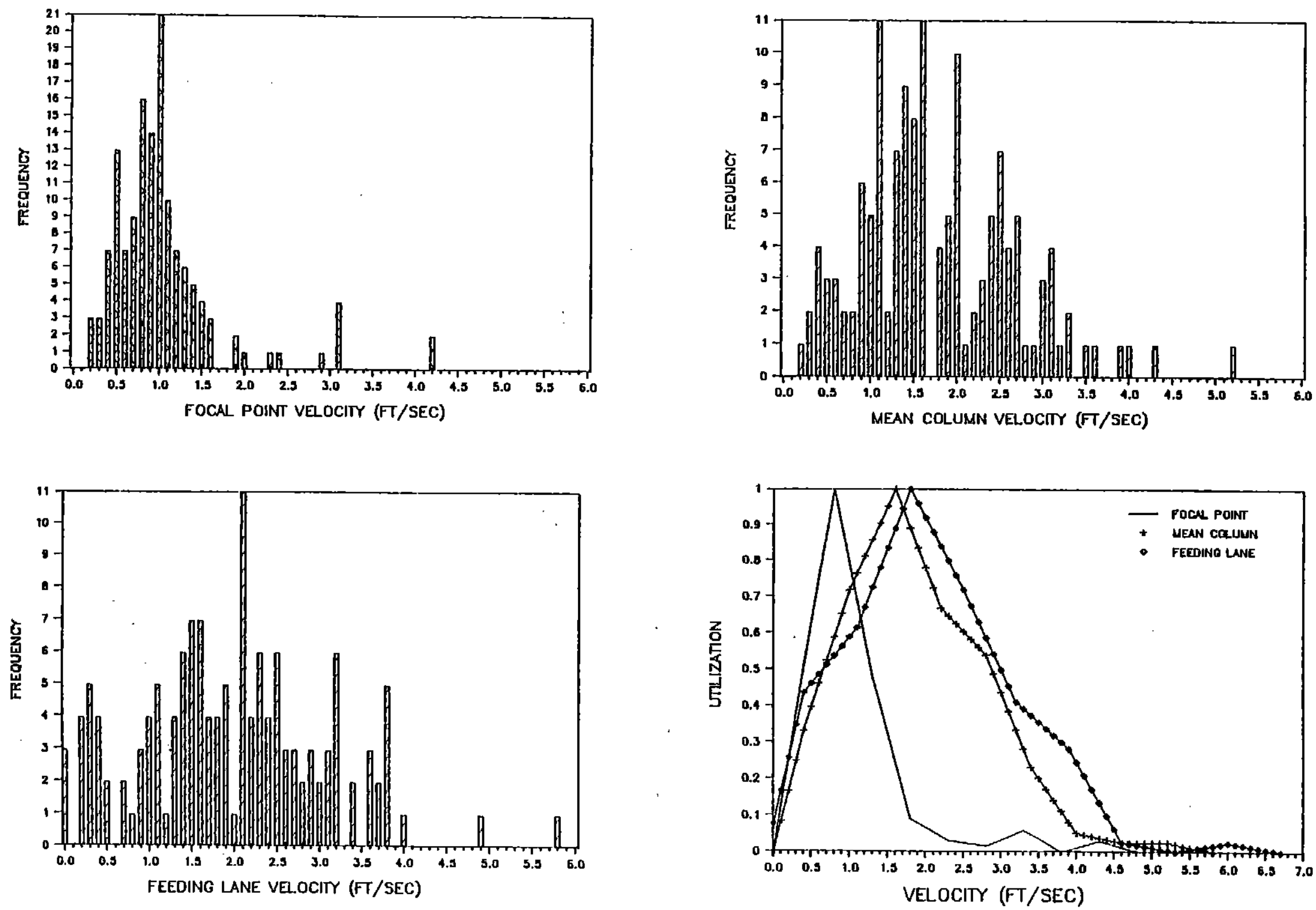


Figure 2. Frequency distributions and preliminary utilization criteria describing water velocities selected by juvenile steelhead trout in the Trinity River.

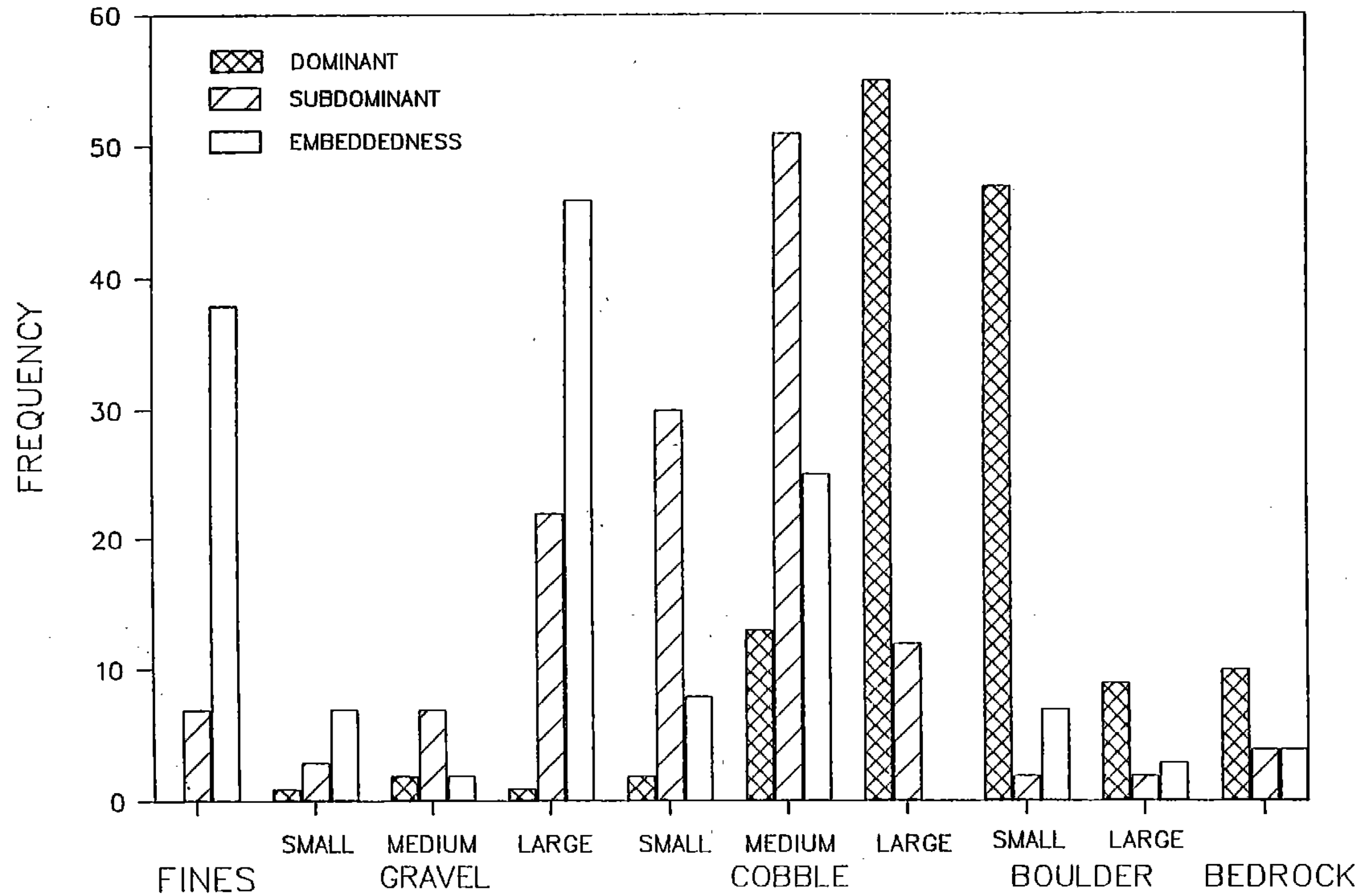


Figure 3. Substrates selected by feeding juvenile steelhead trout in the Trinity River.

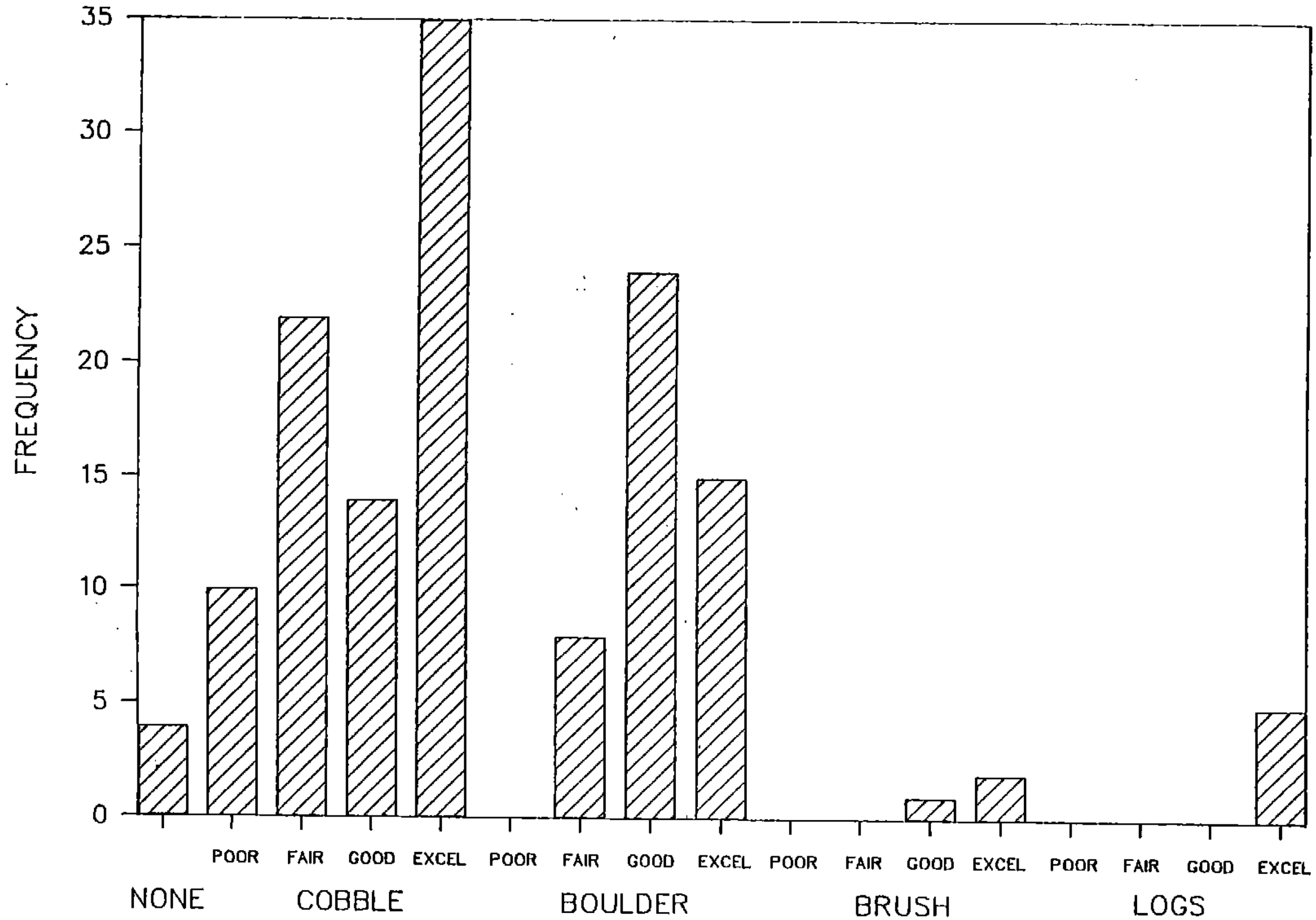


Figure 4. Cover types used by feeding juvenile steelhead trout in the Trinity River.

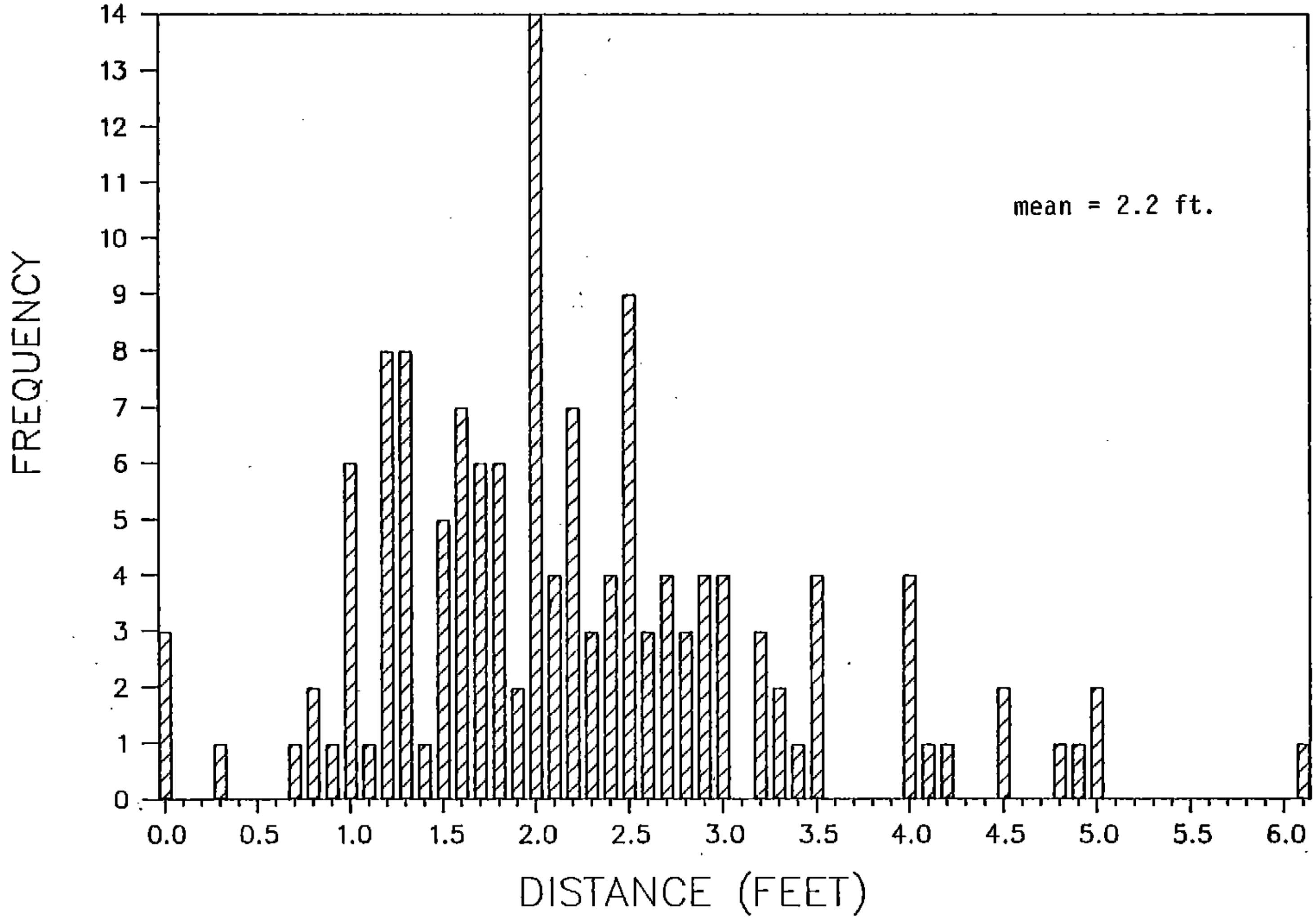


Figure 5. Frequency distribution describing distances traveled by juvenile steelhead trout to capture prey items in the Trinity River.

WATER TEMPERATURE MONITORING

Introduction

During 1988 we continued to monitor water temperatures on the mainstem Trinity River from Lewiston to the Hoopa Valley. Water temperature regimes influence migration, spawning, incubation success, growth, inter and intraspecific competitive ability, resistance to parasites, diseases, and pollutants (Armour 88). Temperature records are useful in explaining trends within the fishery, and will be used to enhance our existing data base for planned use of the Service's Instream Temperature Model (SNTEMP) in 1990.

Methods

Five permanent monitoring sites were used during 1989. Temperature recorders were located at the USGS gaging station at Lewiston (river mile 111), the USGS gaging station at Steel Bridge road (river mile 99), Idaho Bar (river mile 73.5), Burnt Ranch transfer site (river mile 46), and the USGS gaging station at Hoopa (river mile 14.4). Table 1 lists site locations, mileage, and recording periods. Figure 1 shows site locations. Sites were selected to monitor the effects of a varying flow regime and seasonal climatic change on Trinity River water temperatures.

Table 1. Water temperature recorders on the mainstem Trinity River, 1988.

Site	River Mile	Recording Period
Lewiston	111	Oct. 1988 to present
Steel Bridge	99	Oct. 1988 to present
Idaho Bar	73.5	Oct. 1988 to present
Burnt Ranch	46	May 1988 to present
Hoopa	14.4	May 1988 to present

Omnidata Datapod Model 112 temperature/ voltage recorders were used at all sites this year. These units incorporated Omnidata Application Engineering Special #1013 software to record temperatures over a range from 5 to 30 degrees Celsius to the nearest 0.1 degree. Units give readings of maximum, minimum, and mean daily water temperature based on 1440 recordings per 24-hour period. This range was sufficient for water temperatures encountered over the year except for several periods during the months of December, January, and February, when water temperatures dropped below 5 degrees Celsius. When these conditions occurred the datapods recorded temperatures as 5 degrees Celsius.

Data recorded by the datapods is stored on data storage modules (DSM). These are nonvolatile storage microchips which can be

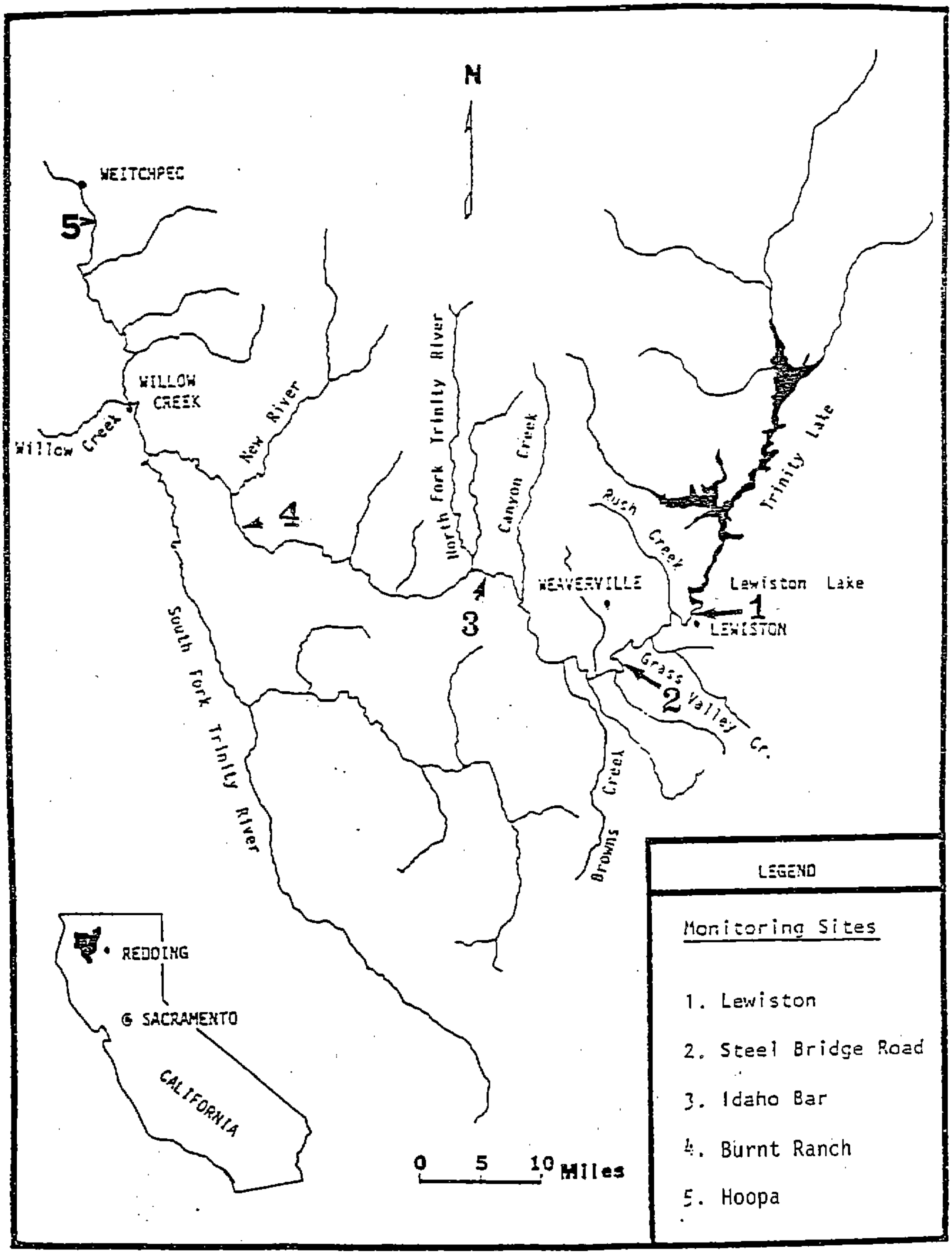


Figure 1. Distribution of temperature monitoring sites on the Trinity River from October 1988 through September 1989.

removed and replaced without interruption of the data record. The DSM will retain data in the event of flooding or power loss. Records are transferred from DSM to computer files using a Omnidata Datapod Model 217 DSM reader.

Datapods at the Lewiston and Steel Bridge sites were stored inside locked USGS gaging houses. Long lead thermistors were run in pipes underground to the river for these units. All other units were encapsulated in water-resistent camera housings, enclosed in armored cases, and submerged in moving water at suitable depths to cover the range of flows over the year. DSM's were exchanged approximately every 30 days in each datapod. Batteries in each unit were replaced every three months.

Results

For the purposes of this report we divided the river into three sections. The upper river is described as the reach from Lewiston to Dutch Creek. The middle river extended from Dutch Creek to the South Fork Trinity confluence. The lower river is described as the reach from the South Fork Trinity to the confluence with the Klamath River.

In the upper river water temperature remained relatively stable throughout the year. Temperature in this section is controlled by releases from Lewiston Dam. In the middle and lower sections river water temperatures drop and remain low during winter and early spring, then rise in response to higher air temperatures in the late spring and summer.

Figure 2 is a temperature summary of all sites. Figures 3, 4, 5, and 6 display data collected from Lewiston, Steel Bridge, Idaho Bar, and Hoopa respectively.

Several equipment malfunctions occurred with probes at Lewiston, Steel Bridge, and Cedar Flat. At Lewiston most of the data from October and December, 1988, and the latter half of September 1989 were lost. At the Steel Bridge site data from the last week of October, all of November, and most of December 1988 are missing. At Cedar Flat data was interrupted for extended periods in May, June and July. Due to these problems Cedar Flat data has been excluded from discussion and comparison.

The appendix contains mean daily temperatures measured at all sites throughout the year, as well as monthly maximum and minimum temperatures.

Discussion

Trinity River temperatures can be characterized in relation to their proximity to Lewiston Dam. Upper river temperatures are stable as far down river as the Steel Bridge probe and appear to

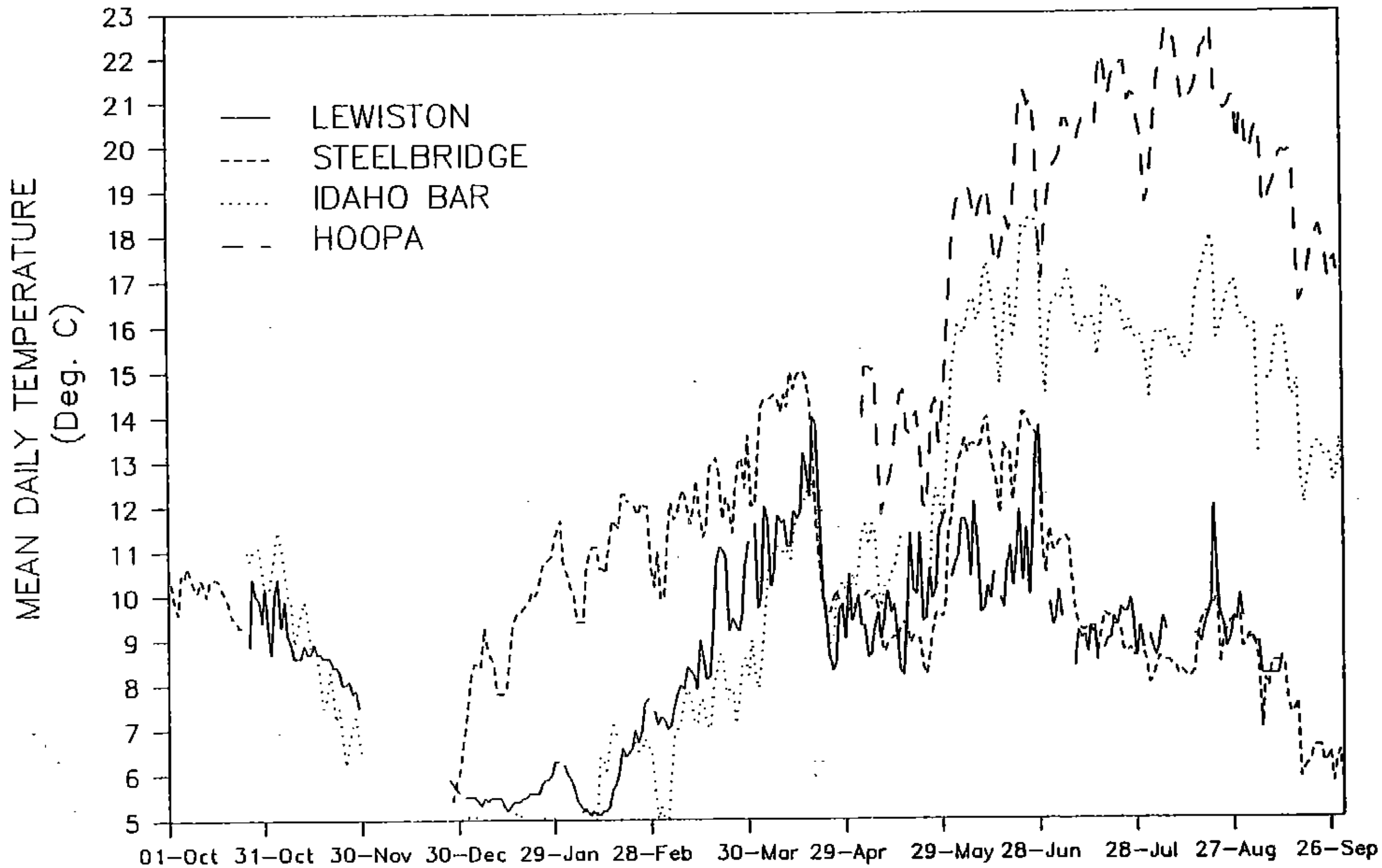


Figure 2. Mean daily water temperature at four sites on the mainstem Trinity River, October 1988 - September 1989.

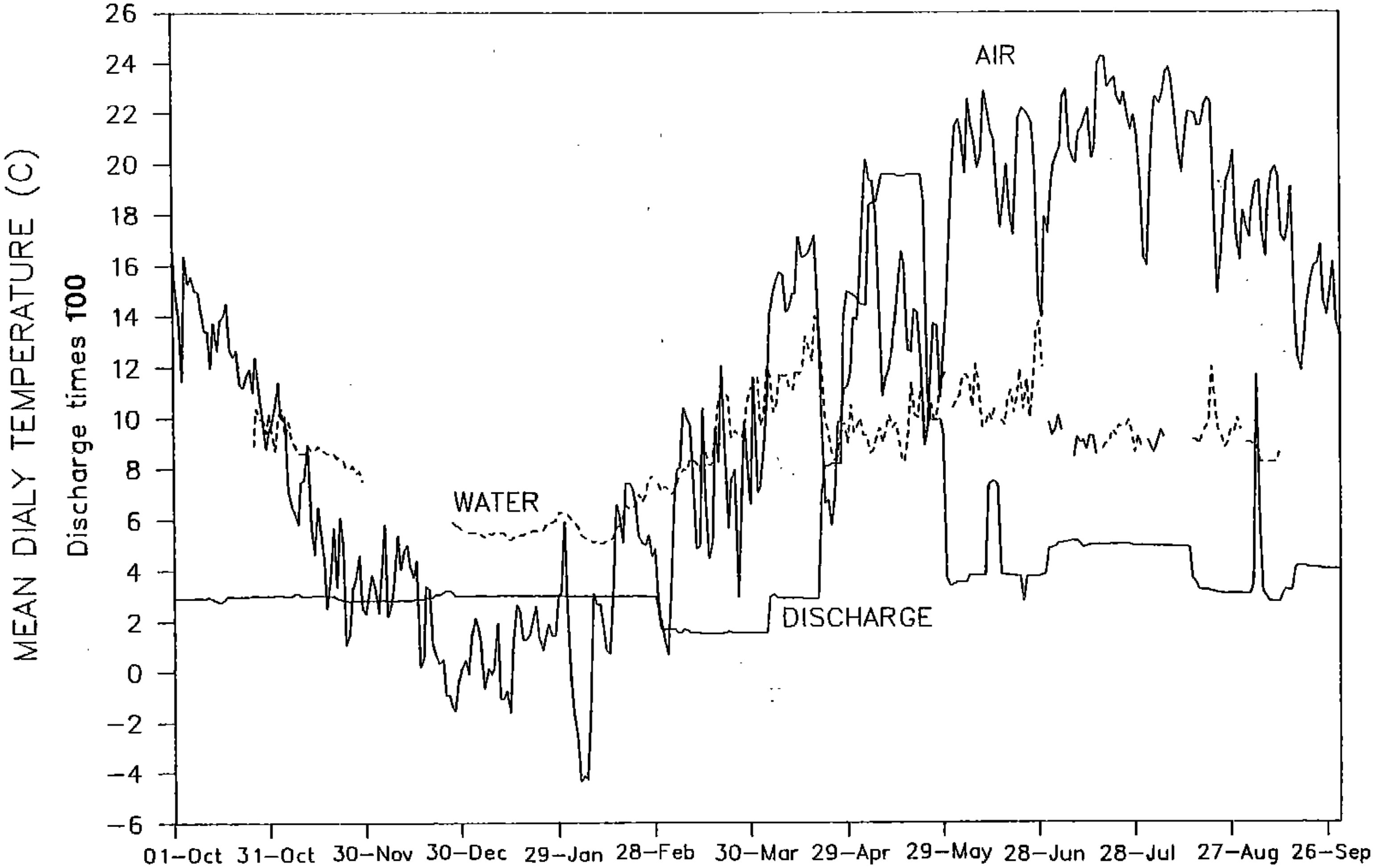


Figure 3. Mean daily water temperature, air temperature, and discharge for Trinity River at Lewiston California, October 1988 - September 1989.

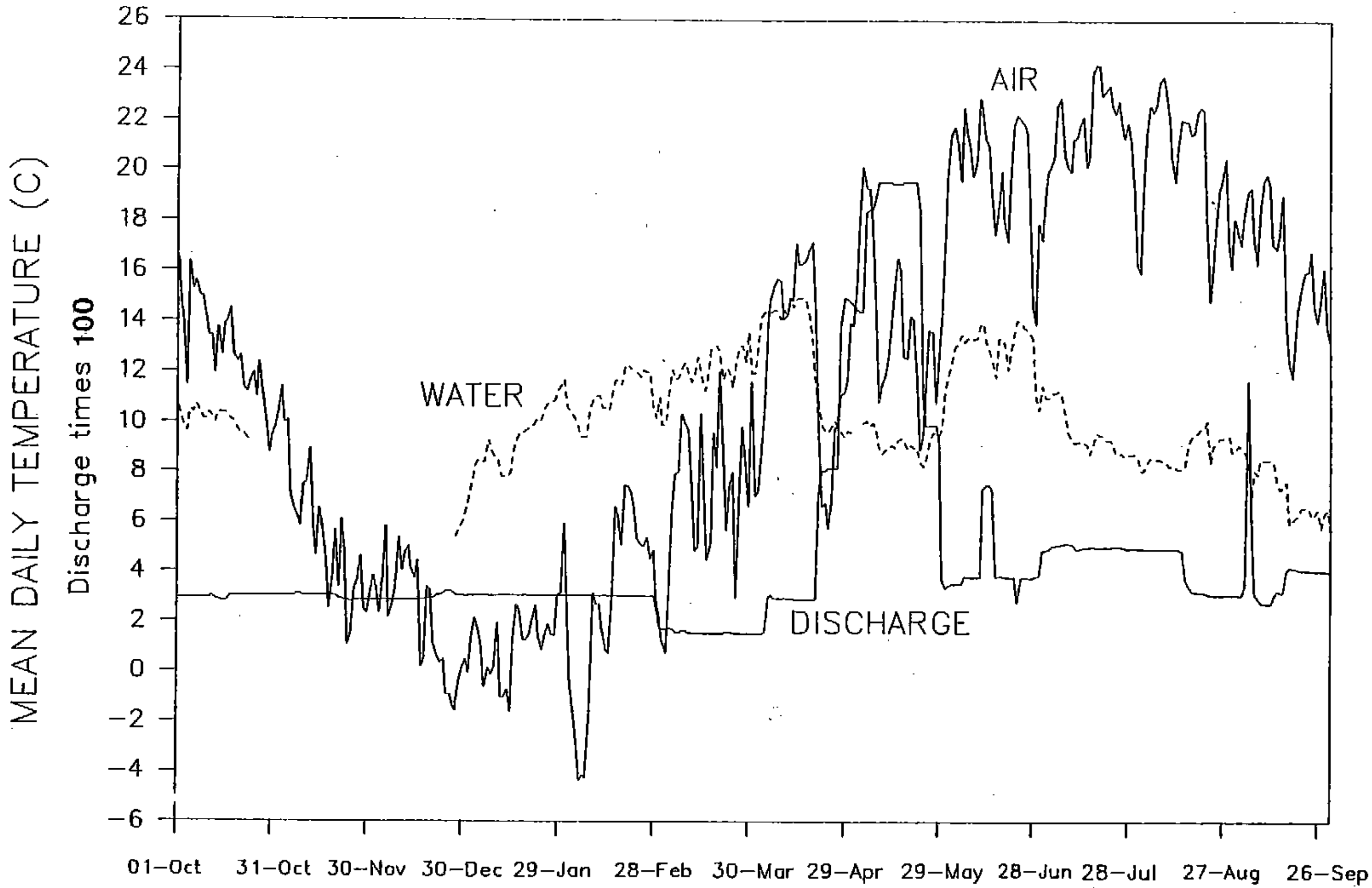


Figure 4. Mean daily water temperature for Trinity River at Steelbridge, October 1988 - September 1989. Air temperature and discharge recorded at Lewiston, California.

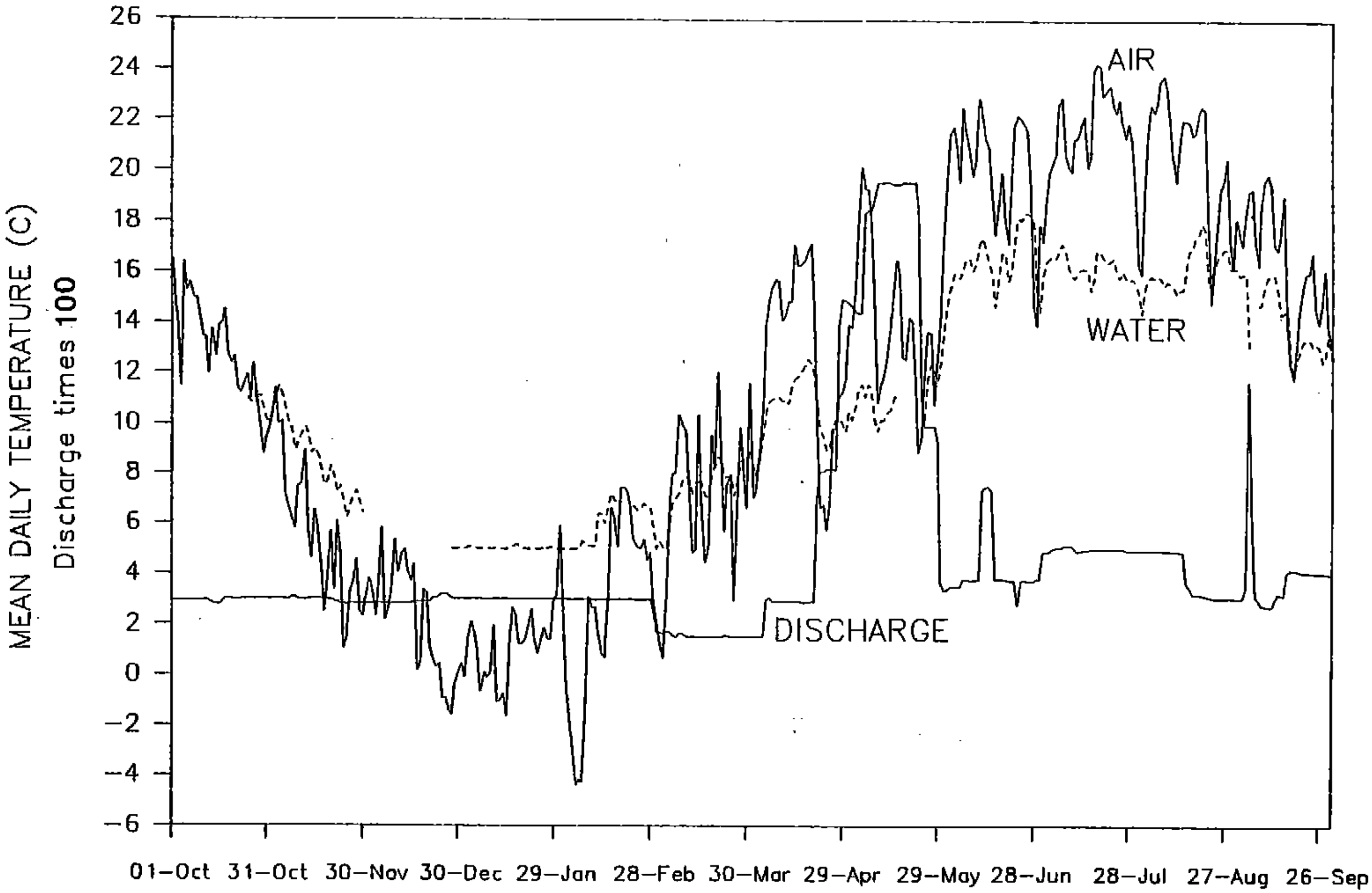


Figure 5. Mean daily water temperature for Trinity River at Idaho Bar, October 1988 - September 1989. Air temperature and discharge recorded at Lewiston, California.

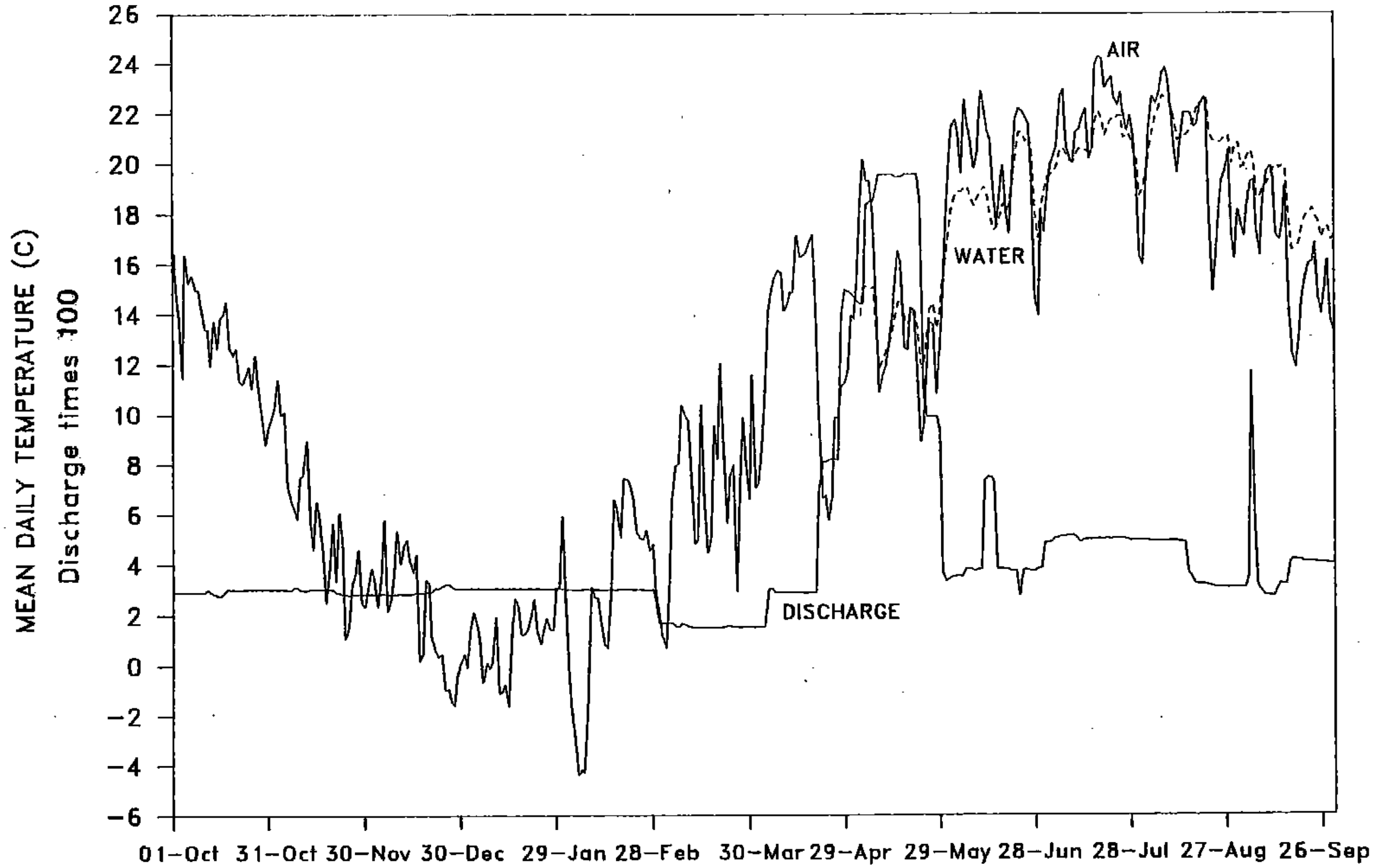


Figure 6. Mean daily water temperature for Trinity River at Hoopa, October 1988 - September 1989. Air temperature and discharge recorded at Lewiston, California.

be controlled by discharge at Lewiston Dam. In uncontrolled river systems ambient air temperature is a major factor influencing water temperature. However, in the upper Trinity ambient air temperature seems to have a lesser extent of control on temperature of the water. Figure 3 shows that temperatures ranged from 5 to 15 degrees Celsius over the study period. Winter months proved to be coldest with a warming trend through the spring. With the exception of increased flows in May the temperature profile remained stable throughout the summer, with a gradual decline in the fall.

Data presented in our 1988 annual report concur with 1989 findings. Lewiston water temperatures ranged from 5.6 to 13.1, and 5.1 to 13.8 degrees celsius for 1988 and 1989 respectively. Steel Bridge Road water temperatures ranged from 5.0 to 17.4, and 5.4 to 14.1 degrees celsius for 1988 and 1989 respectively. Peak temperatures occured in late June both years, while low temperatures occured in winter months.

Water in the upper river is warmer in the winter, and colder in the summer and fall compared to pre-dam conditions. Warmer water during the winter accelerates salmonid egg incubation time. This in turn means fry will migrate out of the gravel sooner than occurred before the dam was built. This in itself may not be a problem. However, after emergence fry are exposed to colder water for a longer period of time compared to pre-dam conditions. These fish tend to have slow growth rates until the water begins to warm in the spring (section III.4).

Cooler water temperatures in the summer and fall are beneficial to holding adult chinook and steelhead trout. Sixteen degrees Celsius is thought to be the threshold at which egg mortality is increased in holding fish. The temperatures recorded during 1989 stayed well under this level.

The middle section of the river, represented by the Idaho Bar probe, showed several interesting trends (Figure 4). Water temperatures dropped drastically as a response to colder winter air temperatures. Then at the onset of spring as the air temperatures rose water temperatures in turn elevated. The Idaho Bar temperatures were generally colder than those at Lewiston and Steel Bridge throughout the winter. In the spring the relationship reversed. Spring and summer water temperatures were higher than the upper river's. This trend suggests that temperatures in this section of the river are driven more by ambient air temperature than by releases from Lewiston Dam.

Our past years data reinforce the fact that ambient air temperature and meteorlogical conditions control middle river water temperature. This effect is especially pronounced at lower discharges. The same seasonal trends in water temperature were noted in our 1988 annual report. Ranges of water temperatures in 1988 and 1989 are very similar, with peaks occuring in late June and lows occuring in December.

Hoopa Valley water temperatures, representative of the lower river, showed a similar pattern to the middle river (Figure 5). It should be noted that data is available only from early May through September. However, late spring and summer water temperature variations are very closely linked with ambient air temperatures.

In May our office evaluated a discharge of 2000 CFS in the mainstem Trinity. This, coupled with a minor storm which lowered ambient air temperature considerably, depressed water temperatures at all sites four to seven degrees Celsius. It is unclear at this point which factor, the increased discharge or the depressed ambient air temperature, was responsible for lowering water temperature. Next year, during calibration of the Service's SNTEMP model, discharge from Lewiston Dam will be evaluated as a management tool for water temperature moderation in the Trinity River.

III. FISH POPULATION CHARACTERISTICS AND LIFE HISTORY RELATION SHIPS

CHINOOK SALMON SPAWNING DISTRIBUTION

Introduction

In 1988 we surveyed the mainstem Trinity River to monitor the spawning distribution of Chinook Salmon. It is important to keep an index on the distribution of spawning in the mainstem in order to assess trends of habitat use in the basin. Surveys have been done yearly since 1986 and are expected to continue for the remainder of the study.

Methods

During November 1988 we made ten raft float trips along 78.5 miles of the mainstem Trinity River. Starting at Lewiston Dam (river mile 111.9) we covered the entire reach to Cedar Flat (river mile 47.5). The reach between Cedar Flat and Hawkins Bar (river mile 39) was skipped because of dangerous rapids. The remaining two reaches we covered were from Hawkins Bar to Salyer (river mile 32.4) and from Camp Kimtu (river mile 26) to Tish Tang (river mile 17). The reach from Salyer to Camp Kimtu was skipped because of poor water visibility.

Reaches were drifted in an inflatable raft with a rowing frame. Two staff personnel, one rowing, the other observing and recording locations and numbers of redds, made each trip. The redds were located visually by positioning the raft in the channel adjacent to spawning areas. To insure complete coverage, side channels and areas too shallow to float were waded. Redd numbers and locations were noted on photocopies of aerial photographs.

Results

Table 1 summarizes data collected during the spawning survey. A total of 3922 redds were recorded in the 78.5 river miles drifted. Figures 1 and 2 show major spawning locations along with reach delineations. Major spawning locations are defined as areas containing fifty or more redds.

Discussion

The 1988 spawning escapement estimate for the Trinity River was 57,727 chinook salmon (California Department of Fish and Game 1988, preliminary estimates). This is the third largest run (behind 1986 and 1987) since California Department of Fish and Game began estimation of adult escapement in 1978. The estimate is for the entire basin upriver of Willow Creek, excluding Trinity River Hatchery returns.

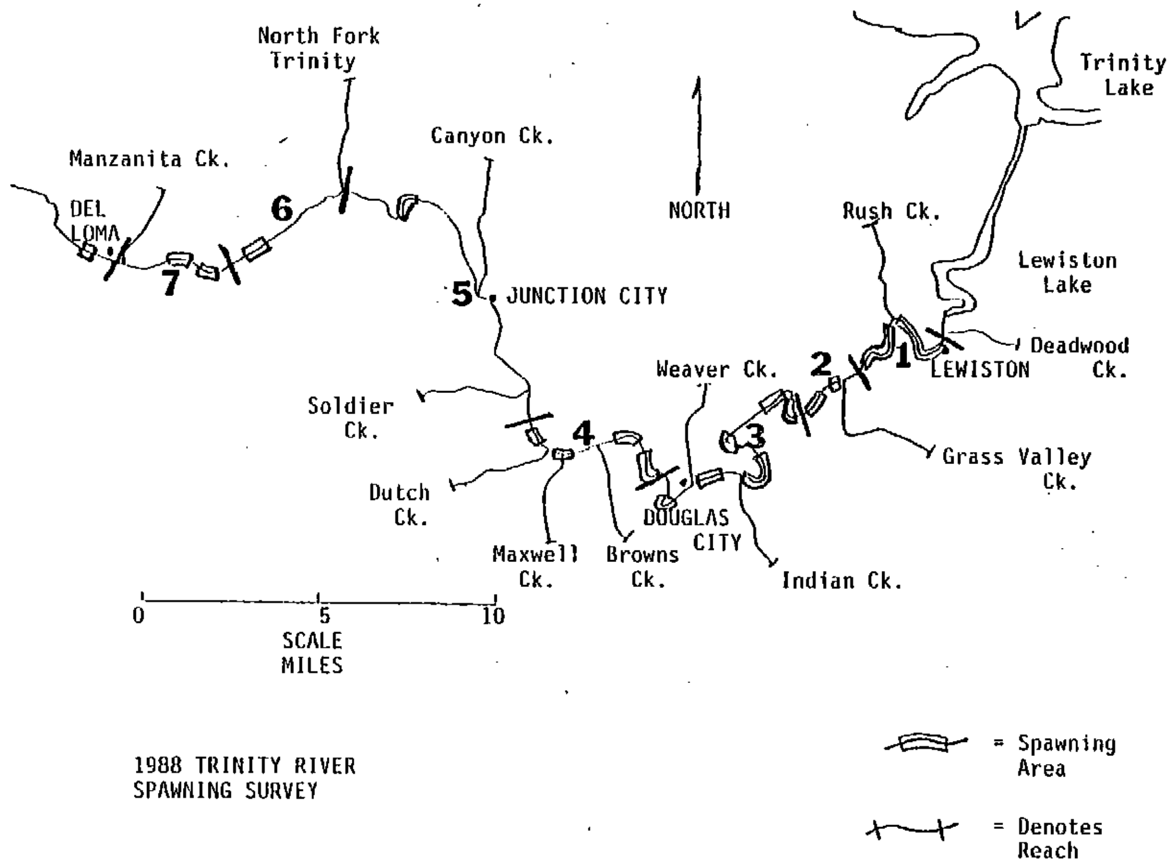


Figure 1. Chinook spawning distribution for the Trinity River, California, November 1988.

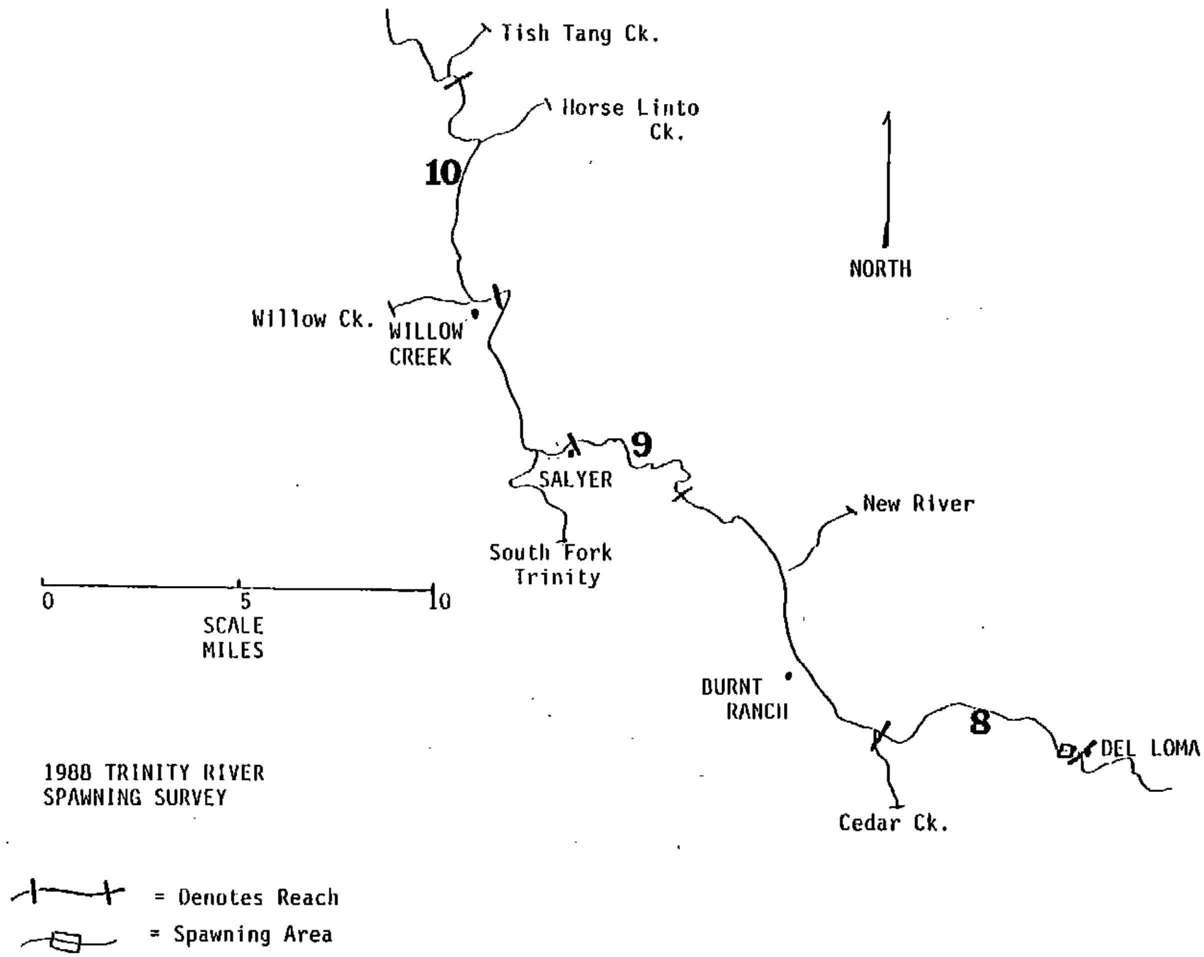


Figure 2. Chinook spawning distribution for the Trinity River, California, November 1988.

The California Department of Fish and Game conducted several spawning surveys of the river prior to and after construction of Lewiston and Trinity dams. Their purpose was to determine the amount of spawning habitat lost due to inundation, and to monitor spawning distribution after completion of the Trinity River project. Gibbs (1955) concluded that 47% of mainstem chinook spawning activity occurred above the proposed dam site, 47% between Lewiston and Canyon Creek, and 6% on the reach from Canyon Creek to the North Fork Trinity. Rogers (1968, 1970, 1971) surveyed redds on the reach from Lewiston Dam to the North Fork Trinity, he reported that 86.4%, 71.5%, and 85% respectively of redds were observed on the reach above Douglas City.

In 1989 high concentrations of spawning activity were seen in the upper river. The majority of activity occurred between Lewiston and Junction City. Lewiston Dam is the barrier to upstream migration of anadromous salmonids on the mainstem Trinity. Fish use the entire reach between Lewiston and Junction City because of its suitability for spawning, not because further migration is not possible. Heavy spawning activity has been observed on this reach in our past surveys, as well as the historical surveys discussed above. This tends to reenforce the importance of this reach as spawning habitat.

Table 1. Chinook salmon spawning survey results for the mainstem Trinity River November 1988.

DATE	REACH		MILES	REDDS
11-03-88	1	New Bridge (Lewiston) to Bucktail	6	845
11-04-88	2	Bucktail to Poker Bar	3	194
11-07-88	3	Poker Bar to Steiner Flat	10	1239
11-08-88	4	Steiner Flat to Junction City	11	785
11-09-88	5	Junction City to North Fork Trinity	9	164
11-16-88	6	North Fork Trinity to Big Flat	6.5	122
11-21-88	7	Big Flat to Del Loma	9.5	368
11-28-88	8	Del Loma to Cedar Flat	8.5	145
11-30-88	9	Hawkins Bar to Salyer	6	5
11-02-88	10	Camp Kimtu to Tish Tang	9	55
TOTAL			78.5	3922

Our 1988 survey showed increased spawning activity in the middle river between the North Fork Trinity and Cedar Flat. This years's data concurs with these findings. Especially high numbers of redds were observed from big Flat to Del Loma. Possible explanations for increased spawning there include availability of quality spawning substrate or the possibility the at these fish hatched in the area. Low inflow causing restricted migration into the tributaries is another possible explanation.

Fish used the same areas this year as the 1987 run described in our 1988 annual report. Lime Point, Big Bar Bridge, Sailor Bar, and Canadian Bar were again areas of considerable spawning. This reach was only partially covered for the 1986 run described in our 1987 annual report, which omitted the section from Junction City Campground to Del Loma. In 1986, 119 redds were seen on the reach from Del Loma to Cedar Flat, as compared to 145 this fall.

Lower river spawning activity was relatively low this year. In the reach between Hawkins Bar to Salyer very little spawning was observed, possibly because visibility was restricted. The reach between Camp Kimtu and Tish Tang, which was not surveyed in 1987, had 55 redds this year compared to 21 in 1986. This section was surveyed very early this season and more spawning might have been observed if later observations had been made.

JUVENILE POPULATIONS

In 1989, we continued to monitor mainstem Trinity River juvenile salmon populations by underwater observations at the Cemetery, Steelbridge, Steiner Flat, and Junction City sites, and at the Hayden Flat campground.

Our method, as in previous years, was to ascend a 200-foot rope up the river edge at selected locations: Cemetery (river mile 109), Steelbridge (river mile 99), Steiner Flat (river mile 92), and Junction City Campground (river mile 77). At Hayden Flat (river mile 54) we surveyed a 473-foot section of the river bank by crawling or swimming up the cobbled river bottom.

As in past years, chinook fry emerged from the gravel in significant numbers by about mid-February. We made counts at the four upper sites in late March, late May, and early July, and an additional count was made at the Cemetery site in late February before fish were visible at the lower sites. We surveyed the Hayden Flat site once, on March 30.

Figures 1 shows chinook fry and juvenile numbers for each of the four upper sites. All fish numbers are reported as individuals per linear foot of the river's edge.

Results and Discussion:

Numbers of rearing chinook were generally highest earlier in the season, and declined with time, as in past years. As in past years populations increased somewhat at Junction City, probably reflecting a general downward migration. There was a rise in the count at Steelbridge in early July, probably because of hatchery releases through June.

Fish counts in 1989 were comparable to counts in 1987 and 1988, and again noticeably higher than counts made in 1986. We were unable to make counts during the high flows of 1500 to 2000 cfs from April 28 to May 23, an important segment of the rearing season. We surveyed the upper four sites on May 25 at a flow of 1000 cfs, and found populations comparable to the previous two years, ranging from 2.46 fish per linear foot at Cemetery to 1 fish per linear foot at Steiner Flat. This indicates that the 2000 cfs release did not have a major effect on in-river rearing population densities, although it may have aided survival of the many chinook that normally migrate downstream in May.

The count at Hayden Flat on March 30 showed heavy use of edge and backwater habitat by rearing chinook. We counted 384 fry chinook along 470 feet of edge, and approximately 500 in an adjacent small backwater. These numbers were comparable to those seen in 1987 and 1988.

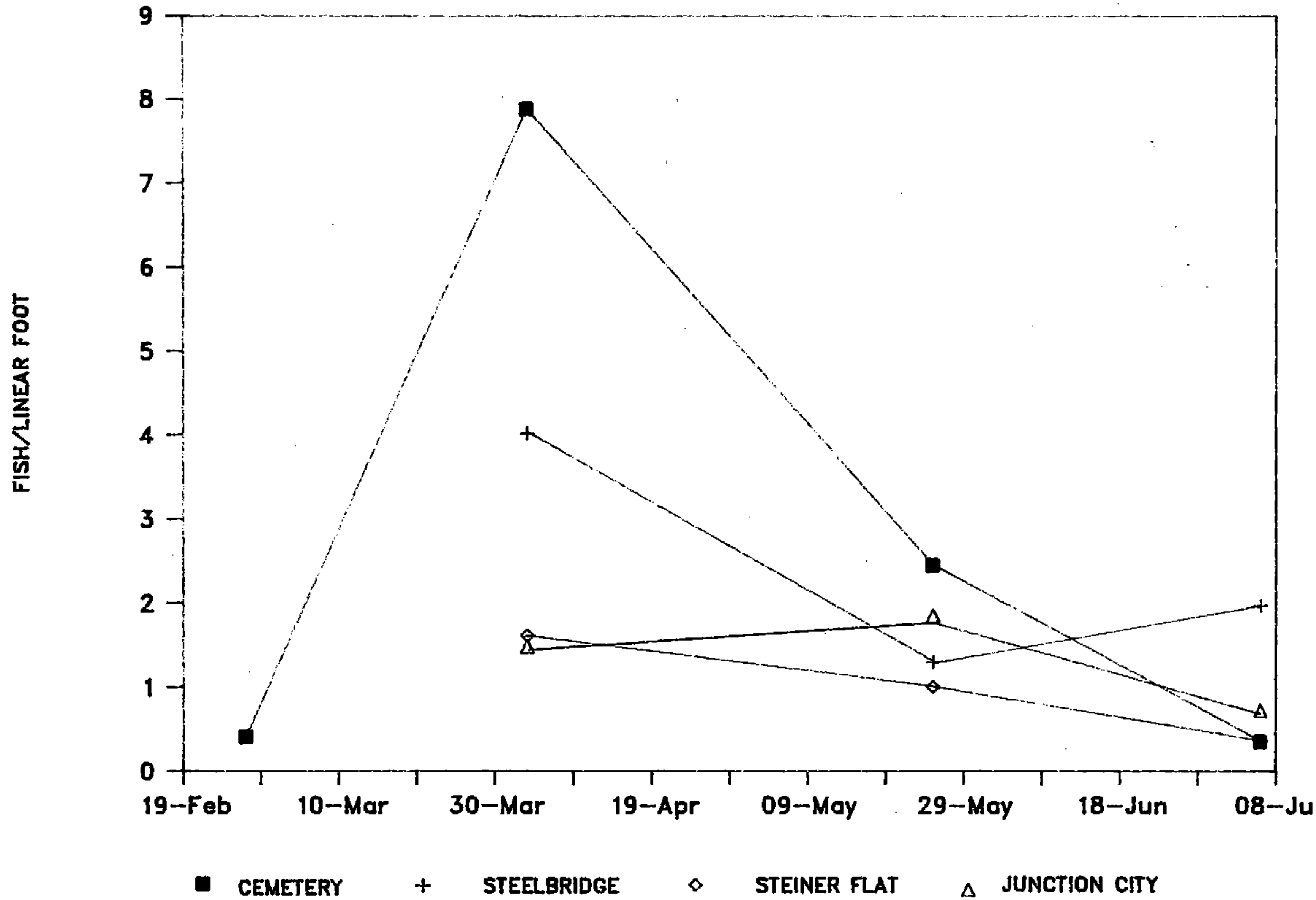


Figure 1 Rearing chinook salmon counts at four upper Trinity River sites, spring 1989.

HABITAT REQUIREMENTS FOR JUVENILE CHINOOK

INTRODUCTION

The Trinity River Flow Evaluation is composed of six major study tasks. Task 3 of the study is composed of two objectives: 1) To determine the amount of salmon and steelhead habitat available in the Trinity River under various flow conditions and the various levels of habitat rehabilitation that may be achieved either through the Trinity River Basin Fish & Wildlife Management Program or through other resource actions, 2) To determine the amount of habitat required for each salmon and steelhead life-stage to sustain those portions of fish populations in the Trinity Basin that were historically dependent on the Trinity River downstream of Lewiston Dam.

Currently, in order to determine fish population levels that the Trinity River is capable of supporting, weighted usable area estimates are multiplied by fish densities for a certain species and lifestage that have been described under Task 4 (studies of fish populations and life history characteristics). The implied assumptions are that observed fish densities correspond to or are obtained under conditions of maximum carrying capacity, and that multiplication of these fish densities by weighted usable area result in a direct relationship between actual fish abundance and weighted usable area estimates.

The goal of this study is to validate habitat use of transect cells as predicted by IFIM weighted usable area estimates, and to determine if a relationship between observed fish densities and cell joint preference factors exists. Should a direct relationship between fish density and predicted suitability from joint preference factors be found, an estimate of the total standing crop can be determined by multiplying total WUA by the maximum estimated fish density (95% CI) observed for cells with an equivalent suitability of 1.0.

Juvenile chinook salmon were selected as our evaluation species for two reasons: 1) we felt they would be the most likely species to meet the assumption of carrying capacity since 47,169 natural spawning chinook salmon were estimated in the Trinity River above Willow Creek in 1988 (CDF&G, 1988) providing for a large recruitment of naturally produced fry in 1989, and 2) chinook salmon juveniles have the shortest freshwater lifestage, therefore biological impacts which may influence the population may be less severe than those which may be expected to effect other species which rear for one or more years. Thus, physical habitat parameters may reasonably be assumed to be the primary factor affecting carrying capacity for this lifestage.

STUDY SITE

We originally planned to sample five study sites between Lewiston and the confluence of the North Fork Trinity River, however, heavy rain and snow storms during March 1989 delayed our sampling until April. High river flows and turbid water conditions prevented us from sampling study sites located downstream of Lewiston. Therefore, effort was concentrated in the Cemetery study site located three river miles below Lewiston Dam. A description of the Cemetery study site may be found in our 1986 annual report (USFWS, 1986).

Thirteen IFIM transects have been monitored within the Cemetery study site since 1986. Of these, five transects were selected for this evaluation on the basis of habitat type. Transect 1 represents habitat typical of upper river runs. The majority of depths across the transect range between 2 and 3.5 feet and mean column velocities were less than 3 cubic feet per second. The substrates across transect 1 range from small boulders to gravel from right to left. Transect 2 is located across a riffle with cobble substrates. The total depths are less than 2.5 feet with mean column velocities ranging up to 4.5 feet per second. Transect 3 contains two chutes with backwaters located along the river edges. Mean column water velocities exceed 5 cubic feet per second in the left chute. The right and left edges of this transect contain cobbles and small boulders. Bedrock is located underneath both chutes and sand is the primary substrate present in the quiet water area between the two chutes. Transect 7 is located across the bottom of a riffle at the upstream end of Sawmill Pool. A backwater and sandy ledge is present along the right bank. Across the thalweg substrates are composed of large cobbles embedded in approximately 10 to 30 percent sand. Transect 9 is located across the lower half of Sawmill Pool. The total depth is slightly over 6 feet and mean column velocities were less than 2 feet per second. The right bank is formed by bedrock ledges which change to cobbles across the thalweg. A gravel bar forms the left bank of the transect.

METHODS

IFIM field data was collected following those procedures recommended by the U.S. Fish & Wildlife Service's, National Ecology Research Center's, Aquatic Systems Branch (Bovee and Milhous, 1978; Trihey and Wegner, 1981). Water depths were measured with a top setting wading rod and mean column velocities were measured with a Price AA current meter. Water surface elevations were measured with a spirit level and fiberglass level rod from established benchmarks with an assumed elevation of 100.00. Distances and vertical locations were measured with a surveyor's rope which was zeroed on iron head pins. Hydraulic field data was collected on April 7, at a river discharge 300 cubic feet per second.

The resulting field data was constructed into IFG-4 input decks and run through the USFWS's microcomputer IFG-4 and HABTAT programs. The habitat preference criteria utilized in the HABTAT program were developed using direct observation techniques on the Trinity River by Hampton (1988). Simulated mean column velocities and water depths for each transect were obtained by examination of the calibration details provided by the IFG-4 program output with IOC option 2 set on. Individual transect cell suitability estimates were obtained from the HABTAT program with IOC option 13 turned on. The resulting information was then combined and analyzed on micro-computer spreadsheet software for easy comparison.

In order to assist field data collection of fish use, painted cobbles were placed across each transect during IFIM field data collection to denote IFIM cell boundaries. In order to simplify accurate identification of cells by snorkel divers, vertical distances (ft) were written on each cobble with an indelible marker.

Fish utilization across each transect was determined by snorkel divers as follows. At the beginning of each sample day ropes were strung tight across each transect with the aid of ascenders, carabiners, and pulleys. After allowing the ropes to rest for at least an hour, one diver would cautiously approach the rope from downstream and attach an additional pulley and tag line. The diver would then use the pulley and tag line to slowly ferry across the transect, while maintaining a distance of approximately 6 feet downstream from the transect. The divers controlled movement across each transect by slowly angling his body in either direction. The snorkel diver would then count the number of juvenile chinook salmon located within each cell as denoted by the white cobble markers. Fish numbers were recorded on underwater slates. Observations were generally made between 1:00 and 4:00 pm. On April 12 we conducted one set of observations between 9:30 and 11:00 am.

Fish densities were calculated for each cell by dividing the average number of fish observed by the cell area sampled. The cell area was determined by multiplying the cell width by the observational cell length (6 ft). The observed fish densities were then paired with their corresponding joint preference factors and sorted in ascending order. Joint preference factors were then organized into 0.05 intervals and their corresponding fish densities were averaged within these interval widths. A linear regression was then calculated between cell joint preference factors and average observed juvenile chinook salmon densities. Stat-Pak statistical software was used to obtain the results of the regression equation and 95% confidence intervals about the regression line.

RESULTS

A total of thirteen fish sample observations were completed between April 6 and April 19, 1989. River flows throughout the sampling effort were maintained at 300 cubic feet per second. Figures 1 through 5 present study transect profiles , as predicted by the IFG-4 program, predicted cell joint preference factors from the HABTAT program output, and the average juvenile chinook salmon densities that were observed for each cell.

A regression analysis of average juvenile chinook salmon density on cell joint preference factors is presented in Figure 6. The resulting regression equation is as follows:

$$Y = 4.881968E\text{-}02 + 0.43043 * X$$

where, **X = Predicted cell joint preference factor**
Y = Estimated juvenile chinook salmon density (fish/ft^2)
r^2 = 0.6637

Based on these results, optimum habitat, that is habitat cells with a joint preference factor of 1.0, should contain 0.48 juvenile chinook salmon per square feet. Habitat cells with a joint preference factor of 0.0 should contain 0.05 juvenile chinook salmon per square feet.

DISCUSSION

The development of a relationship between habitat quality as predicted by IFIM and juvenile chinook salmon densities brings us one step further in our quest to develop habitat ratios that may be used to accurately identify factors limiting chinook salmon production within the Trinity River. Although these results increase our confidence in the Instream Flow Incremental Methodology as being the best approach to use in our situation there are some aspects of our findings that require additional discussion.

During our field observations on juvenile chinook salmon we noted four parameters that include both behavioral and physical aspects that affected our final results.

The HABTAT program predicted joint preference factors ranging from 0.45 to 0.76 for the habitat cells located between verticals 93 and 116.5 on transect 2 (Figure 2). However, juvenile chinook salmon were rarely observed in these habitat cells. While conducting our observations of this area we consistently observed juvenile steelhead trout, which leads us to postulate that the predatory behavior of the steelhead within these habitat cells probably deterred juvenile chinook salmon from entering this area. This was the only instance within our sample sites that

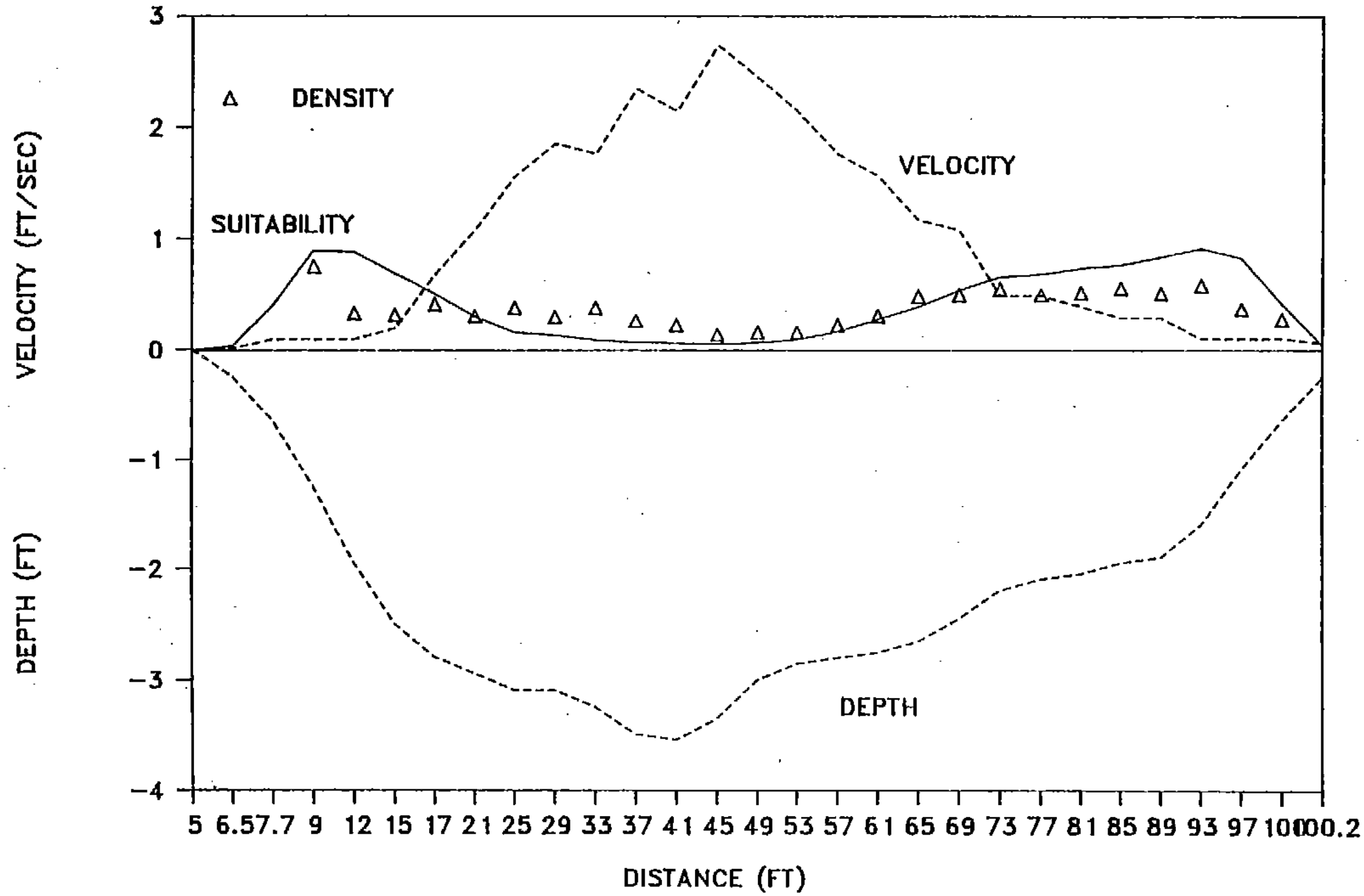


Figure 1. Profile of transect 1 showing the observed densities of juvenile chinook salmon per cell in association with the habitat suitabilities predicted for each cell by the HABTAT program.

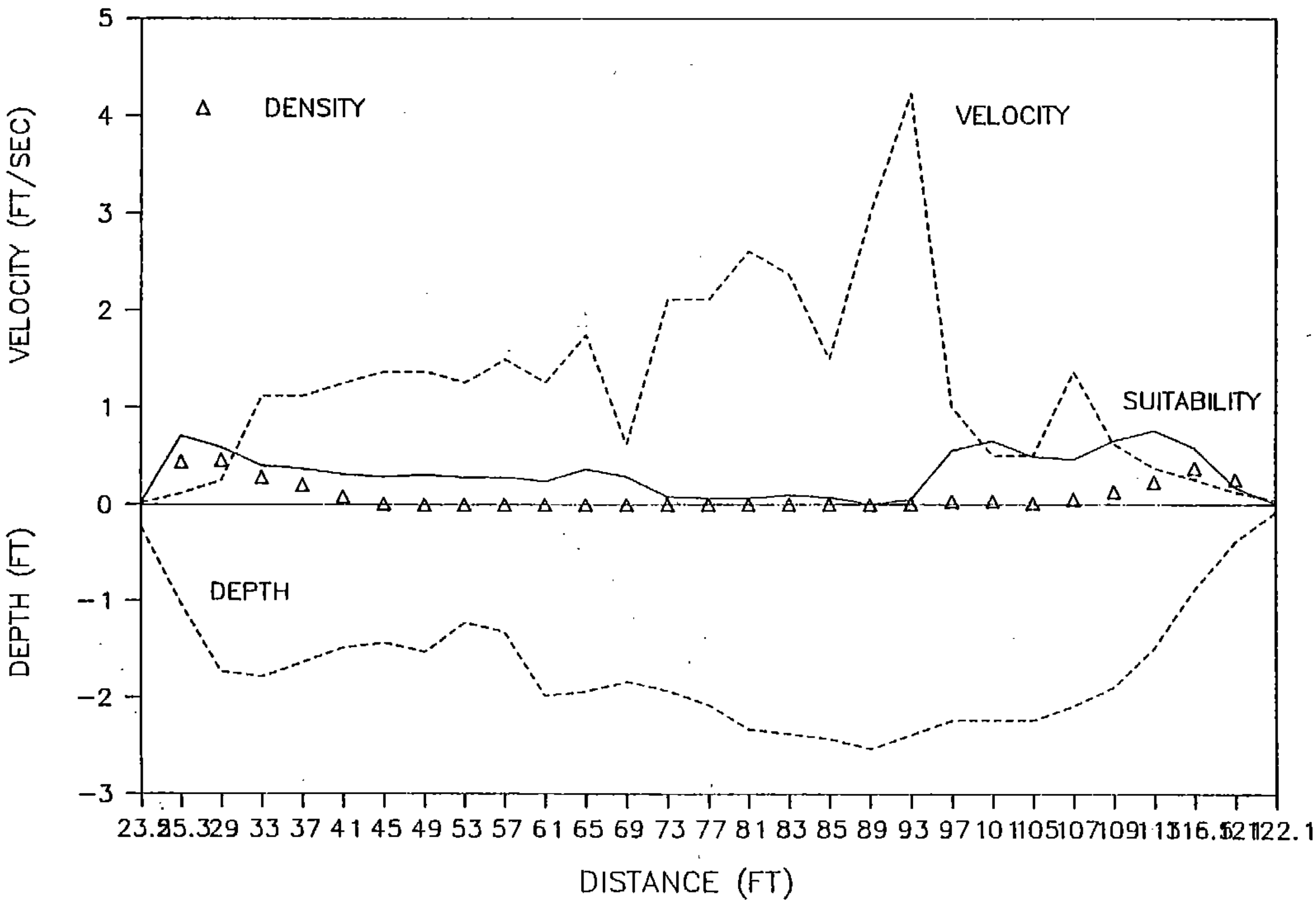


Figure 2. Profile of transect 2 showing the observed densities of juvenile chinook salmon per cell in association with the habitat suitabilities predicted for each cell by the HABTAT program.

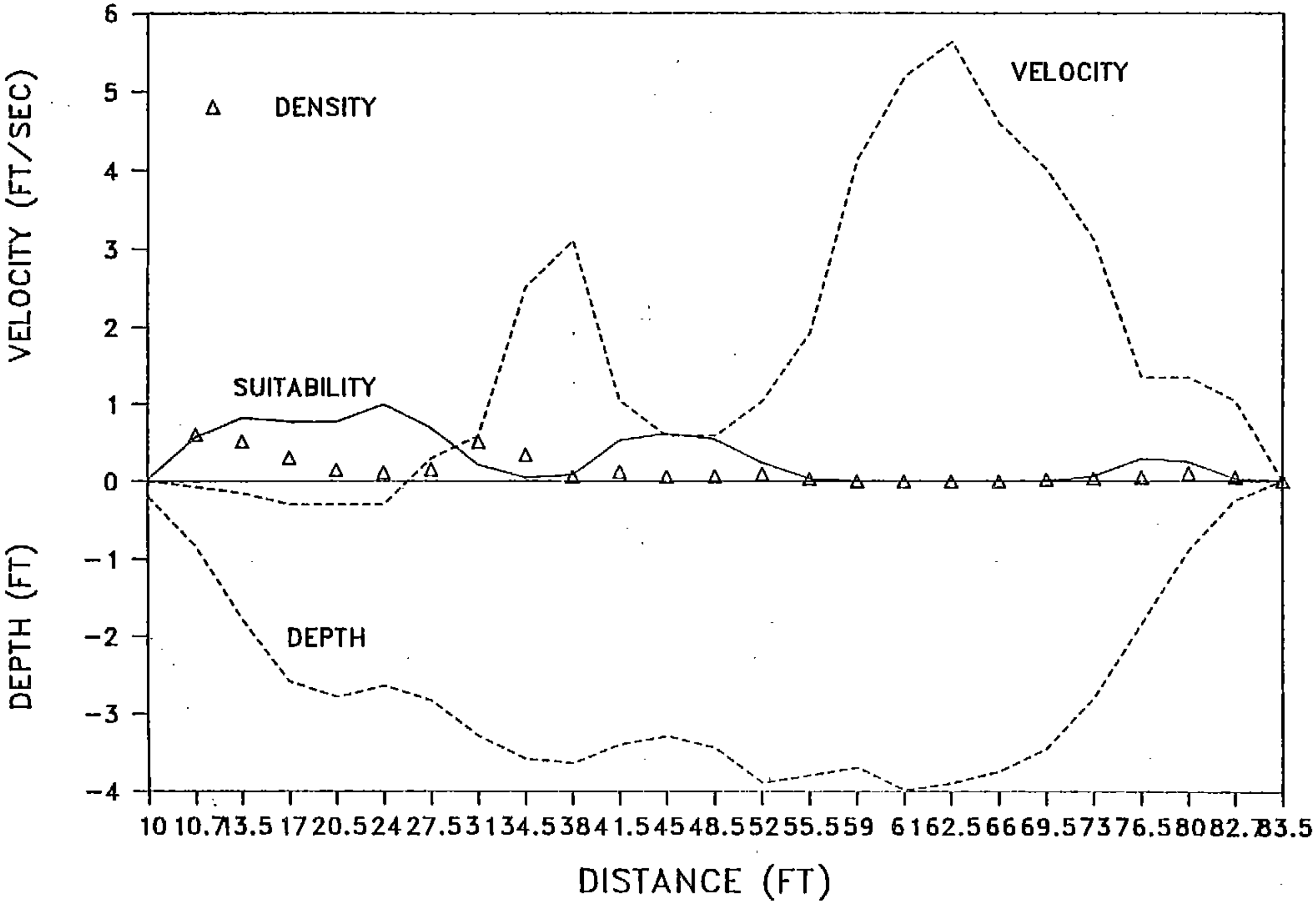


Figure 3. Profile of transect 3 showing the observed densities of juvenile chinook salmon per cell in association with the habitat suitabilities predicted for each cell by the HABTAT program.

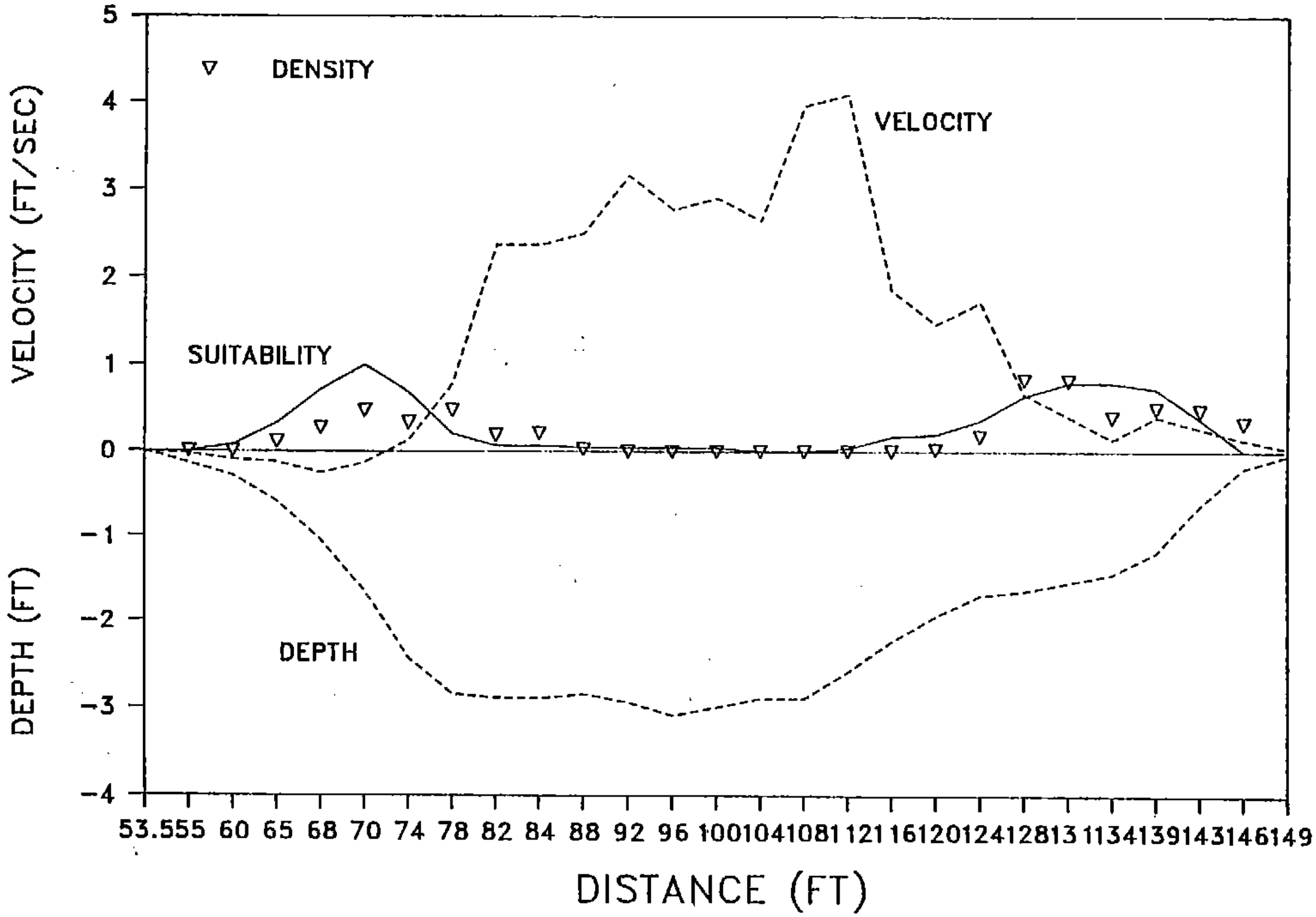


Figure 4. Profile of transect 7 showing the observed densities of juvenile chinook salmon per cell in association with the habitat suitabilities predicted for each cell by the HABTAT program.

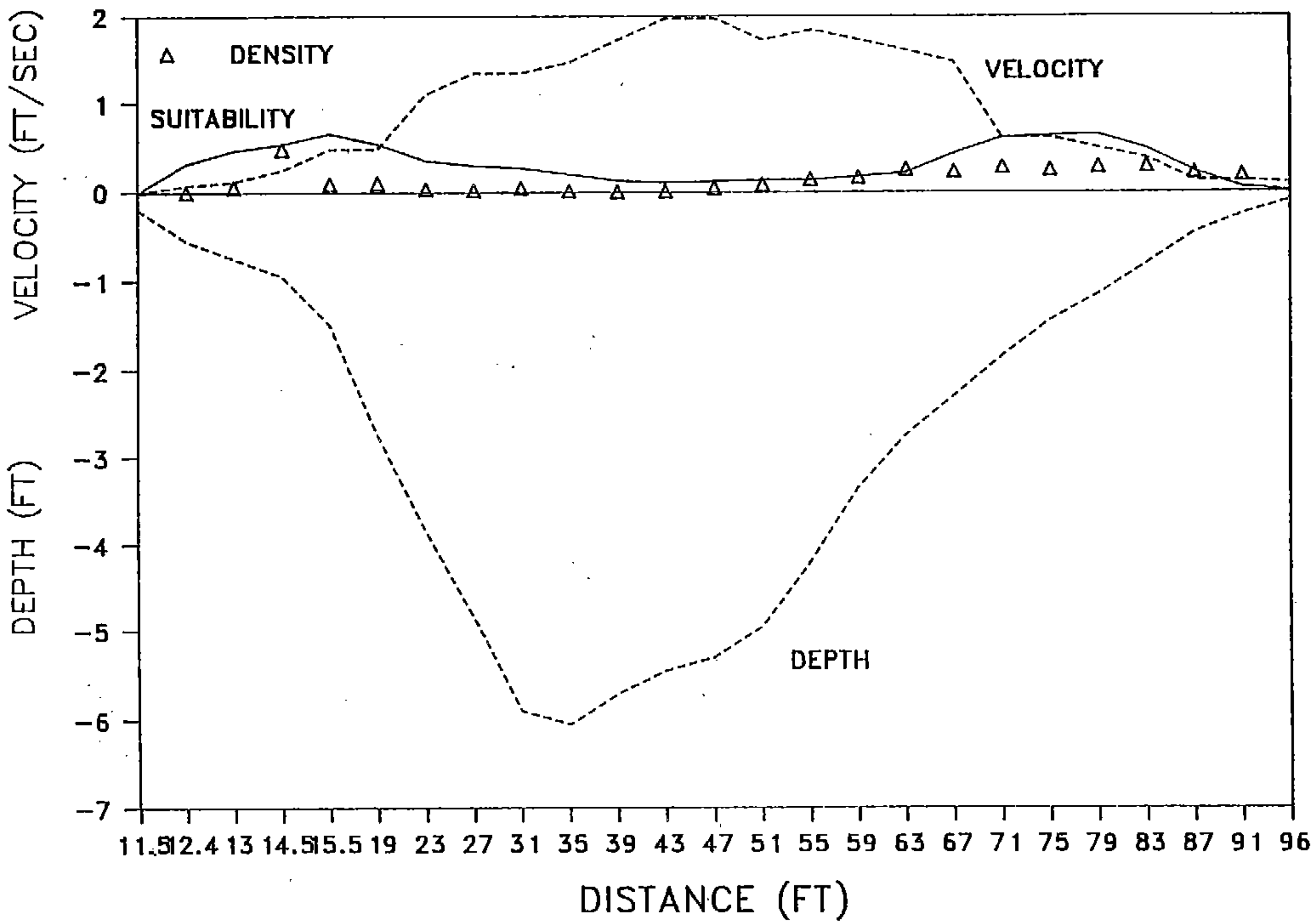


Figure 5. Profile of transect 9 showing the observed denisities of juvenile chinook salmon per cell in association with the habitat suitabilities predicted for each cell by the HABTAT program.

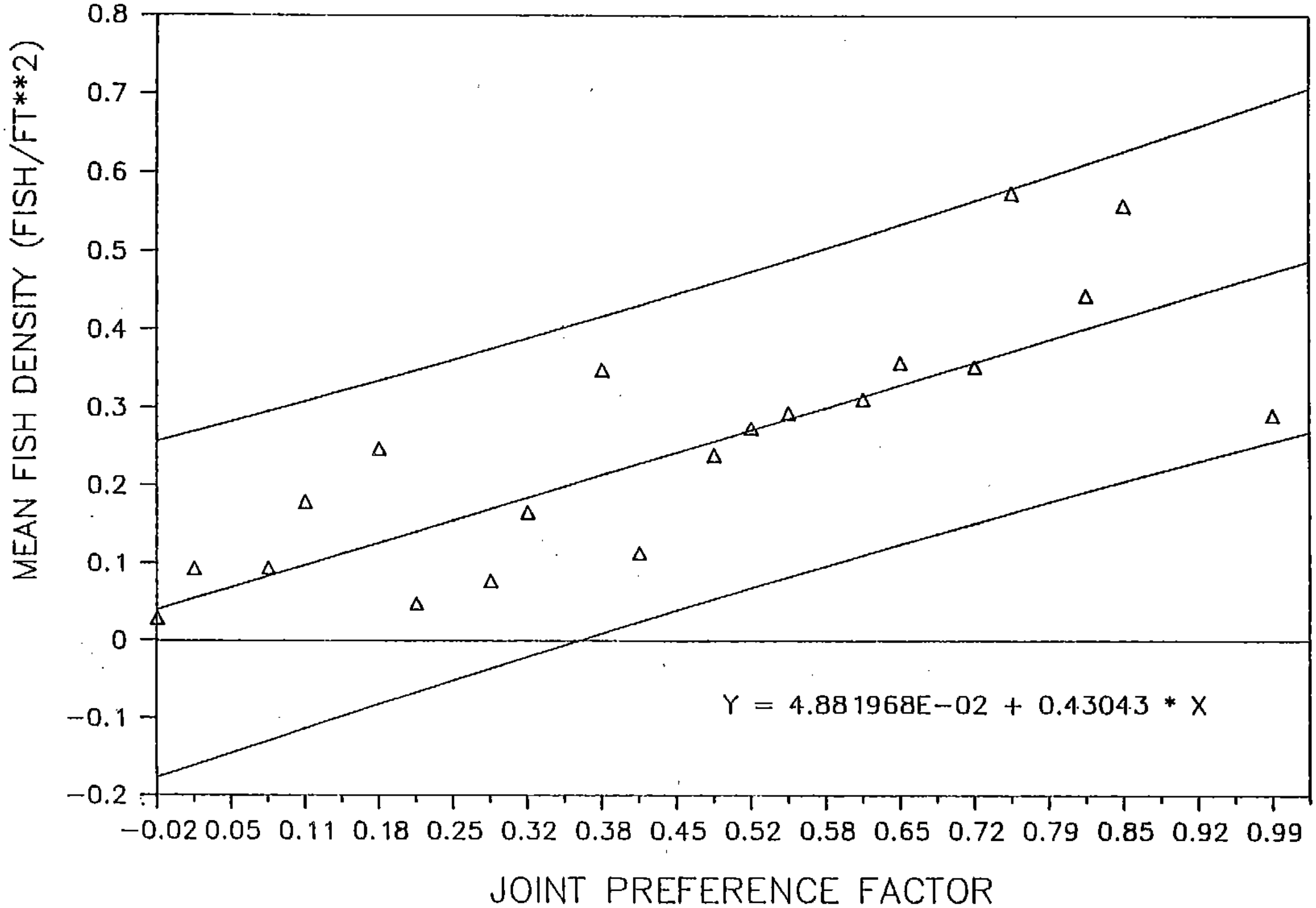


Figure 6. Regression analysis between average juvenile chinook salmon densities and joint preference factors predicted by the HABTAT program.

interspecies behavior seemed to affect habitat use by juvenile chinook salmon.

During the habitat preference study we found that juvenile chinook salmon selected different microhabitats at different hours or the day. At night juvenile chinook salmon tended to congregate in slow or still water areas in close proximity to substrates or cover items adjacent to the river edges (Hampton, 1988). During daylight hours juvenile chinook salmon moved out into faster water areas away from the bank. This behavior trait was also observed during this study on April 12 when we sampled each transect four times, twice in the morning starting at 9:30 am and twice in the afternoon starting at 1:30 pm. During the afternoon observations we noticed that juvenile chinook salmon had distributed into habitat cells that were vacant during the morning observations. It appears that changes in habitat selection from preferred evening microhabitats to preferred afternoon microhabitats occur gradually throughout the daylight hours. Therefore, saturation of all available microhabitats probably isn't complete until late afternoon. This behavioral trait should be considered in future habitat preference criteria work if the full range of utilized rearing habitat is to be effectively measured.

The highest densities of juvenile chinook salmon that were observed during our study occurred in cells that contained less than optimum habitat as predicted by HABTAT program output joint preference factors, yet were adjacent to shear velocity zones. For example, the habitat cell located at 126 feet on transect 7 (Figure 4) received a joint preference factor of 0.648, yet the observed density of juvenile chinook salmon using this cell was 0.826 and was the highest density calculated for all habitat cells. The mean column velocity modeled for the vertical at 124 feet was 1.72 feet/second and the mean column velocity modeled for the vertical located at 128 feet equalled 0.66 feet/second. Therefore, the predicted mean column velocity for the habitat cell itself equaled 1.19 feet/second when in actuality the majority of cell contains water velocities less than 1.0 feet/second. Slower water velocities would of resulted in a higher joint preference factor for the habitat cell thus yielding a better fish density/joint preference factor relationship. The shear zone present at vertical 124 provided a good feeding lane for juvenile chinook salmon located in the habitat cell. This problem could have been corrected by establishing smaller habitat cells during IFIM data collection.

Another velocity shear zone sampled with similar characteristics is located between habitat cells at 76 and 80 feet. In the habitat cell located at 76 feet we observed 0.47 juvenile chinook salmon per square feet. The HABTAT program predicted a joint preference factor of 0.195 for the same habitat cell. The water velocity predictions made by the IFG-4 program for the verticals located at 74, 78, and 82 feet were 0.13, 0.79, and 2.38 feet/second respectively. The velocity shear zone is located in the habitat cell at 80 feet adjacent to the habitat cell located at 76 feet where high juvenile chinook salmon densities were found.

These findings suggest that the current habitat preference criteria developed for juvenile chinook salmon may need further refinement in order to better reflect current habitat use. Chinook salmon escapement to the Trinity River in 1984 and 1985 equaled 5,654 and 9,217 adults above Willow Creek. The majority of habitat preference data for juvenile chinook salmon was collected in 1985 and 1986, which would have been fry produced by the 1984 and 1985 spawners. In 1986, 1987 and 1988 chinook salmon spawing escapements have equaled 92,548, 71,920 and 44,616 adults respectively. Since completion of the habitat preference study fry and juvenile chinook salmon densities have been much higher and the extent of habitats used by young chinook salmon has probably increased habitats near saturation. It seems apparent that during our habitat preference data collection period the habitat was underseeded, resulting in criteria that may not include all microhabitats used by juvenile chinook salmon. This spring we intend to direct more effort to increasing our habitat use data base as well as obtain additional information regarding fish densities in relation to WUA.

The same velocity shear zones that produce optimum rearing habitat for juvenile chinook salmon may in some cases isolate midstream habitat from juvenile chinook salmon. For example, on transect 3 the HABTAT program predicted that three habitat cells with joint preference factors of 0.533, 0.622, and 0.533 were located at 39.75, 43.25, and 46.75 feet respectively. However, the observed densities of juvenile chinook salmon within these three habitat cells were 0.124, 0.058, and 0.062 fish per square feet. Based on the regression equation presented here we would expect to find juvenile chinook salmon densities for these three habitat cells to equal 0.27, 0.31, and 0.27 fish per square feet. The presence of high velocity zones on both sides of these habitat cells restricted movement of juvenile chinook salmon from either bank, thus preventing these habitat cells from reaching their full potential. Future habitat restoration projects that seek to increase juvenile chinook salmon habitat in swift water areas should keep these considerations in mind.

JUVENILE SALMONID GROWTH

Introduction

In 1989, growth sampling of juvenile salmonids was continued at seven study sites on the Trinity River. Growth sampling of juvenile salmonids began in January of 1986 and continued through July of 1989.

Methods

We used six of the nine study sites sampled in 1987 (U.S. Fish & Wildlife Service, 1987). These sites are Cemetery, Steel Bridge, Steiner Flat, Junction City, Del Loma, and Tish-Tang. Our Bucktail site was moved to a location approximately 1/2 mile upstream from the Brown's Mountain Road Bridge (river mile 105.6) on the left bank, because catches were low at the original location. Occasionally, high flows forced us to sample an area downstream of Evans Bar on the left bank (river mile 84.4) in place of our Junction City site.

At each study site fish were collected with a backpack electroshocker. We sampled in an upstream direction in riffles or runs, with one person electroshocking and a second person following behind to capture shocked fish with a dip net. Captured fish were anesthetized with tricaine methanesulfonate, measured for fork length to the nearest millimeter, and weighed to the nearest gram. No data were collected on fin-clipped fish or any other fish believed to be of hatchery origin. All fish were returned to the river.

Data Analysis

Age-class determinations for juvenile steelhead were made from length-frequency histogram analysis. Instantaneous growth rates in length (Bagenal, 1978) were calculated for steelhead on a seasonal basis for each age class as follows:

$$G = \frac{\ln \bar{L}_2 - \ln \bar{L}_1}{\triangle T}$$

where: G = Instantaneous rate of length increase

$\bar{L}_1$ = Initial mean fork length for year class

$\bar{L}_2$ = Final mean fork length for year class

$\triangle T$ = Change in time in years

Results

Between January 1986 and July 1989 a total of 14,564 juvenile trout and salmon were collected. A breakdown of the total numbers of each species is presented in Table 1.

Table 1. Total number of juveniles, by species and sample year, captured in growth sampling efforts from January 1986 to July 1989, Trinity River, California.

	Sample Year			
Species	1986	1987	1988	1989
Chinook Salmon	892	1201	1328	1771
Coho Salmon	320	111	407	317
Steelhead Trout	1293	2030	1717	1244
Brown Trout	443	515	389	586
Total	2948	3857	3841	3918

In the fall of 1988 escapement in the basin upstream of the South Fork Trinity, excluding hatchery returns, was estimated at 57,727 adult fall chinook (California Department of Fish and Game). The majority of these adults could not ascend upper river tributary streams because of low flows, and spawned in the mainstem. The low water year also may have increased the spawner distribution in the lower river.

The 1989 year class of chinook fry began emerging from the gravel in January and exhibited growth rates comparable to 1986, 1987, and 1988 year classes (Figure 1). Statistical analysis of growth rates of all juvenile chinook salmon year classes sampled show no significant differences. A length frequency distribution is presented in figure 2.

Coho salmon fry began emerging from the gravel in March, two months later than the chinook salmon fry. Coho salmon juveniles were captured as far downstream as Del Loma, but the majority (93.4%) of juvenile coho were found in the upper river above Douglas City. Mean forklength of juvenile coho salmon through July of 1989 are compared to the growth of the 1986, 1987, and 1988 year classes in Figure 3, Figure 4 displays a length frequency distribution.

Juvenile steelhead trout are found throughout the river. Fry steelhead trout first appeared in April at all study sites.

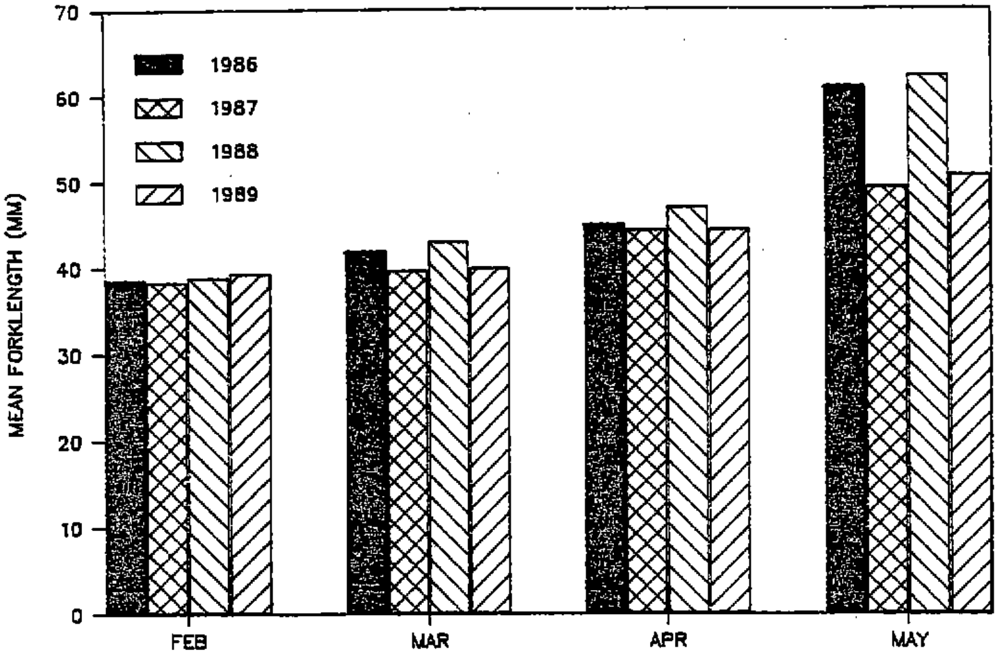


Figure 1. Comparison of mean forklengths of juvenile chinook salmon between 1986, 1987, 1988, and 1989 year classes for the Trinity River, California.

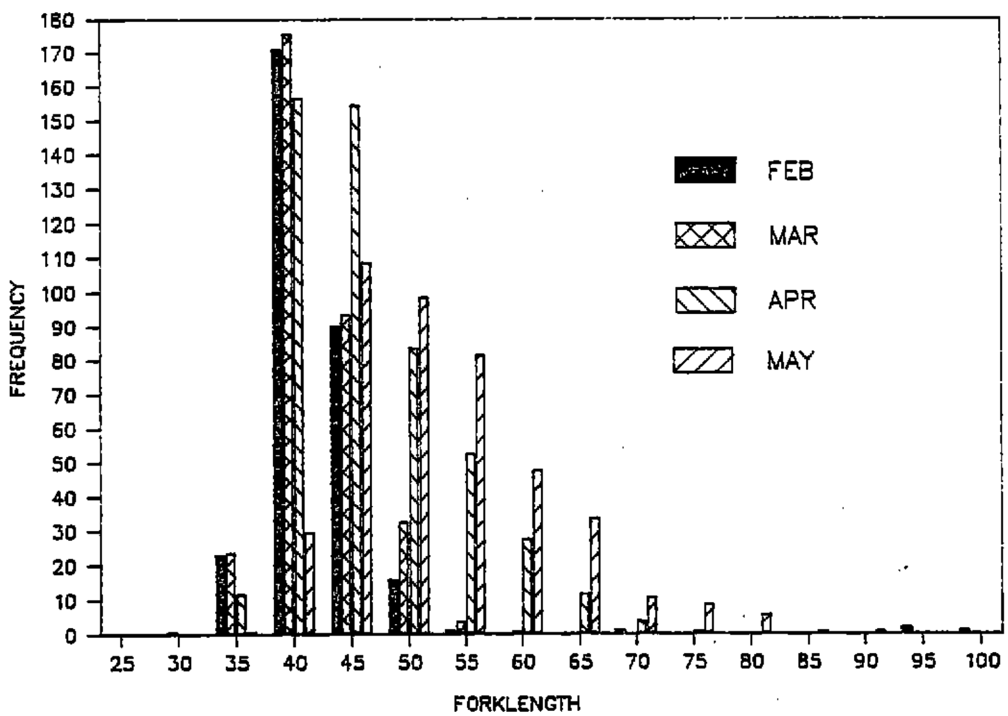


Figure 2. Frequency distribution of forklengths for juvenile chinook salmon in the Trinity River, California, for 1989.

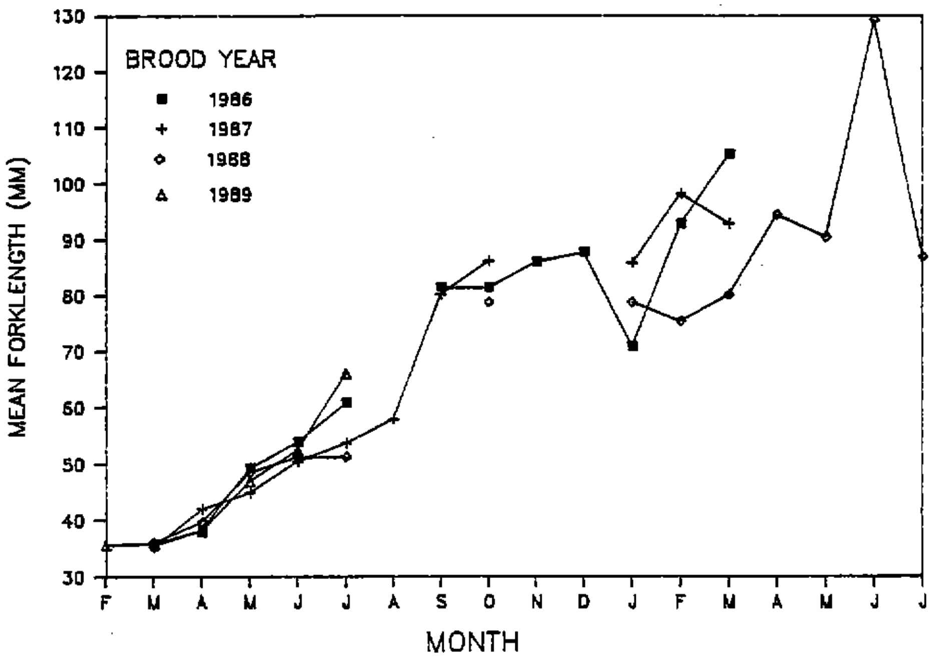


Figure 3. Comparison of mean forklengths of juvenile coho salmon between 1986, 1987, 1988, and 1989 year classes for the Trinity River, California.

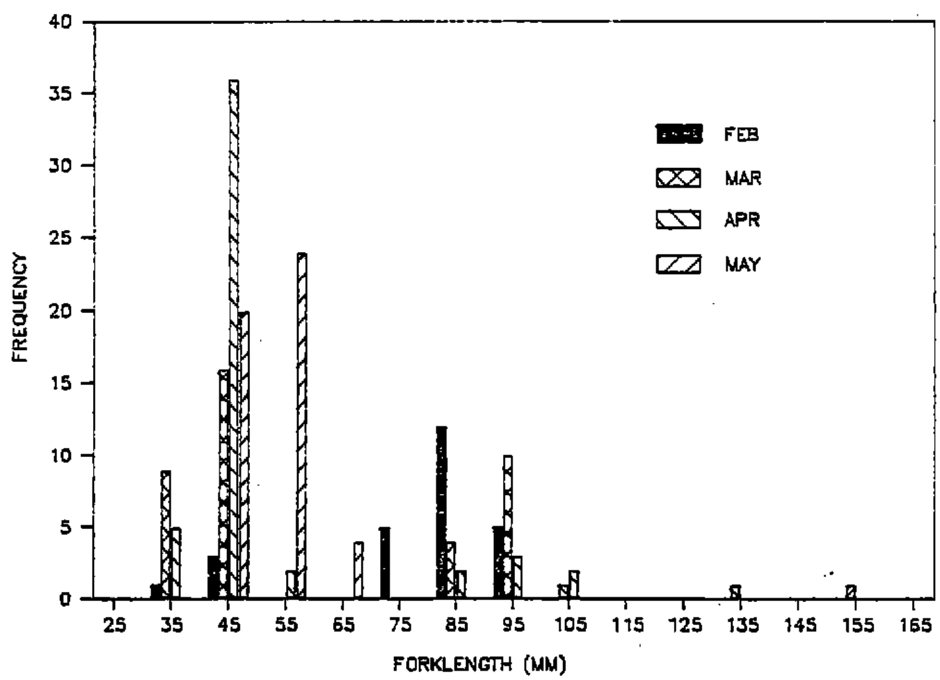


Figure 4. Frequency distribution of juvenile coho salmon in the Trinity River, California, for 1989.

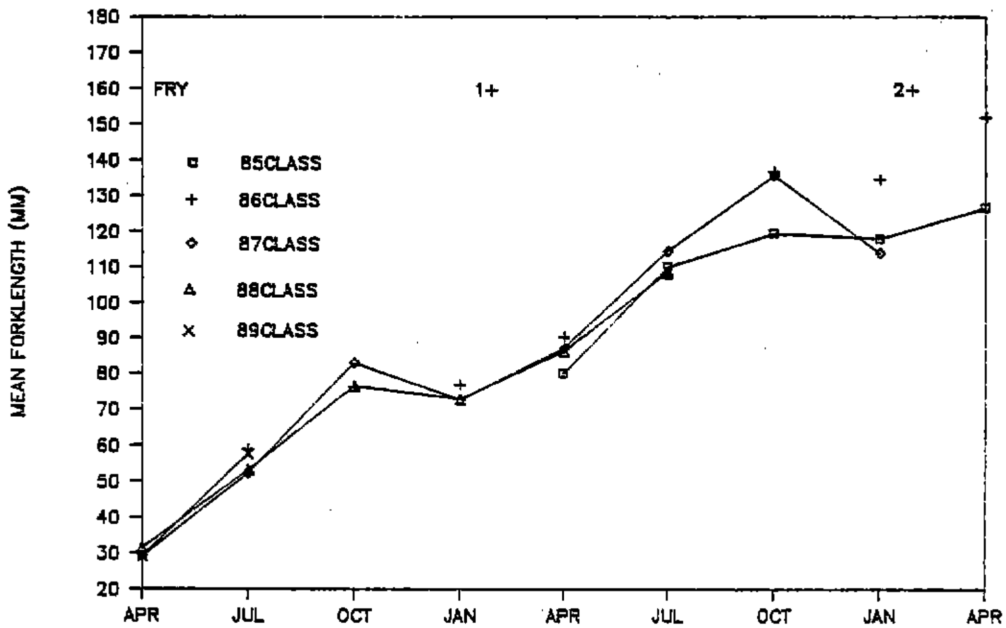


Figure 5. Comparison of mean forklengths of juvenile steelhead between 1985, 1986, 1987, 1988, and 1989 year class for the Trinity River, California.

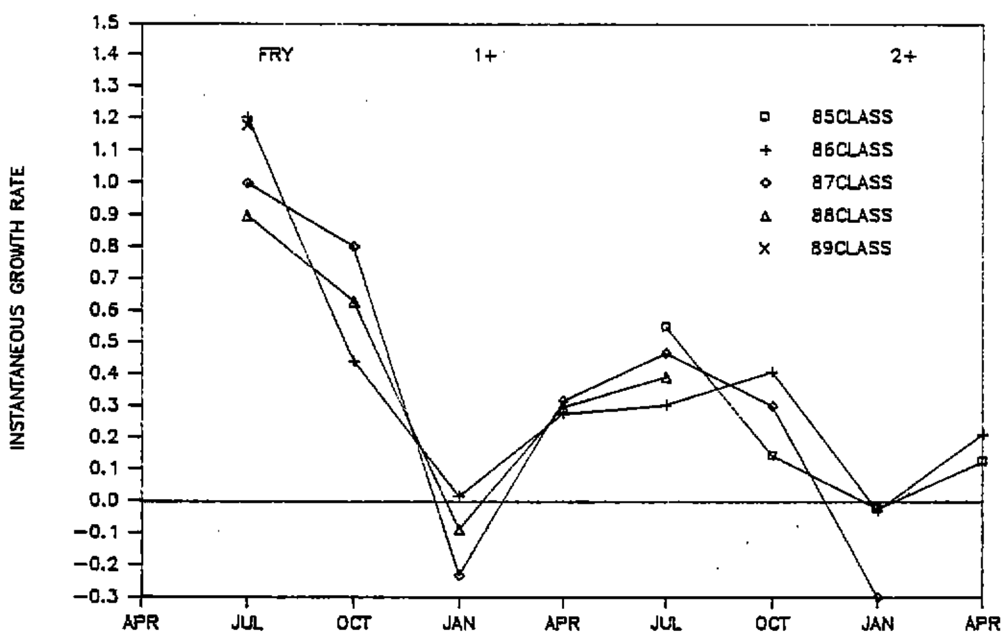


Figure 6. Seasonal instantanious growth of juvenile steelhead for 1985, 1986, 1987, 1988, and 1989 year classes in the Trinity River.

Growth of juvenile steelhead was analyzed on a seasonal basis with samples in April, July, October, and January. Figure 5 presents mean fork lengths over time for the last five year-classes.

Instantaneous growth rates for the same five year-classes are presented in Figure 6.

Discussion

Chinook salmon: Statistical analysis of juvenile chinook salmon between year classes 1986, 1987, 1988, and 1989 revealed no significant differences in mean forklengths in May. May was chosen for analysis because by that month fish have been emerging since January, and should show differences in forklength as a function of their emergence timing. May is also the critical pre-smolting period preceding downstream migration.

Single variable analyses of variance (ANOVA) were run to evaluate growth of fish. We used two separate parameters in our evaluation. First, variance between years was analyzed by pooling each year class. Then the 1989 year class was analyzed on a site basis, to detect any differences among fish of the same year class attributable to their location in the river. Both ANOVA results confirm that there are no significant differences present (see appendix).

We expected to see differences in forklength and instantaneous growth from site to site within the river, with warmer lower-river temperatures producing larger fish. However, spring chinook, which are first to emerge from the gravel, reproduce only in the upper river. These fish have a longer period of growth compared to lower river fish, and this may have evened out the average sizes and apparent growth rates.

Our findings show no significant differences in mean forklengths of fish on either a river-wide or site-to-site comparison. The most obvious cause for this is a lack of isolation between sites; fish are constantly migrating downstream during the rearing season, and later-emerging fish mix with larger fish throughout the river.

Mean forklengths of juvenile chinook salmon for several different watersheds in California are compared in Table 2.

Table 2. Mean forklengths of juvenile chinook salmon for several watersheds in California.

River\ Source	FEB	MAR	APR	MAY
Trinity\ U.S. Fish and Wildlife Service				
1986	39	42	45	61
1987	39	40	45	50
1988	39	43	47	62
1989	40	40	45	51
Trinity\ California Department of Fish and Game				
1984				57
1985			45	58
1986				64
1987				53
Bogus Creek\ California Department of Fish and Game				
1989	38	39	50	57
Sacramento\ U.S. Fish and Wildlife Service				
1984	41	45	65	70
American\ U.S. Fish and Wildlife Service				
1983	38	40	46	67
San Joaquin\ Turlock Irrigation District				
1986	38	64	79	81
1987	41	51	65	
1988		51	74	
1989		47	70	
Tuolumne\ Turlock Irrigation District				
1986	40	52	64	53
1987	42	47	56	69
1988	38	47	48	43
1989	39	46	55	67

Comparison of these figures suggests that Trinity River fish are basically the same size as in other systems at the beginning of the rearing season. By March, however, San Joaquin and Tuolumne River fish have grown larger than Trinity stocks. By April all systems except the American River have fish of greater length than Trinity fish. In May, Bogus Creek and Tuolumne River fish have caught up to the Trinity, but all other systems have larger fish. Water temperature, food supply, time of emergence, and genetic variation may account for these differences.

<u>Coho Salmon</u>. A relatively strong run of coho salmon returned to the Trinity River in the fall of 1988 and the winter of 1989. Coho spawn and emerge from the gravel later than chinook, with emergence beginning in March seeming to be the norm for the

Trinity River. Our catch rates were highest in the spring months, tailing off in the fall and winter to very low levels.

A single variable ANOVA (see appendix) was run between mean forklengths of all coho year classes on a river-wide basis. Fish in June have been rearing for three to four months, and water temperatures are warmer and more conducive to growth, so any size differences should be most pronounced in June. The ANOVA's show no significant difference at 95 percent confidence intervals in mean forklengths over the four year classes sampled.

Steelhead. Adult escapement in the Trinity River for the winter of 1988-1989 was comparable to winters of 1987-1988 and 1986-1987. Fry emergence throughout the river began in April.

Average forklengths of the last five year classes (Figure 5) showed little variation from year to year. Instantaneous growth rates (Figure 6) were highest in the spring and summer, followed by a decline in the fall. They were negative in four of the five year classes in winter, probably because of the emigration of larger fish.

PROGRAM PLANNING, DIRECTION, AND COORDINATION

The direction of the Trinity River Flow Evaluation Program has been affected by the drought conditions experienced since 1985. Trinity River flows in three of the five years since the Evaluation Program began have been reduced due to dry or critical dry year classifications. As a result evaluation activities have evolved in response to limited supplies of available water rather than an approach aimed at defining baseline habitat conditions within the full range of flows expected or possible, then evaluating change. For the most part progress has been made despite limited water supplies. With only five field seasons remaining, however, a major objective of the evaluation program, monitoring flow-related habitat change over time, may not be achieved.

Generally, activities associated with the Trinity River Flow Evaluation Study planned for 1990 will continue to focus on: 1) the analysis of salmon and steelhead habitat available in the mainstem Trinity River at various streamflow regimes; 2) the continued monitoring of salmonid habitat needs and use; and, 3) the determination of habitat and population characteristics influenced by streamflows and the degree to which they are affected by streamflow within the Trinity River. In addition, as mainstem Trinity River Restoration Program projects are completed we will continue assessment activities to document habitat gains and use by salmon and steelhead trout.

Determination of Habitat Availability and Needs (Task 3)

Efforts within this study task during 1990 will be affected by the available supply of water for the Trinity River. Initial plans are to expand upon the analysis begun in 1985 and to evaluated habitat availability at flows of 3000 cfs, 1500 cfs, 1000 cfs, and 300 cfs. Actual habitat measurements are necessary at these flows because of the discontinuous morphology of the river channel. While this makes field data gathering more difficult it creates a more accurate modeling effort. Should drought conditions persist, and water supplies to the Trinity be limited, we will modify efforts planned within this study element and take the opportunity provided to evaluate low flows.

We will continue to monitor mainstem water temperatures. Temperature data, along with those already gathered, will be used as validation points in completing a river network analysis using the Service's Instream Water Temperature Model. An initial model run will be completed during 1990 with the preliminary results presented in our 1990 annual report.

Detailed evaluations of newly constructed or existing side-channel habitats along the Trinity River will continue during 1990. We plan to focus on the utilization of these habitats by juvenile salmonids, the amount of new habitat created, and the degree of change over time. These evaluations are being closely coordinated with ongoing work being conducted by the Trinity River Restoration Program and are aimed at determining the effectiveness of artificial side-channels Trinity for juvenile salmonid rearing.

In an effort to gain a better understanding of the relationship between hydrology, micro- and macro-habitat modeling, and fish production we have entered into an agreement with the Service's Aquatic Systems Branch or the National Ecology Research Center in Fort Collins, Colorado. The goal of this effort is to integrate the information that has been gathered on the Trinity River to develop criteria upon which to predict population responses to changes in habitat conditions. Efforts during 1990 will concentrate on a review of historical records and development of a detailed study plan. If such an effort is feasible, completion would coincide with the rest of the Evaluation Program.

Fish Population Characteristics and Life History Relationships (Task 4)

Efforts within this task will continue with: 1) steelhead spawning microhabitat use data collection; 2) continued collection of conditional habitat use criteria for juvenile steelhead; 3) development of habitat area requirement information for chinook salmon fry; and 4) development of information on water temperature requirements of Trinity River salmonids.

If flows are reduced by drought conditions, we will continue to monitor holding habitat and habitat use of spring chinook salmon between Lewiston and the North Fork Trinity.

Study Coordination

Close coordination with the Trinity River Basin Fish and Wildlife Management Program Field Office will continue. We will continue to monitor and evaluate all main-stem habitat restoration projects undertaken by the restoration program.

Finally, coordination efforts will continue with the Bureau of Reclamation, the California Department of Fish and Game, the Hoopa Valley Tribe, and Trinity County concerning Trinity River flows, hatchery operations, temperature regulation, and other fishery or habitat management efforts planned for 1990.

As mentioned earlier, the recent drought conditions, experienced within the Trinity and throughout California, have affected the Trinity River Flow Evaluation. Throughout 1989 we have been involved in a mid-program review. This review has been aimed at evaluating the current status of the Flow Evaluation, relative to program goals and objectives, and the tasks necessary to complete the job. A major undertaking for 1990 will be to complete this evaluation and to make any planning revisions deemed necessary for completion of the Trinity River Flow Evaluation.

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APPENDIX

Water Temperature Records

TRINITY RIVER AT LEWISTON, CA.
WATER TEMPERATURE (DEG. C) OCTOBER 1988 TO SEPTEMBER 1989

LOCATION: On right bank approximately 0.8 miles downstream from Lewiston Dam, housed within the USGS gage station at Lewiston Ca.

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	*	9.3	*	5.5	6.2	7.4	11.6	9.4	10.4	9.8	9.1	9.0
2	*	8.7	*	5.5	6.0	7.1	9.7	9.7	10.7	9.3	8.8	9.0
3	*	10.1	*	5.5	5.9	7.3	10.1	10.0	10.9	9.5	8.6	8.9
4	*	10.4	*	5.5	5.7	7.2	12.0	9.3	11.7	10.1	8.9	8.9
5	*	9.3	*	5.4	5.4	7.0	11.6	9.3	11.7	9.5	9.5	8.2
6	*	9.9	*	5.3	5.3	7.1	10.2	8.6	11.4	5.0	9.2	8.2
7	*	9.1	*	5.5	5.2	7.5	10.6	8.7	10.4	8.4	*	8.2
8	*	8.9	*	5.4	5.2	7.8	11.8	9.3	12.1	5.1	*	8.2
9	*	8.6	*	5.5	5.1	8.0	11.6	9.6	11.2	8.4	*	8.2
10	*	8.6	*	5.5	5.2	7.9	11.7	9.0	9.6	9.2	*	8.2
11	*	8.6	*	5.5	5.1	8.4	11.1	9.5	9.7	9.0	*	8.6
13	*	8.9	*	5.5	5.1	8.3	11.1	10.1	10.2	9.1	*	*
14	*	8.7	*	5.3	5.2	8.2	11.9	9.6	9.9	8.7	*	*
15	*	8.7	*	5.2	5.2	7.9	11.7	9.8	10.5	9.3	*	*
16	*	8.9	*	5.3	5.3	9.0	11.9	9.1	13.1	9.3	9.1	*
17	*	8.7	*	5.4	5.7	8.6	13.2	8.3	9.9	8.5	9.1	*
18	*	8.7	*	5.4	5.8	8.1	12.7	8.2	9.7	17.7	8.9	*
19	*	8.6	*	5.4	6.1	8.2	12.2	9.4	10.7	8.8	9.3	*
20	*	8.6	*	5.5	6.6	9.3	14.0	11.4	11.1	9.0	9.6	*
21	*	8.6	*	5.5	6.4	10.8	13.8	10.1	10.2	9.0	9.8	*
22	*	8.4	*	5.6	6.5	11.1	11.9	10.0	10.9	9.5	12.0	*
23	*	8.4	*	5.6	6.6	11.0	9.9	11.4	11.9	9.3	10.4	*
24	*	8.3	*	5.6	7.0	10.8	9.4	9.4	10.3	9.7	9.5	*
25	*	8.0	*	5.6	6.7	9.2	8.6	9.5	11.5	9.6	9.3	*
26	8.9	8.0	*	5.8	7.0	9.5	8.3	10.6	10.0	9.6	8.8	*
27	10.4	8.1	*	5.9	7.6	9.3	8.5	9.9	11.5	9.9	9.0	*
28	10.0	7.8	5.9	5.9	7.7	9.2	9.7	10.2	13.4	9.4	9.5	*
29	9.9	7.9	5.8	6.0	*	9.6	9.8	11.5	13.8	8.6	9.4	*
30	9.4	7.5	5.7	6.3	*	10.7	9.0	11.7	12.0	9.3	10.0	*
31	10.2		5.6	6.3	*	11.2	10.5	11.9	*	8.8	9.5	*

MONTHLY TOTALS

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
AVE	9.8	8.7	5.8	5.6	6.0	8.8	11.0	9.8	11.0	9.2	9.4	9.0
MAX	10.4	10.4	5.9	6.3	7.7	11.2	14.0	11.9	13.8	17.7	12.0	9.0
MIN	8.9	7.5	5.6	5.2	5.1	7.0	8.3	8.2	9.6	5.0	8.6	8.9

TRINITY RIVER AT STEEL BRIDGE ROAD, CA.
WATER TEMPERATURE (DEG. C), OCTOBER 1988 TO SEPTEMBER 1989

LOCATION: On the left bank approximately 11.2 miles downstream from Lewiston Dam, housed within the USGS gage station near Limekiln Gulch.

DAY	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	*	10.6	*	*	7	10.6	10.2	12	9.6	11.8	11.5	8	9.1
2	*	10.2	*	*	7.6	10.5	11	13.1	9.8	12.4	11	8.1	9
3	*	9.8	*	*	8.3	10.2	9.9	14.2	*	13	11	8.4	8.8
4	*	9.6	*	*	8.5	10	10	14.4	*	13.2	11.2	8.6	8.4
5	*	10.5	*	*	8.4	9.4	11.3	14.4	10	13.5	11.2	8.5	7
6	*	10.4	*	*	8.4	9.4	12.1	14.4	10.1	13.2	11.3	8.5	8.1
7	*	10.7	*	*	9.3	9.4	11.7	14.5	9.9	13.4	11.2	8.5	7.9
8	*	10.4	*	*	8.8	10.6	11.8	14.4	10	13.4	10.3	8.4	8.5
9	*	10.2	*	*	8.6	11	12.2	14.1	9.7	13.3	9.6	8.4	8.5
10	*	10.1	*	*	8.5	11.1	12.4	14.5	9	13.4	9.3	8.2	8.5
11	*	10.4	*	*	7.8	11.1	12	14.2	8.7	13.9	9.2	8.3	8.5
12	*	10.2	*	*	7.8	10.6	11.6	15	8.9	14	9.2	8.2	8.4
13	*	10	*	*	7.8	10.6	12	14.6	9	13.2	9.3	8.1	7.6
14	*	10.4	*	*	8	10.5	12.6	14.9	9.1	12.8	9.2	8.2	7.3
15	*	10.4	*	*	8.8	11.2	11.8	15	9	12.5	9.1	8.3	7.4
16	*	10.4	*	*	9.4	11.7	11.3	15	9.3	11.8	8.7	9.1	7.6
17	*	10.3	*	*	9.6	11.6	11.5	14.8	9.4	13.4	9.2	9.4	5.9
18	*	10.1	*	*	9.6	11.5	12.9	14.3	9.3	13.2	9.6	9.6	6.1
19	*	10	*	*	9.7	12.3	13	13.2	8.9	13.2	9.5	9.6	6.2
20	10.1	9.7	*	*	9.8	12.3	13.1	11.5	9.1	12.1	9.5	9.8	6.3
21	10.3	9.5	*	*	9.9	12.1	12.7	10.7	9	12.8	9.3	9.8	6.6
22	10.3	9.5	*	*	10.1	*	11.7	9.9	9	13.5	9.3	10.1	6.6
23	10.7	9.3	*	*	10	12	12.2	9.6	8.4	14.1	9.2	8.4	6.6
24	10.6	9.3	*	*	10.2	11.8	12	9.6	8.2	14	8.7	9.1	6.2
25	10.6	*	*	*	10.6	12.1	11.4	9.9	8.6	13.8	8.7	9.2	6.3
26	10.7	*	*	*	10.8	12	12.4	10.1	9.2	13.7	8.8	9.4	6.5
27	11	*	*	*	10.8	12	13	9.8	9.6	13.6	8.6	9.4	5.8
28	10.4	*	*	5.4	10.9	10.6	13.1	9.6	9.6	13.3	8.7	9.5	6.3
29	10.6	*	*	5.8	11.3	*	12.4	9.4	9.5	11	8.7	9.5	6.5
30	10.6	*	*	6	11.5	*	13.6	9.7	9.8	10.5	8.7	8.8	5.7
31	*	*	*	6.5	11.7	*	12	*	11.4	*	8.5	8.9	*
MONTHLY TOTALS													
AVE	10.5	10.1	*	5.9	9.3	11.0	12.0	12.7	9.3	13.0	9.6	8.8	8.5
MAX	11.0	10.7	*	6.5	11.7	12.3	13.6	15.0	11.4	14.1	11.5	10.1	9.1
MIN	10.1	9.3	*	5.4	7	9.4	9.9	9.4	8.2	10.5	8.5	8	7

TRINITY RIVER AT IDAHO BAR CA.
WATER TEMPERATURE (DEG C), OCTOBER 1988 TO SEPTEMBER 1989

LOCATION: On right bank approximately 1.0 miles upstream from Highway 299 bridge across the North Fork Trinity River near Helena, Ca.

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	*	10.1	*	5.0	5.0	5.8	8.2	10.5	14.8	16.0	14.4	15.9
2	*	10.5	*	5.1	5.0	5.0	7.9	10.2	15.4	16.5	15.4	16.0
3	*	11.0	*	5.1	5.0	5.3	8.6	10.7	16.0	16.6	15.8	16.0
4	*	11.5	*	5.1	5.0	5.0	9.6	11.4	15.9	16.7	15.9	13.1
5	*	11.1	*	5.0	5.0	5.0	10.5	11.6	15.8	16.6	15.8	*
6	*	10.5	*	5.0	5.0	6.0	10.9	11.1	16.2	16.9	15.9	*
7	*	10.0	*	5.0	5.3	6.9	11.0	11.6	16.6	17.2	15.8	14.8
8	*	9.8	*	5.0	5.2	7.0	11.1	11.4	16.6	16.8	15.5	14.8
9	*	8.9	*	5.0	5.1	7.2	11.1	10.2	16.1	16.2	15.7	15.6
10	*	9.3	*	5.0	5.1	7.7	10.9	9.7	16.4	15.9	15.6	15.9
11	*	9.6	*	5.0	5.1	7.9	11.0	10.2	17.2	15.8	15.5	16.0
12	*	9.9	*	5.0	6.4	7.7	10.8	10.2	17.4	16.1	15.2	15.9
13	*	9.5	*	5.0	6.4	7.2	11.5	10.5	16.9	16.2	15.4	15.3
14	*	8.8	*	5.0	6.0	7.1	11.8	10.6	16.4	16.2	15.4	14.4
15	*	9.0	*	5.0	6.7	7.7	11.9	11.0	16.0	16.1	16.3	14.5
16	*	8.7	*	5.1	7.2	7.6	12.1	11.3	14.7	15.3	16.9	14.8
17	*	8.2	*	5.2	6.9	7.1	12.3	*	15.8	15.8	17.0	12.6
18	*	7.5	*	5.1	6.8	7.0	12.6	*	16.8	16.9	17.5	12.0
19	*	7.7	*	5.0	*	8.0	12.4	*	16.8	16.8	17.6	12.6
20	*	8.3	*	5.0	*	8.3	12.0	*	15.7	16.6	18.0	12.9
21	*	7.8	*	5.0	*	8.7	10.8	*	16.1	16.4	17.7	13.3
22	*	7.2	*	5.0	*	8.5	9.8	*	17.1	16.5	15.7	13.4
23	*	7.5	*	5.0	6.7	7.8	9.4	*	18.2	16.6	15.9	13.4
24	*	6.8	*	5.0	6.5	7.9	8.9	*	18.1	16.0	16.2	13.1
25	11.0	6.2	*	5.0	6.6	7.9	9.0	10.2	18.4	15.8	16.6	13.2
26	10.8	6.7	*	5.1	6.8	7.1	10.0	11.8	18.4	16.1	16.8	13.1
27	11.0	7.1	*	5.0	6.6	7.7	10.2	12.4	18.3	15.8	17.0	12.5
28	11.1	7.3	5.0	5.1	6.6	8.5	10.3	12.1	18.0	15.7	16.9	12.7
29	11.1	6.8	5.0	5.0	*	8.6	10.0	11.7	15.4	15.8	16.2	13.5
30	10.5	6.4	5.0	5.0	*	8.2	9.7	12.5	14.5	15.6	16.2	12.6
31	10.1	*	5.0	5.0	*	9.0	*	13.5	*	15.2	16.2	*
MONTHLY TOTALS												
AVE	10.8	8.7	5.0	5.0	5.9	7.3	10.5	11.1	16.5	16.2	16.2	15.3
MAX	11.1	11.5	5.0	5.2	7.2	9.0	12.6	13.5	18.4	17.2	18.0	16.0
MIN	10.1	6.2	5.0	5.0	5.0	5.0	7.9	9.7	14.5	15.2	14.4	13.1

TRINITY RIVER AT CEDAR FLAT, CA.
WATER TEMPERATURE (DEG. C), MAY 1989 TO SEPTEMBER 1989

LOCATION: On the left bank approximately 1.0 mile downstream from Highway 299 bridge across the Trinity River at Cedar Flat, at the Burnt Ranch transfer station.

DAY	MAY	JUN	JUL	AUG	SEP
1	*	13.1	*	*	17.9
2	*	12.9	*	*	18
3	*	12.8	*	*	18.6
4	13.8	12.6	*	*	18
5	13.3	13.2	*	*	15.3
6	13	13.8	*	*	15.9
7	12.8	12.8	*	*	16.7
8	12.8	12.7	*	*	17.2
9	12.6	12.8	*	*	17.6
10	12.5	12.6	*	*	18.1
11	12.7	*	*	*	18.3
12	13.5	*	*	*	18.2
13	13.9	*	*	*	17.8
14	13.8	*	*	*	17.3
15	13.4	*	*	*	17.3
16	13.3	*	*	19.6	15.7
17	13	*	*	20.1	13.8
18	12.9	*	*	20.5	14
19	12.8	*	*	20.5	14.5
20	13.2	*	*	20.7	15.2
21	13.3	*	*	20.9	15.3
22	13	*	*	19	15.5
23	12.5	*	*	18.5	15.4
24	12.3	*	*	18.6	15.4
25	12.1	*	*	18.9	15.4
26	11.9	*	*	19.1	14.4
27	12.1	*	*	19.4	14.6
28	12.8	*	*	19.4	15.1
29	13.4	*	*	18.6	14.6
30	13.3	*	*	18.6	14.3
31	13.2	*	*	18.7	*

MONTHLY TOTALS					
AVE	12.9	12.9	*	19.4	16.1
MAX	13.9	13.8	*	20.9	18.6
MIN	11.9	12.6	*	18.5	13.8

TRINITY RIVER AT HOOPA CA.
WATER TEMPERATURE (DEG C), MAY 1988 TO SEPTEMBER 1989

LOCATION: On the left bank near USGS gage facilities adjacent to Hoopa High School.

DAY	MAY	JUN	JUL	AUG	SEP
1	*	17.3	18.9	19.0	19.8
2	*	18.3	19.5	19.7	19.9
3	*	18.8	19.6	20.5	20.3
4	14.0	18.9	19.7	21.3	20.5
5	15.1	18.9	19.9	21.9	20.0
6	15.1	19.1	20.6	22.2	18.6
7	15.0	19.0	20.6	22.7	18.7
8	15.1	18.6	20.3	22.6	19.0
9	13.1	18.3	20.1	22.5	19.2
10	11.8	18.7	20.1	22.2	19.5
11	12.2	18.9	20.4	21.6	19.8
12	12.5	19.1	20.6	20.9	19.9
13	12.8	18.7	20.6	21.1	19.8
14	13.4	17.9	20.5	21.1	19.9
15	14.0	17.3	20.4	21.2	19.7
16	14.5	17.5	20.5	21.4	17.6
17	14.6	17.9	21.7	21.7	16.5
18	13.7	18.4	22.1	22.2	16.7
19	13.6	18.1	21.7	22.3	16.8
20	14.0	18.4	21.1	22.6	17.4
21	14.1	19.3	21.5	22.7	17.9
22	13.4	20.4	21.8	21.2	18.0
23	12.0	21.3	21.7	20.9	18.2
24	11.9	21.2	21.9	20.9	17.9
25	13.0	20.9	21.9	20.8	17.6
26	14.2	21.1	21.0	20.9	17.0
27	14.4	20.5	21.2	21.1	17.4
28	13.4	18.1	21.1	21.1	17.5
29	14.1	17.0	20.5	20.0	16.9
30	15.1	18.2	20.1	20.7	17.1
31	16.3	*	18.7	20.8	*

MONTHLY TOTALS

AVE	13.8	18.9	20.7	21.3	20.1
MAX	16.3	21.3	22.1	22.7	20.5
MIN	11.8	17.0	18.7	19.0	19.8