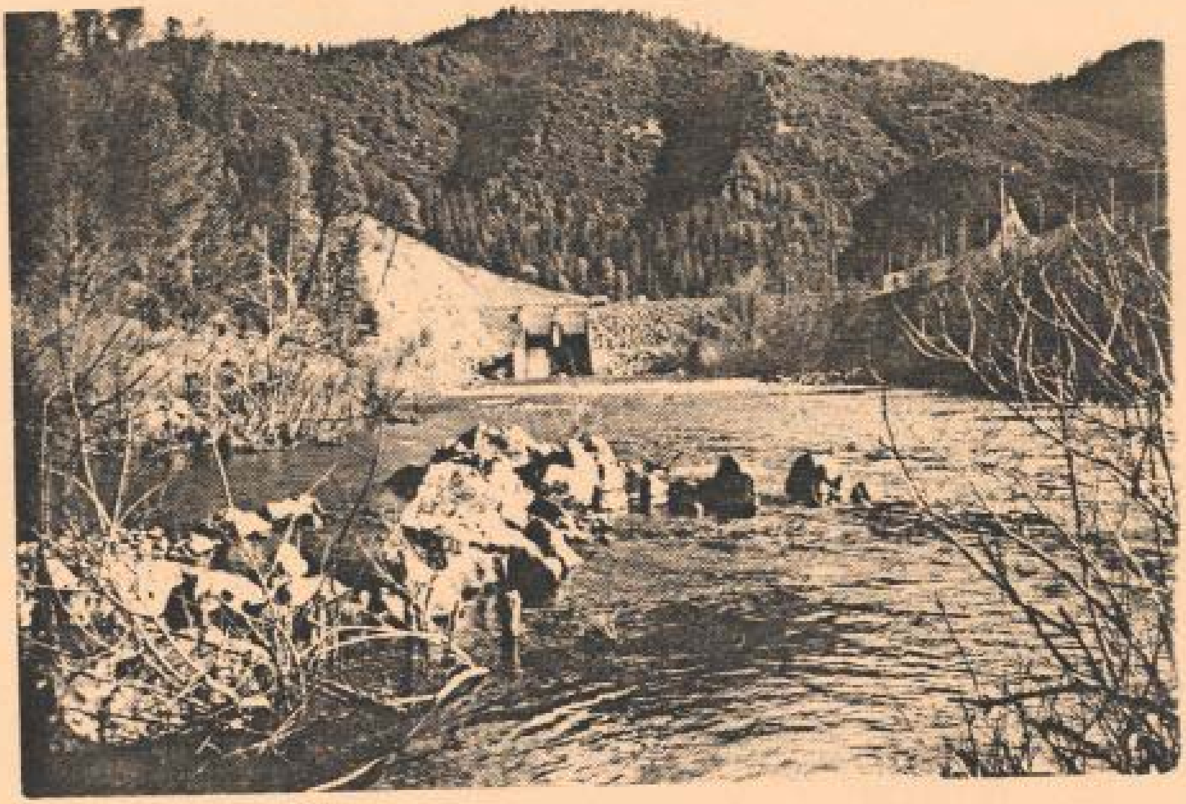
TRINITY RIVER
FLOW EVALUATION STUDY

Annual Report - 1987



Fish and Wildlife Service

U.S. Department of the Interior

ANNUAL REPORT

TRINITY RIVER FLOW EVALUATION STUDY

1987

U.S. Fish and Wildlife Service
Division of Ecological Services
Sacramento Field Office
2800 Cottage Way, Rm. E-1803
Sacramento, California 95825

Prepared by
the staff of

The Trinity River Flow Evaluation Study
P.O. Box 174
Lewiston, California 96052

PREFACE

The following report is the third in a series of annual reports prepared as part of the Trinity River Flow Evaluation Study, a 12-Year study. The U.S. Fish and Wildlife Service is directed to conduct the study as part of a decision by the Secretary of the Interior in January 1981 to increase releases from Lewiston Dam. It is hoped that through this undertaking, we will gain a better understanding of the dynamic forces which influence and control the destiny of the Trinity River salmon and steelhead. The culmination of this effort is to provide a report to the Secretary. The report is to use the knowledge which we gain through this study and recommend an appropriate course of action for future management of Trinity River flows. Through this effort the Secretary can than fulfill his responsibilities for the preservation and propagation of the Trinity Rivers indigenous fishery resources.

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

Michael E. Aceituno, Project Leader
Trinity River Flow Evaluation Study
U.S. Fish and Wildlife Service
Division of Ecological Services
2800 Cottage Way, Room E-1803
Sacramento, California 95825

SUMMARY

We are in the 3nd year of a 12-year evaluation study to monitor the rehabilitation of fishery habitat in the Trinity River resulting from increased releases below Lewiston Dam. These releases and the 12-year evaluation study were part of an agreement between the Service and the Bureau of Reclamation which was reached in December 1980 and approved by the Seretary of the Interior on January 14, 1981. This agreement is primarily aimed at the rehabilitation of the anadromous fishery resources of the Trinity River.

Accomplishments during 1987 include:

1. The development of Category II (utilization) and Category III (preference) habitat suitability criteria for fry, juvenile, and spawning lifestages of chinook and coho salmon and steelhead trout;

2. The description of baseline microhabitat area available for spawning and rearing salmon and steelhead within the mainstem Trinity River from Lewiston Dam to Hoopa Valley;

3. An analysis and description of changes which occurred in mainstem Trinity channel morphology after a major hydrologic event during the winter of 1986;

4. An initial evaluation aimed at determining the importance of Trinity River discharge on the general quantity and quality of mainstem side-channel salmonid rearing habitat;

5. The initiation of a mainstem Trinity River water temperature monitoring program aimed at providing validation data for future development of a stream temperature model for the Trinity;

6. The continuation of efforts to identify and quantify population chaaracteristics and life history relationships for salmonids occupying the various reaches of the Trinity River;

7. The completion of an evaluation of spawning riffles restored in 1986 to determine the effectiveness of the effort and to monitor the subsequent use of these habitats by salmon for spawning.

A significant spinoff from the study to date has been our ability to use interim and preliminary study reports to develop initial information useful to the Trinity River Basin Fish and Wildlife Management Program Field Office.

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PERSONNEL AND ACKNOWLEDGEMENTS

The following persons contributed to this report:

Mike Aceituno, Project Leader:
Summer Water Temperature, Program Planning, Direction, and Coordination, 1988 Instream Flow Evaluation POS, Fluctuation Flow Evaluation POS, Water Temperature Monitoring POS, editing.

Randy Brown, fishery biologist:
Flow Requirements for Side Channel Maintenance.

Andy Hamilton, fishery biologist:
Hydrology, Baseline Habitat, Morphological Changes 1985-86, Study Site Maps, Juvenile Salmonid Rearing Populations and Habitat Use, Salmonid Juvenile Survival, Downstream Migration by Juvenile Salmonids, editing.

Mark Hampton, fishery biologist:
Habitat Preference Critera, Juvenile Salmonid Growth, Evaluation of Restored Spawning Riffles, Habitat Preference Criteria Verification POS, Salmonid Habitat Requirements POS.

Phil North, fishery biologist:
Poker Bar Substrate Evaluation, field work.

Rick Macedo, fishery biologist:
Salmonid Habitat Requirements POS, Juvenile Survival POS, field work.

Bill Somer, fishery biologist:
Juvenile Salmonid Food Habits, Invertebrate Studies, Invertebrate Studies POS.

Fishery biologist Melanie Wilson the FWS Sacramento Ecological Services Field Office served as an intermittent member of our staff, helping sustantially with our field and office work. Gwyn Hampton provided editorial assistance and kept our Lewiston office in order. Richard Huxley, a draftsman at FWS in Portland, prepared final copies of our IFIM site and riffle restoration evaluation maps.

Mary Buck and Dr. Roger Barnhart, of Humboldt State University contributed an evaluation of constructed spawning riffles.

Mike Stempel, Fish and Wildlife biologist with the Trinity River Management Program , Weaverville Field Office, helped with field work, as did Joe Krakker, a biologist with the California Department of Fish and Game.

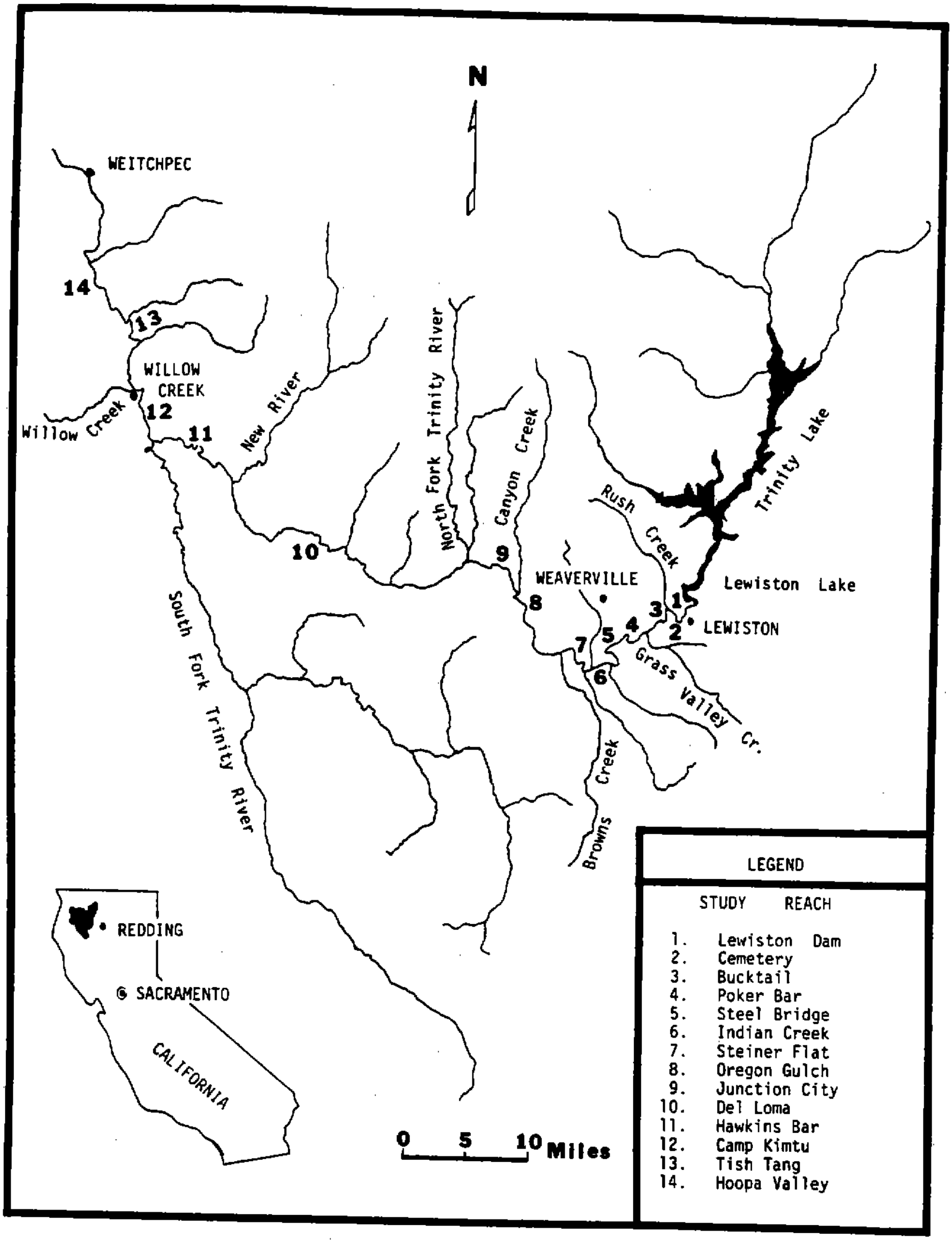

Figure 1. Trinity River Basin with Study Site Locations.

INTRODUCTION

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

The Trinity River Division of the 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 112, and Trinity Dam five miles upstream. Lewiston Dam is the upstream limit 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 agreemement 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 implememted; 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.

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 six 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 Developmemt.

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 Availibility 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); and

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; and

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; and

b) To develop recommendations to the Secretary and to other resource management agencies concerning future management options and needs.

The following report summarizes project activities, primarily on TASKS 2, 3, and 4, during 1987. The final section on program planning, direction, and coordination describes the focus of study efforts planned for 1988.

HYDROLOGY

The Trinity River at Lewiston drains 719 square miles of mountainous terrain, comprised of the southeastern Trinity Alps watershed, the east slope of the Salmon Mountains, the south slope of the Scott Mountains, and the west slope of the Trinity Divide.

Because of its high elevation, this watershed produces much of its runoff as spring snowmelt, and peak natural flow generally occurs in May, after a fall and winter increase corresponding to rainfall intensity. Figure 1 shows the monthly averages of high, median, and low flows recorded at the USGS gauge in Lewiston from 1911 to 1953, prior to the closing of Trinity Dam. Historically, this pattern persisted downstream to the North Fork, where accretion from major lower-elevation tributaries began to shift the peak of the hydrograph to the left (Fredericksen-Kamine, 1980, Appendix B, Figure 8). Instantaneous peak flows, which help define the shape of a river through massive scour, sediment transport, and deposition, occurred at any time during the winter: the peak recorded flow at Lewiston, 71,600 cfs, was on December 22, 1955, and the flood of 1964, which filled the new Trinity Dam, happened just before Christmas.

STUDY FLOWS

When the dam was closed, flows over a few hundred cubic feet per second were cut off, except for occasional emergency releases following severe winter storms. Figures 2 through 4 show, for example, the Lewiston mean monthly flows over the three years that we have been monitoring the river; Figure 5 shows all three study flows compared on a logarithmic scale to the historical flow pattern.

1985 (Figure 2) was a dry year in areas of the Central Valley Project tributary to the Sacramento River, and water available for the Trinity was distributed uniformly except for a brief peak in February intended to attract steelhead adults to the upper river, and a peak of 450 cfs released in July for our flow study. In 1986 (Figure 3) there was a major storm in mid-winter, and up to 6,500 cfs were released from Lewiston Dam during late February and March. A second peak occurred during our flow study in July and early August, when we measured a Lewiston discharge of 800 cfs. In 1987 (Figure 4) there were no floods, and high flows were released in the spring to mimic natural flows as much as the available water allowed. Relatively high flows continued through the summer to accommodate concerns about summer holding habitat and downriver conveyence of hatchery fish.

IMPORTANCE OF FLOW

If peak catastrophic flows helped shape the pre-dam river, making it a series of wide gravel bars where the underlying geology permitted, and giving it deep holes where there were outcrops of resistant bedrock, the more persistent pattern of low summer to fall flows and high spring runoff did as much to define its biota. Before the dam was built, the natural flow regime made the Trinity River a chinook salmon and steelhead stream. The salmon spawned in fall low water, reared in high winter flows, and went downstream with the peak spring runoff. Steelhead trout, which spawned predominantly in tributaries and in the main-stem above Lewiston, could rear in low-flow summer riffles where temperatures were favorable.

These figures show how much water was in the upper river during the events and studies described in this report. They also show the general conditions that the native fish and invertebrates of the Trinity River evolved to live in.

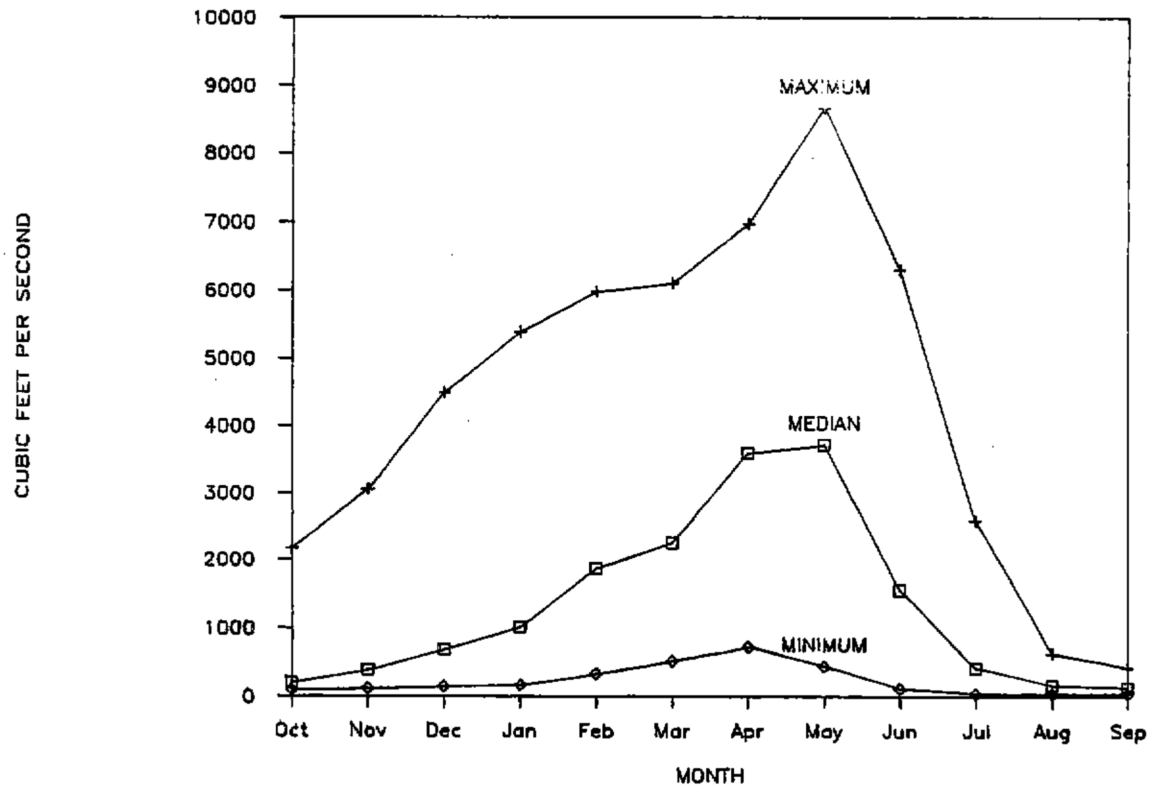

Figure 1. Monthly mean high, median, and low flows at Lewiston, 1911-1953.

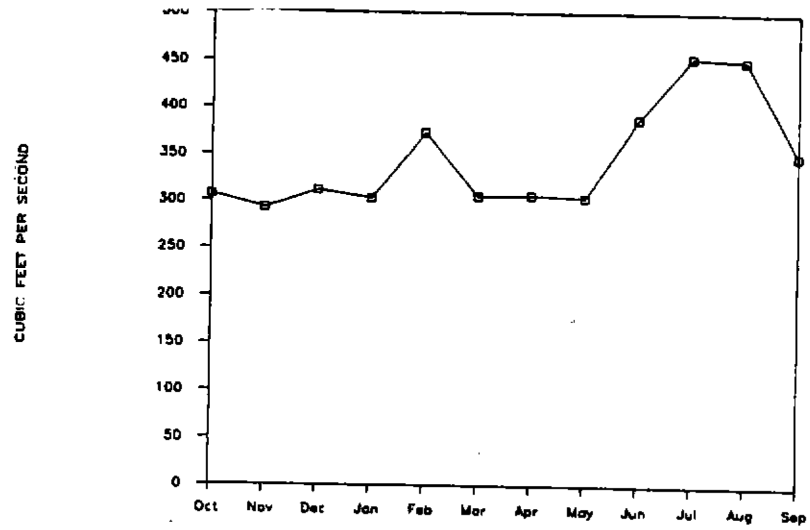

Figure 2. Monthly mean flow at Lewiston, 1985.

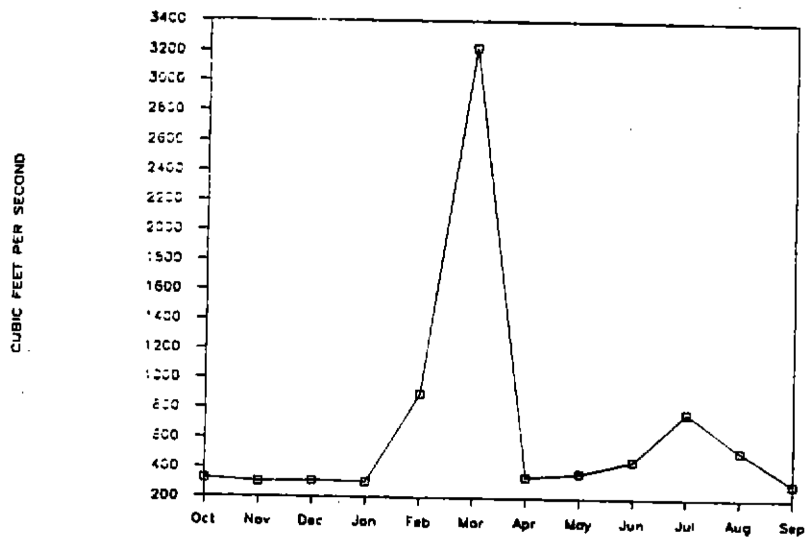

Figure 3. Monthly mean flow at Lewiston, 1986.

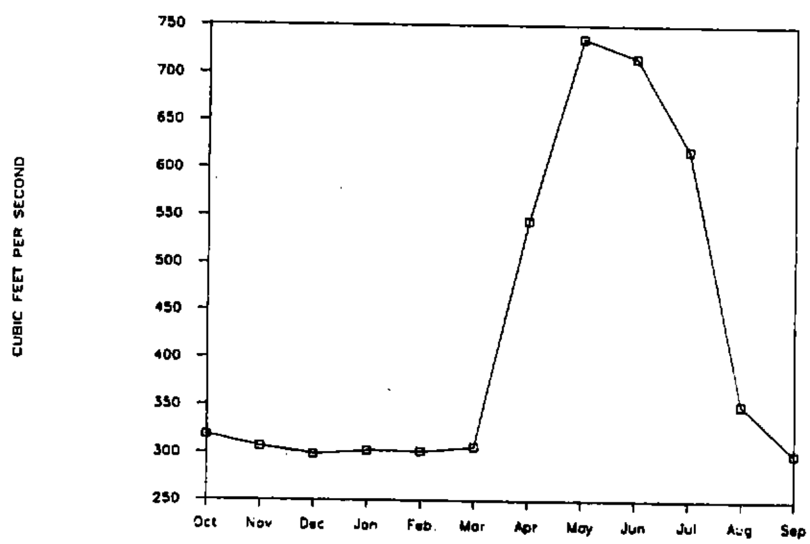

Figure 4. Monthly mean flow at Lewiston, 1987.

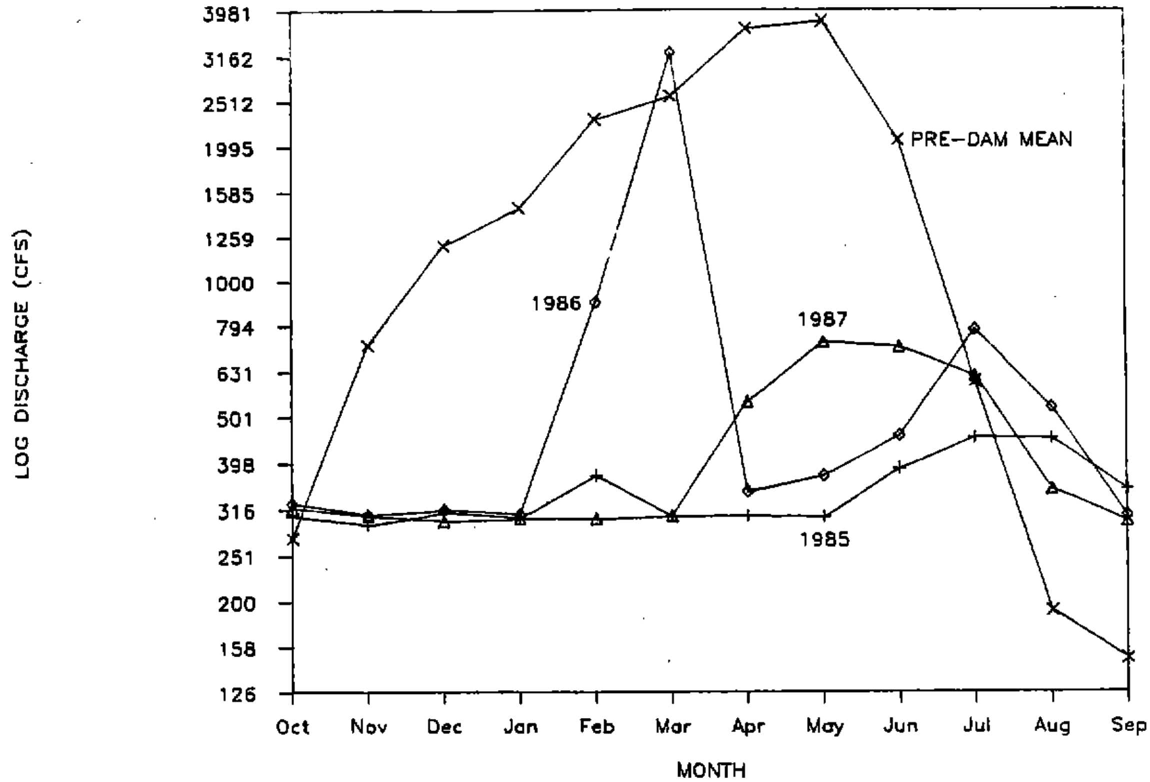

Figure 5. Monthly mean flow at Lewiston, 1985, 1986, and 1987 with average 1911-1953 monthly mean flow.

HABITAT PREFERENCE CRITERIA DEVELOPMENT

The Trinity River Flow Evaluation Study uses the Physical Habitat Simulation Program (PHABSIM) of the Instream Flow Incremental Methodology (IFIM) to monitor salmonid habitat changes within the Trinity River. A key component of the IFIM is the development of habitat suitability criteria for each lifestage and species of concern. Habitat suitability criteria are simply a means of describing those microhabitat parameters (depth, velocity, cover, and substrate) that are most utilized or preferred by the target species. Suitability criteria may be placed into three categories dependent on the methodology used in their development (Bovee 1986). Category I criteria are based upon professional judgment or information gathered through literature review. Category II criteria are developed from observations taken on the target species in the field. These criteria may not represent actual microhabitat preference since not all habitat types may be available to the target species during the period of data collection. Therefore, category II criteria only describe those habitats selected by the target species under the environmental conditions which exist at the time of sampling. Category III criteria are developed from both observations of microhabitat use and available habitat. Theoretically, by considering the microhabitats used with those available, through the use of a mathematical equation, a development of actual microhabitat preference should result. Category III criteria would therefore be independent of the habitat available during the sample period allowing these criteria to be used when environmental conditions change.

Category II and III criteria were developed for fry, juvenile, and spawning lifestages of chinook and coho salmon and for juvenile and spawning lifestages of steelhead trout in the upper Trinity River (Hampton 1987). Observations of microhabitat use began in January of 1985 and ended in March of 1987. Observations were made within IFIM study sites located between Lewiston Dam and the Hoopa Valley. Observations of habitat use were made by a snorkel diver, from the bank, or from a raft. Observations from a raft were effective for observing microhabitats that were selected by spawning anadromous salmonids. Habitat availability measurements were taken in 1985 by selecting 150 random locations within each study site for each discharge sampled during habitat use data collection. Collection of random habitat measurements was stopped in 1986 after a comparison of available habitat estimates obtained from IFG-4 program output were found to yield similar results (Aceituno and Hampton, in press; U.S. Fish & Wildlife Service, 1986). Use of habitat availability estimates generated from IFG-4 program output allowed greater effort to be focused on habitat use data collection in the last year of data collection. Effort also shifted to the upper Trinity River, above the North Fork Trinity River confluence, because accurate discharge estimates were not obtained during lower river sampling in the previous year. Without these discharge estimates modeling of lower river habitat availability was impossible. Fortunately this did not affect any significant sampling effort for 1985 since lower river habitats were rarely sampled because of unfavorable conditions such as high water and low water visibility.

Chinook salmon fry were found in marginal habitat types where slow water velocities and abundant cover items were present. Woody debris, undercut banks, and cobble substrates provided fry salmon with velocity shelters and escape cover from surface-feeding predators. As chinook salmon grew larger they became less dependent on marginal habitats and began to use areas with higher water velocities in deeper water. Object cover still played a key role in providing velocity shelters in deep run and riffle habitats. In deep pool habitats, schools of juvenile chinook salmon positioned themselves in relationship to ever changing eddies and shear velocity zones where food items could be easily taken in the drift. In pool habitats the majority of juvenile salmon would feed near the water surface and would flee to deep water when frightened from above. At night time fry and juvenile chinook salmon congregated into slow velocity habitats in close proximity to the river substrates or cover items.

Spawning chinook salmon preferred depths ranging from 1.1 to 1.2 feet with mean column velocities from 1.3 to 2.0 feet per second. Because the majority of spawning was done at depths near 1.0 feet, category II criteria describing nose velocities and mean column velocities selected by spawning chinook salmon were similar. Preferred spawning substrates ranged from 2 to 6 inch diameter gravel and cobble that were less than 40% embedded in fines. The majority of redds were located in close proximity to the river banks where either overhanging vegetation, emergent aquatic vegetation, or woody debris was located. Cover did not seem to be nearly as important as water velocity in determining redd site suitability by chinook salmon. Adult salmon did appear to be frightened more easily when located in open areas versus areas located in shade or near large cover items.

Fry coho salmon selected similar microhabitats as fry chinook salmon, and the two species were often found together in the same schools. Aggressive behavior between the species was rarely observed. As coho salmon became larger they did not shift their habitat selection to areas of faster velocity as did chinook salmon. Juvenile coho salmon sought out slow water habitats present in backwaters, side channels, and marginal habitats adjacent to long slow runs and pools. These microhabitats nearly always contained abundant cover in the form woody debris, aquatic vegetation, and overhanging vegetation. Substrates present in these habitats was composed of fine sand, silt, organic debris, or larger particles that were highly embedded in fines. Habitat selection differences provided for species segregation between juvenile coho and chinook salmon.

Spawning coho salmon preferred depths from 0.9 to 1.2 feet with mean column velocities ranging from 0.8 to 1.2 feet per second. For redd construction coho salmon selected smaller substrates than chinook salmon. Coho salmon spawned in substrates composed of gravels ranging in diameter from 1 to 3 inches that were embedded less than 20% in fines. On the Trinity River nearly all of the coho salmon spawning is done in the upper river within 3 miles of Lewiston Dam. This reach contains a large number artificially constructed spawning riffles and may not be very representative of natural habitat conditions that exist in the majority of the Trinity River. This is particularly true of the substrate conditions present in the upper river where large amounts of decomposed granitic sand are absent.

Development of category III criteria describing habitat preference for fry steelhead trout could not be developed because of an insufficient number of use observations taken during the study period. This was the result of low adult escapement levels during 1985 and 1986. The total number of adult steelhead taken at Trinity Hatchery in 1985 and 1986 was 142 and 461 respectively. From the use observations that were made, fry steelhead appeared to prefer marginal habitats adjacent to riffles, and runs. Fry steelhead selected focal points in close proximity with the substrate or near cover items which provided a velocity shelter. Unlike fry chinook or coho salmon, fry steelhead were often found in turbulent water present in shallow riffles. Their association with velocity shelters on or near the stream bottoms allowed them to use these more turbulent microhabitats. Fry steelhead were rarely observed in monotypic habitats present in long slow runs or pools.

Juvenile steelhead trout preferred run, riffle, and riffle-pool transition habitats that provided a high degree of velocity diversity. Preferred depths ranged from 2.0 to 3.5 feet with mean column velocities from 1.1 to 1.4 feet per second. Juvenile steelhead actively defended feeding stations in riffles and across the tail end of run habitats. Object cover, boulders, large cobbles or woody debris, played an important role by providing velocity shelters where juvenile steelhead could establish feeding stations with little effort. When found in riffle-pool transition habitats groups of juvenile steelhead were often seen feeding in the same locations without displaying any aggressive behavior among themselves. In these microhabitats steelhead were usually positioned underneath areas of high surface water velocity along the ledge located at the upper boundary of the pool. In these locations juvenile steelhead could maintain focal points in near zero velocity water and still take advantage of drift organisms provided by the riffle upstream. Cover objects were seldom present in these riffle-pool transition habitats, however, surface turbulence did provide concealment from surface predators.

Shear velocity zones, areas of rapid velocity change, proved to be an important hydraulic characteristic present in the microhabitats selected by juvenile steelhead trout. Shear velocity zones provide juvenile steelhead with opportunistic feeding stations, where focal points can be established in slow water velocity and still be in close proximity to high water velocity areas where food, available in the form of drift, is more easily accessible and more abundant. Net energy gain in these microhabitats is probably optimized because less energy is expended to maintain focal points and distances traveled to capture prey items are reduced. This behavior characteristic caused problems when developing preference criteria that accurately describe preferred water velocities for juvenile steelhead. During field data collection, if water velocities are recorded at the focal point, the resulting criteria does not consider water velocities across the shear velocity zone, yet it is this hydraulic characteristic which the target species is most likely selecting for. The development of conditional criteria that consider both focal point velocity and water velocities in adjacent cells may alleviate these problems.

Collection of habitat use data for adult steelhead trout was hindered by poor sampling conditions and low escapement numbers to the upper Trinity River. Adult steelhead trout spawn from December through April when winter storms commonly cause increased turbidity and flows which prevent effective use sampling. Returns of adult steelhead to Trinity Hatchery from 1985 to 1987 were 142, 461, and 3,780 respectively. The presence of a fairly good run in 1987, combined with good sampling conditions, gave the opportunity to obtain an adequate number of spawning observations to develop category III criteria. Steelhead trout preferred depths of 1.1 feet with mean column velocities from 1.1 to 2.1 feet per second. Preferred substrates were composed of gravels from 1 to 3 inches in diameter that less than 20% embedded in fines.

The concept that category III criteria, by eliminating habitat bias, may be transferred to other streams or rivers is questionable. Development of category III criteria is dependent on the available habitat present within the area of study. Therefore, if a habitat type is not present within the study area the influence of that habitat type on the target species habitat selection will not be represented in the resulting category III criteria. Based on this fact, it is important that other researchers validate that the available habitat in the system where the category III criteria are being considered for use is similar to the available habitat present in the system where the category III criteria were developed. Only after the available habitats of the two systems have been found to be similar should category III criteria be transferred.

HABITAT AVAILABILITY AND NEEDS

The purpose of Task 3 is to determine the amount of anadromous salmonid habitat available in the Trinity River downstream from Lewiston Dam under various flow regimes, and to determine the relative habitat requirements of various in-river life-stages of salmon and steelhead.

This year's Task 3 studies included a re-evaluation of habitat data to determine baseline conditions at the beginning of our 12-year effort, an initial evaluation of morphological changes in the river during the first two years of our study, an evaluation of the river flow needed to maintain flow in several major side-channels, and monitoring of summer water temperatures between Lewiston Dam and the North Fork.

BASELINE HABITAT

METHODS AND ASSUMPTIONS

A major emphasis of our Trinity River flow evaluation is a periodic modeling of available salmon and trout habitat with the USFWS Instream Flow Incremental Methodology. Instream Flow method computer programs allow the development of a picture of the amounts of usable area available for spawning and rearing at various river flows. Methods are described in our 1986 annual report, and in Bovee (1978). The system uses field measurements of water velocity, depth, and other physical conditions to predict conditions over a range of flows, and these are compared to the known habitat requirements of species of interest to calculate the available usable area per 1000 feet of river. The methodology provides an excellent way to keep track of micro-habitat measurements running into the thousands for each study site, and it allows an estimation of optimum flows for fish production.

In our 1986 report, we presented estimations of weighted usable micro-habitat area for spawning and rearing chinook salmon, coho salmon, and steelhead trout throughout the river, based on preliminary habitat utilization curves. On the assumption that river morphology did not change substantially in the upper river down to Steiner Flat over the high-water winter of 1986, we used habitat estimates for our upper sites based on field data collected at low Lewiston releases during the summer of 1985 and high releases in the summer of 1986. We have since found that major changes occurred in the bottom profiles and substrate composition over the winter of 1986 in all our sites, and that combining habitat estimates from both systems is therefore probably not valid. Nor can we confidently determine how the changes in river morphology affected habitat, since the 1985 and 1986 simulations were based on measurement of widely differing flows. Therefore, we have chosen to use the 1986 simulation to describe baseline micro-habitat for comparison with future conditions.

The curves we have used to describe the habitat suitable for each species are Category II utilization curves developed from data we have collected since 1984 in the Trinity River, and described fully elsewhere (Hampton, 1987). The major difference in these curves from those we have used previously is that the amount of substrate suitable for spawning has been greatly restricted by a factor for the degree to which gravel is embedded in sand. Previous curves were base on dominant gravel size only, where the new curves recognize the effect of sand in the gravel mixture as a limit on spawning use.

We have ceased to use subtrate utilization curves for fry and juvenile life-stages of all three evaluation species, because our observations show that bottom materials make little difference in habitat choice by rearing salmonids, except where large cobbles and boulders provide refuges for juvenile trout. We have not substituted cover curves, although this is frequently done in habitat modeling, because we have seen no clear preferences for cover. We have recorded numerous instances of all species using areas with no apparent cover, and the highest mainstream population densities we have observed are of fry and juvenile chinook holding and feeding over a gravel bar with no nearby cover (see page 65).

In addition to these changes, we have eliminated study of our site adjacent to the Trinity River Fish Hatchery. This reach, just below Lewiston Dam, is unlike any other part of the river, and is the site of extensive habitat manipulation, and indeed underwent modification by bulldozer while we were measuring it in 1986. Because of this continual change, the site is not suitable for our methods.

FINDINGS

Figures 1 through 18 show the relationship between 1986 available micro-habitat and river flow at eleven Instream Flow Incremental Methodology study sites from Lewiston to Hoopa Valley. The species and life-stages were chosen according to our knowledge of macro-habitat and current species distributions in the river, with all species and life-stages modeled from Lewiston to Dutch Canyon, all life stages of chinook as well as juvenile coho and steelhead shown from Dutch Canyon to Willow Creek, and juvenile life-stages shown for our sites below Willow Creek. As noted above, these are habitat simulations based on velocity and depth measurements taken at a release from Lewiston Dam of 800 cfs, and water surface elevations taken at releases of 300 and 600 cfs. They all show available micro-habitat measured in the field at the higher flows, and estimations of available micro-habitat toward the lower end.

In the upper river, salmonid habitat tends to decrease with increasing flow except at the Cemetery and Bucktail sites, where increased flow opens up new habitat areas in side-channels. Available area for chinook salmon spawning peaks between about 450 and 600 cfs at all sites except Steiner Flat, where it is greatest at low flows. Coho spawning area follows the same pattern, except that at Bucktail there is a decrease in available usable area with higher flows. Usable area for steelhead spawning peaks around 700 to 800 cfs at

Cemetery and Steelbridge, and drops from peaks at low discharge in the other three sites.

In the upper river, Steiner Flat and Bucktail have the greatest amount of spawning habitat, and Steiner Flat provides the least rearing habitat, except for steelhead juveniles. This may be because both sites have a high proportion of fast water, although Bucktail has a side channel that provides good rearing habitat, and because they are least affected by sand deposition from the watershed. Bucktail is above Grass Valley Creek, and far enough below Hoadley Gulch to be less affected by its sediments than is the Cemetery Reach. Steiner Flat, the lowest of our upper river sites, is protected from upstream sediment exports by slow glides and pools above Douglas City, and is subject to more intense flushing flows from Weaver Creek and Reading Creek.

Throughout the river, there is substantially less habitat available for rearing fry than there is for juveniles, which we define as fish over 50 mm in fork length. Although we do not yet know what the habitat area requirements are for each life-stage, it appears from the differences in gross available area that fry habitat may limit fish populations in years when there is good spawning recruitment.

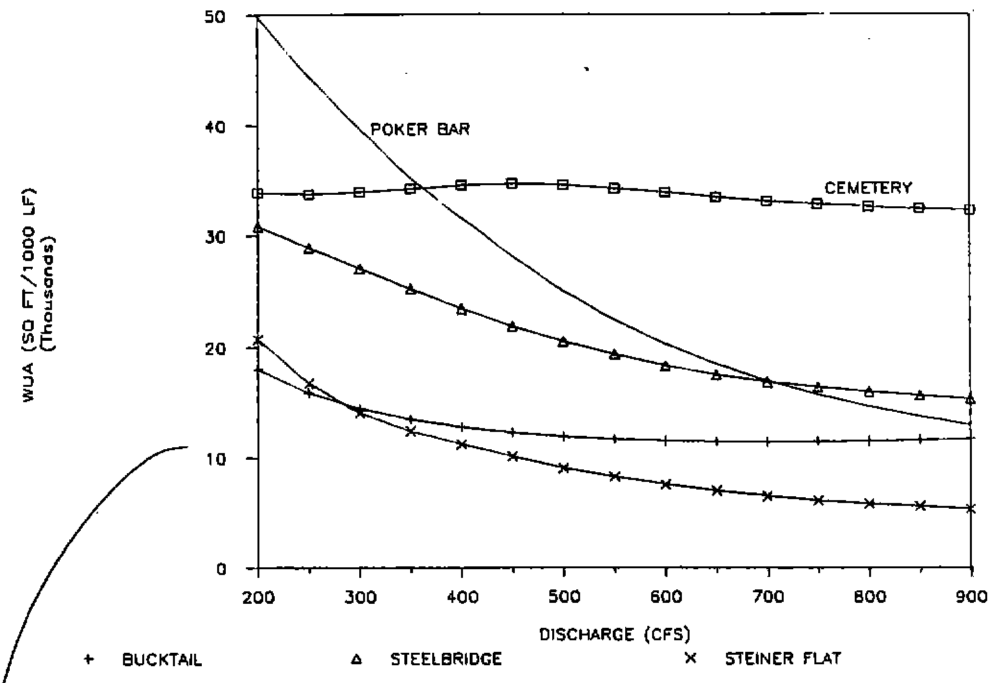

Figure 1. Weighted useable chinook fry rearing area as a function of flow at five sites in the upper Trinity River, 1986.

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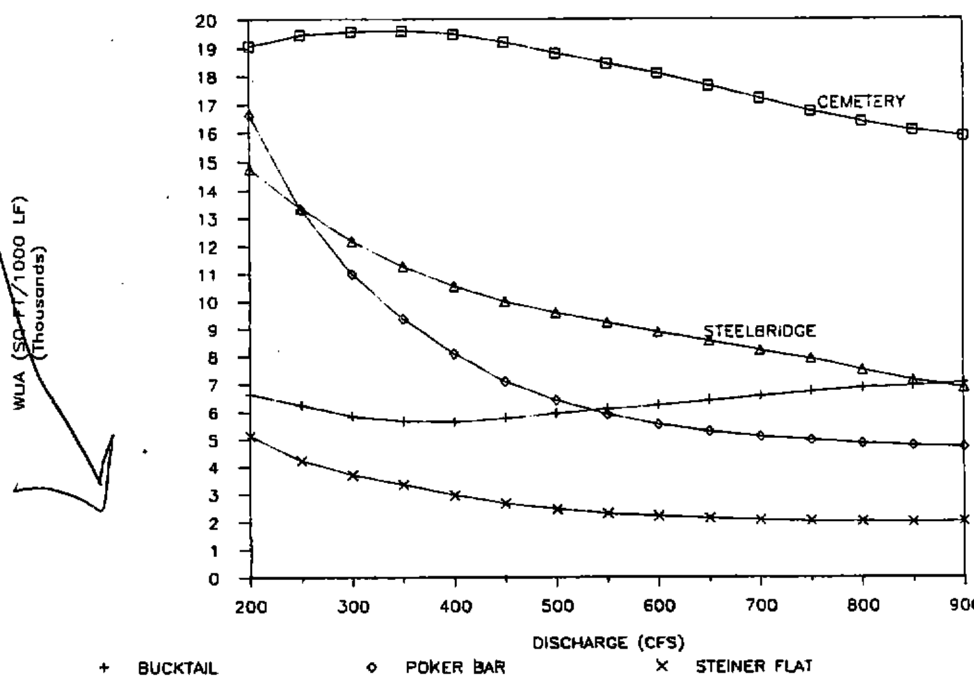


Figure 2. Weighted useable chinook juvenile rearing area as a function of flow at five sites in the upper Trinity River, 1986.

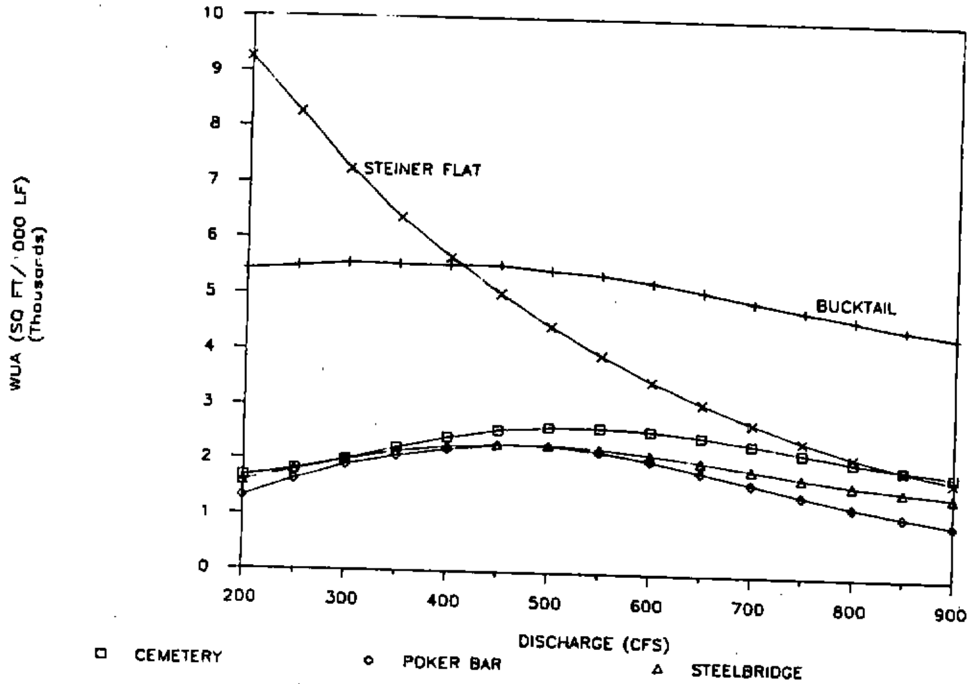


Figure 3. Weighted useable chinook spawning area as a function of flow at five sites in the upper Trinity River, 1986.

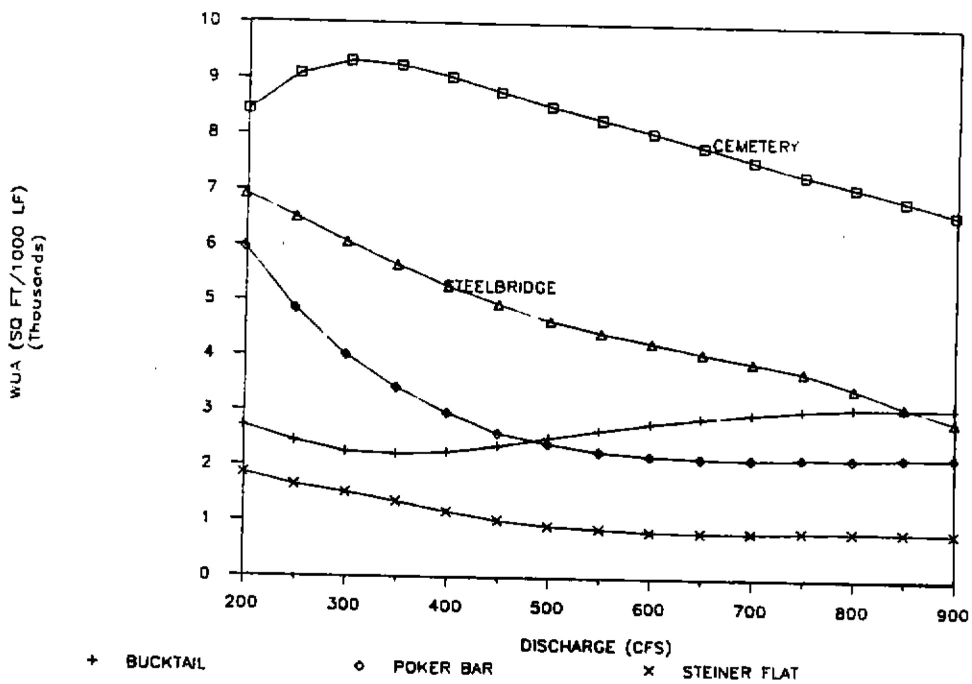


Figure 4. Weighted useable coho fry rearing area as a function of flow at five sites in the upper Trinity River, 1986.

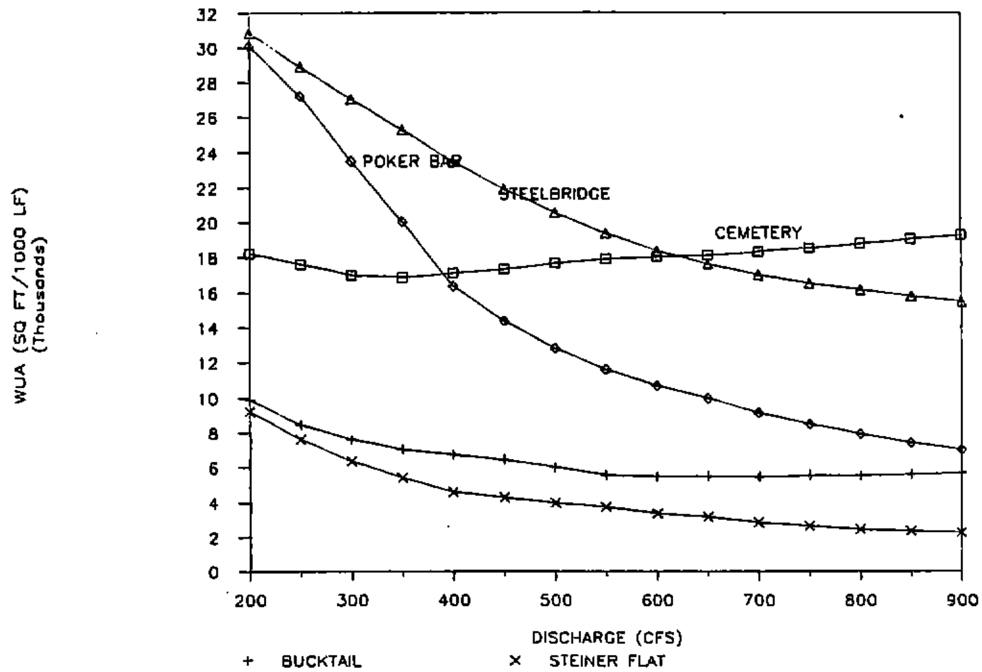


Figure 5. Weighted useable coho juvenile rearing area as a function of flow at five sites in the upper Trinity River, 1986.

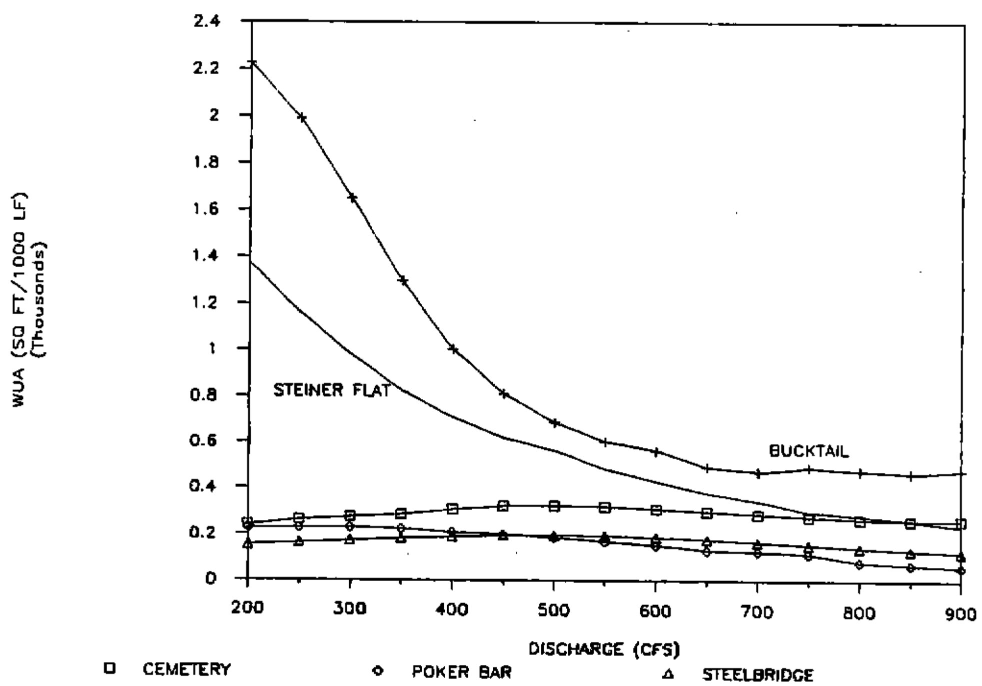


Figure 6. Weighted useable coho spawning area as a function of flow at five sites in the upper Trinity River, 1986.

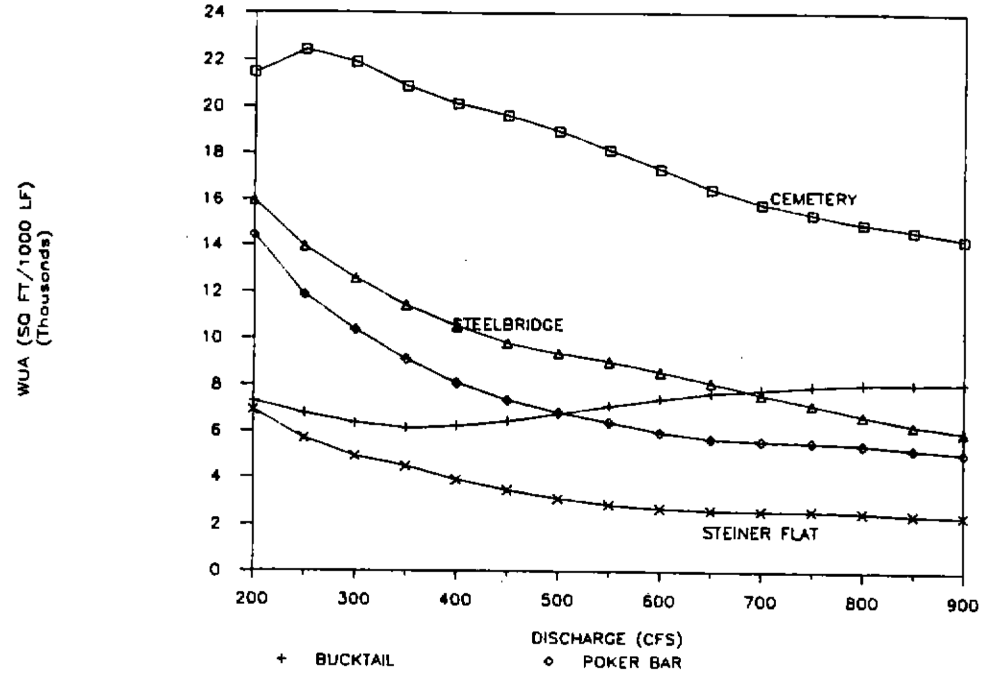


Figure 7. Weighted useable steelhead fry rearing area as a function of flow at five sites in the upper Trinity River, 1986.

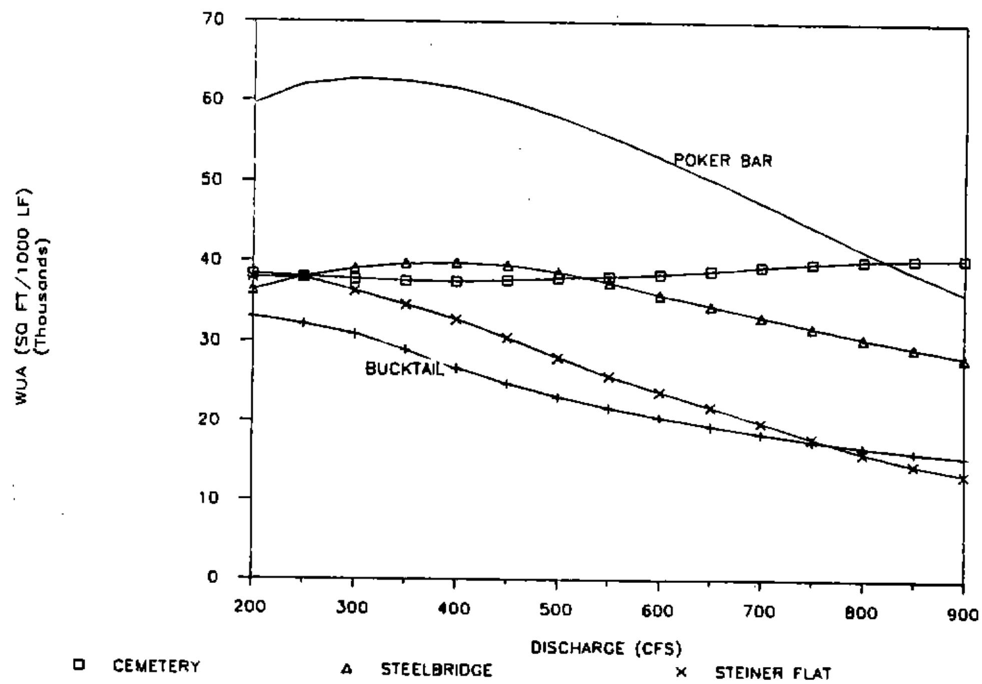


Figure 8. Weighted useable steelhead juvenile rearing area as a function of flow at five sites in the upper Trinity River, 1986.

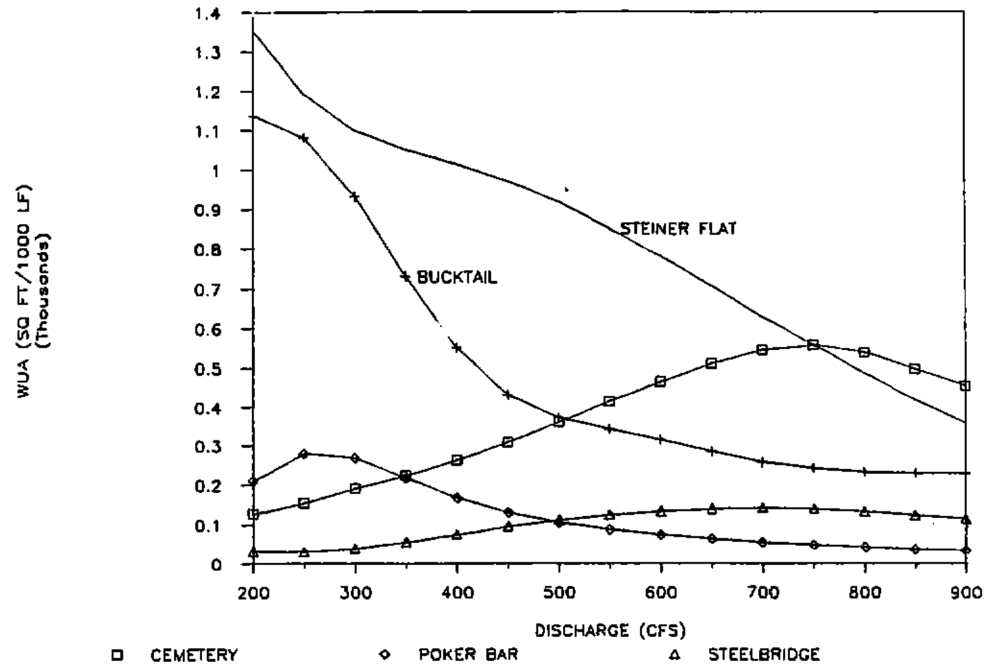


Figure 9. Weighted useable steelhead spawning area as a function of flow at five sites in the upper Trinity River, 1986.

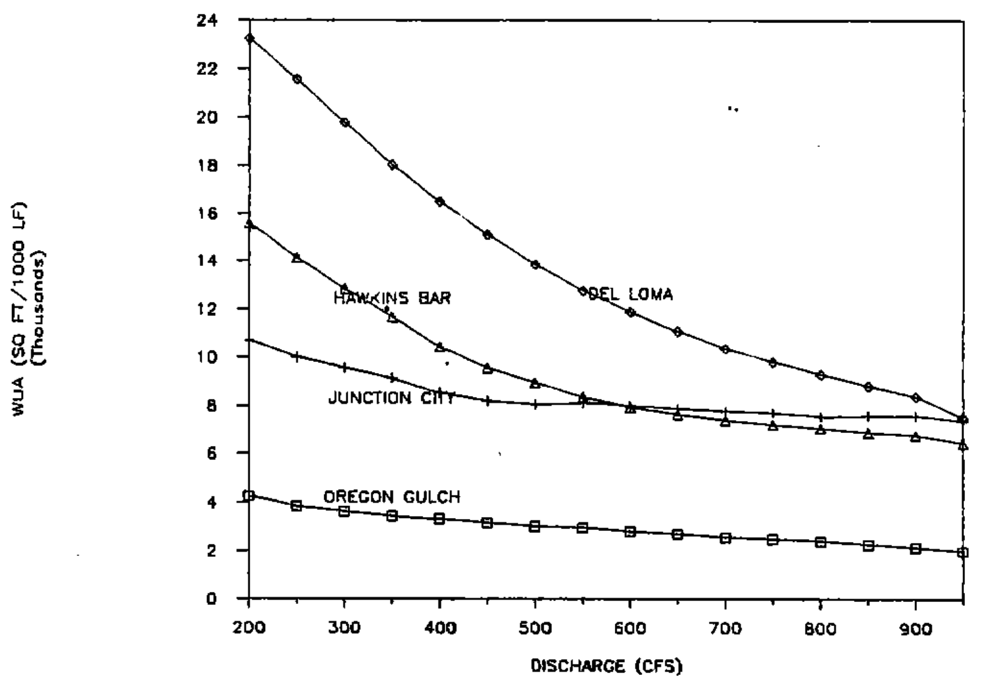


Figure 10. Weighted useable chinook fry rearing area as a function of flow at four sites in the middle Trinity River, 1986.

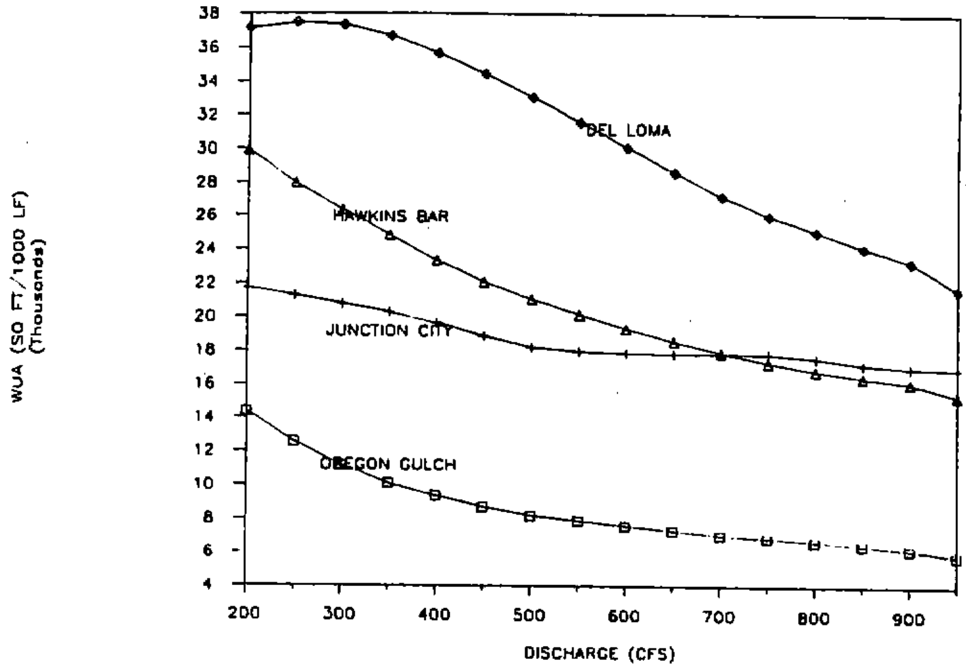


Figure 11. Weighted useable chinook juvenile rearing area as a function of flow at four sites in the middle Trinity River, 1986.

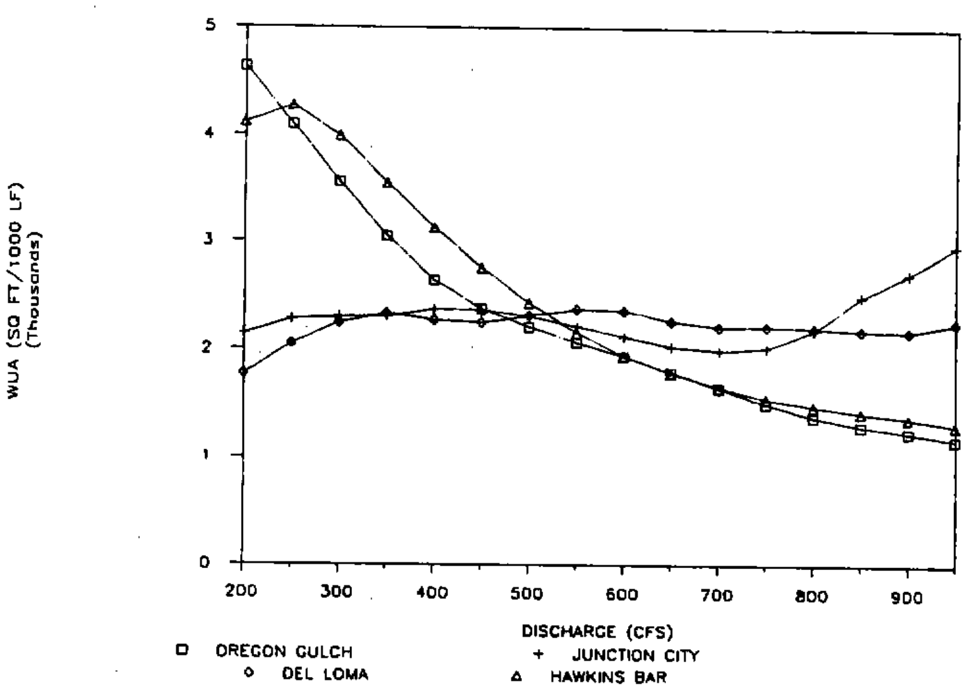


Figure 12. Weighted useable chinook spawning area as a function of flow at four sites in the middle Trinity River, 1986.

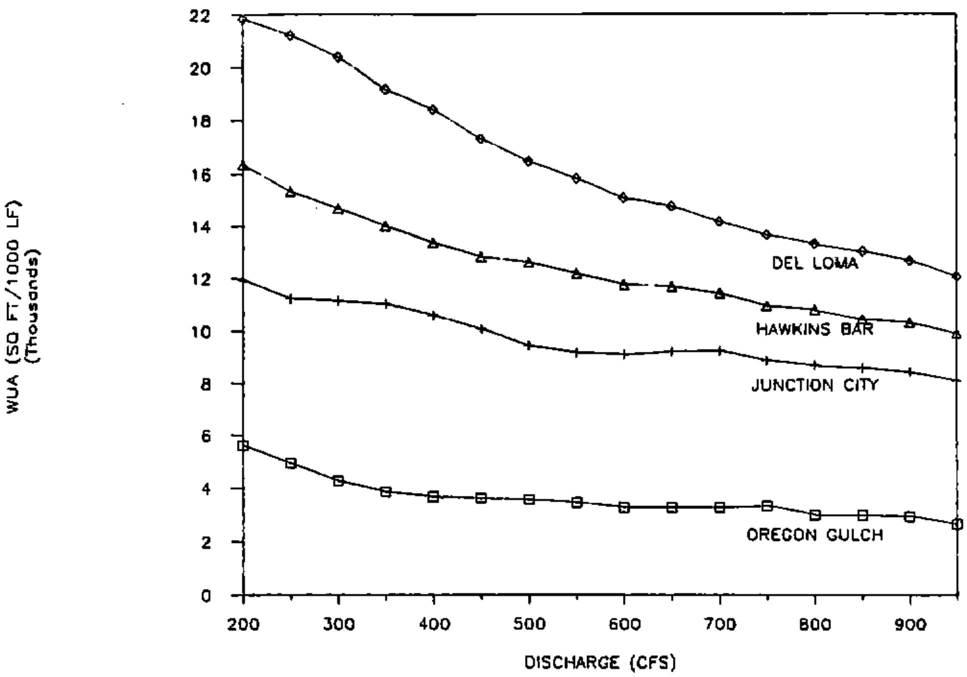


Figure 13. Weighted useable coho juvenile rearing area as a function of flow at four sites in the middle Trinity River, 1986.

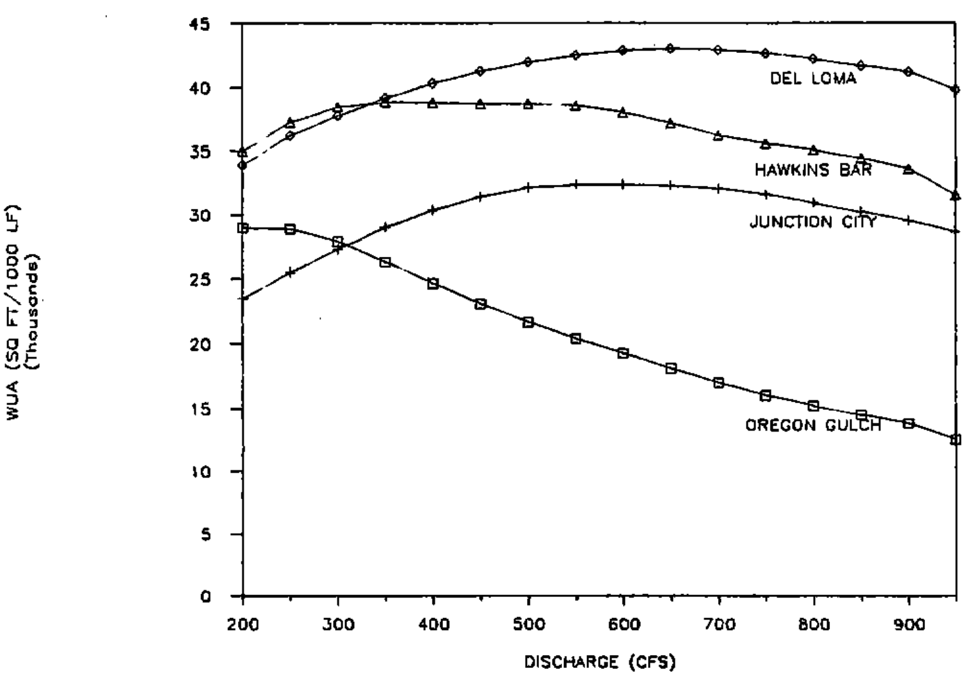


Figure 14. Weighted useable steelhead juvenile rearing area as a function of flow at four sites in the middle Trinity River, 1986.

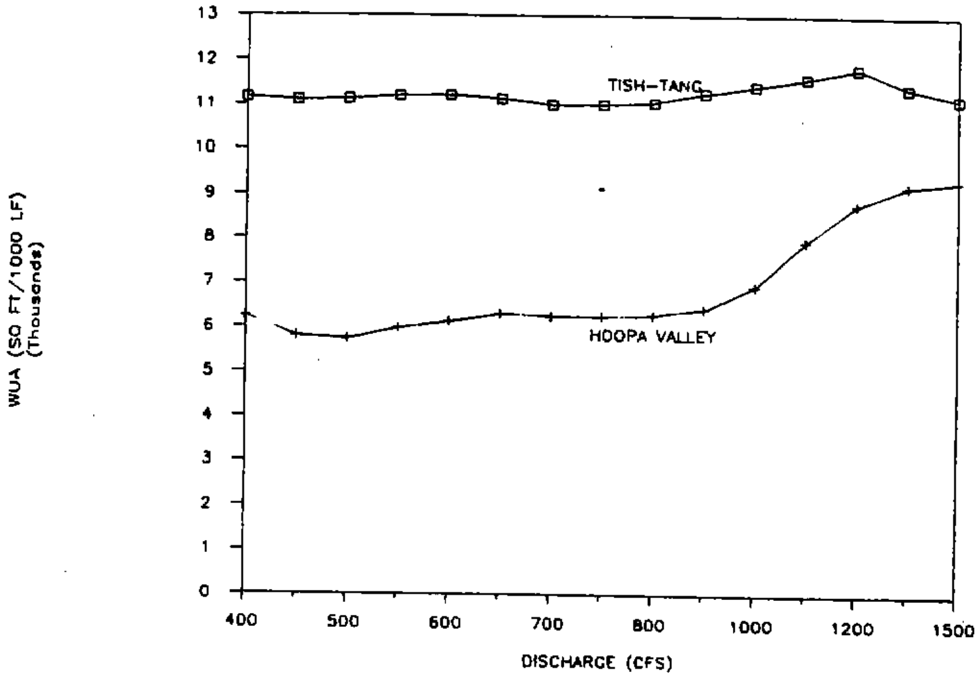


Figure 15. Weighted useable chinook fry rearing area as a function of flow at two sites in the lower Trinity River, 1986.

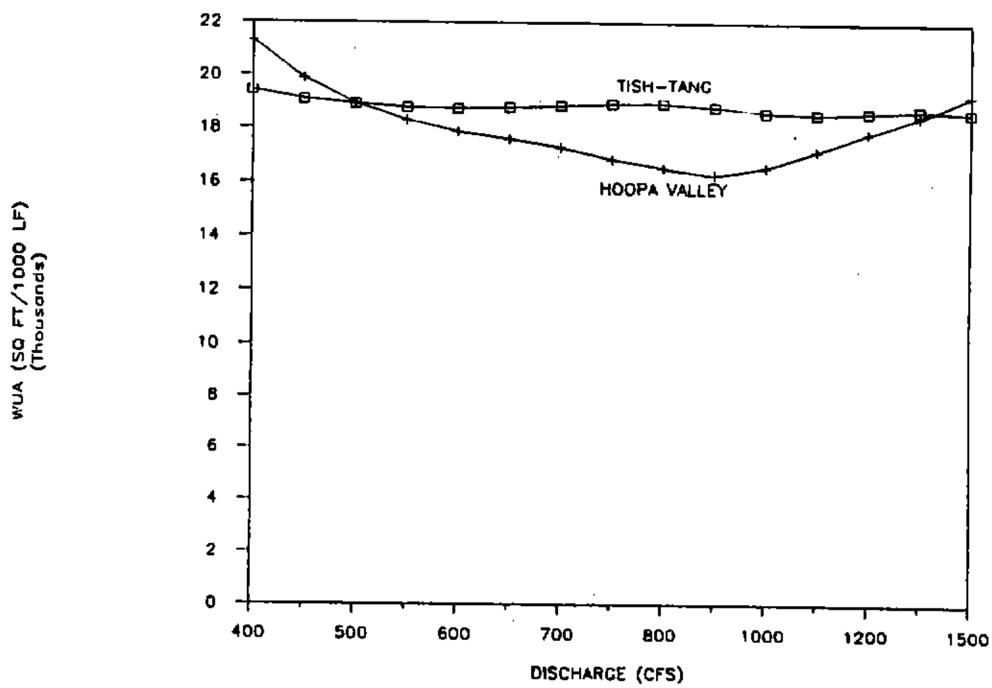


Figure 16. Weighted useable chinook juvenile rearing area as a function of flow at two sites in the lower Trinity River, 1986.

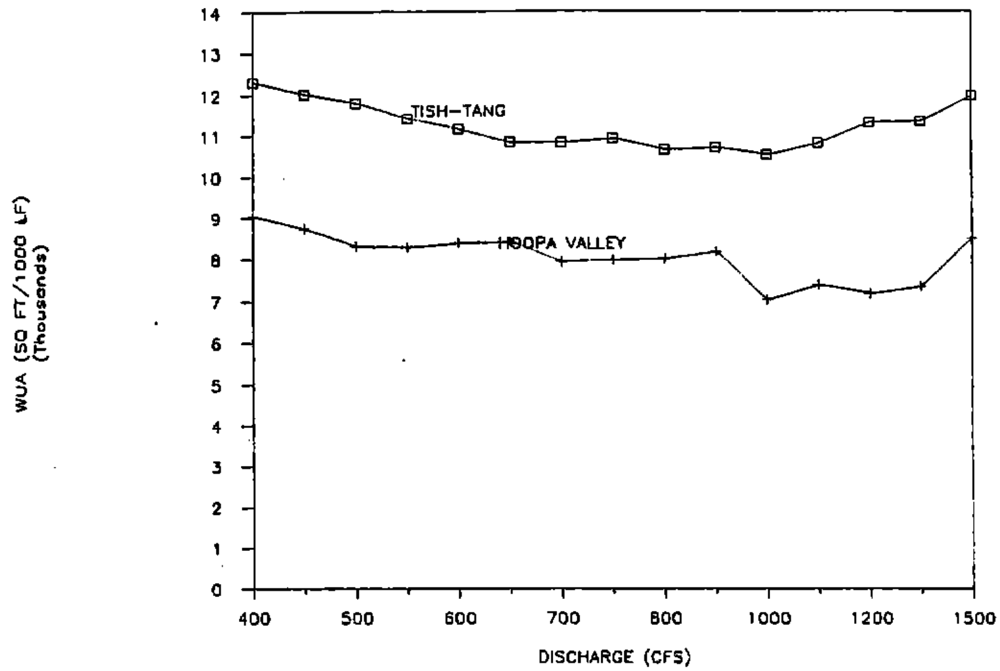


Figure 17. Weighted useable coho juvenile rearing area as a function of flow at two sites in the lower Trinity River, 1986.

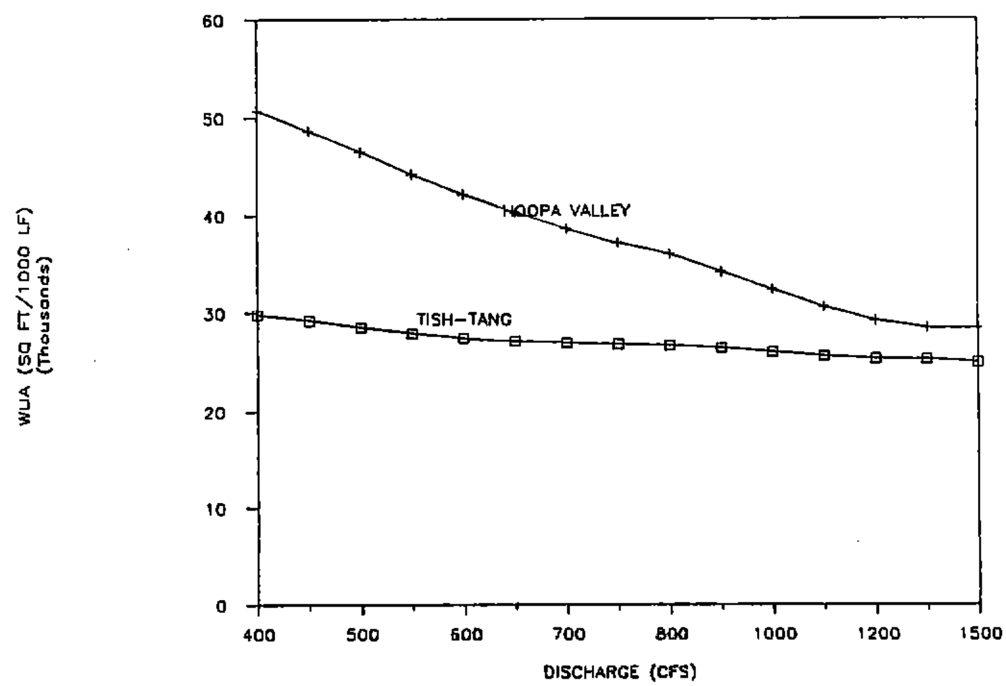


Figure 18. Weighted useable steelhead juvenile rearing area as a function of flow at two sites in the lower Trinity River, 1986.

MORPHOLOGICAL CHANGES, 1985-1986

The Trinity River underwent a substantial change in morphological detail between the summers of 1985 and 1986. The major hydrologic event in the intervening winter was high water during late February and early March, 1986, which grossly altered the river channel between Steiner Flat and the Klamath River, and which caused visually minimal but measurable physical changes from Steiner Flat upstream to Lewiston.

In late February of 1986, our Instream Flow Incremental Methodology study site at Del Loma, 20 miles below the North Fork was a bankful, raging brown torrent, with islands, side channels, and an entire quarter mile of cobble bar inundated by flood water. Upstream, at Junction City, Oregon Gulch, and Steiner Flat the visual effect, though somewhat diminished, was great. At Steiner Flat we electrofished over rocks that the summer before had served as diving platforms, and even in our uppermost site, adjacent to the Trinity River Fish Hatchery below Lewiston Dam, standing waves replaced riffles.

When the water subsided, it was clear that major changes in channel morphology and substrate composition had occurred between Oregon Gulch and Hoopa Valley, which were below uncontrolled major tributary inflows to the river. At Oregon Gulch the river was narrower, deeper, and faster than it had been the year before. At Junction City Campground a major riffle system and cobble bar had been entirely reshaped. At Del Loma an iron pin we had set on a sand-bar was an estimated ten feet under a new accumulation of sediment, and transects that we had waded the year before were accessible only by raft.

Changes at Steiner Flat and above, where the river was more subject to control at Lewiston and Trinity Dams, never exceeding 6500 cubic feet per second, and where the river edges have been steepened and defined by years of constant flow, were less noticeable. The only gross physical changes were just below the old bridge in Lewiston, where a hole dug in the river in the fall of 1985 by the California Department of Water Resources had been half-filled by sand from Hoadley Gulch, and in the run just below Grass Valley Creek, which was covered by decomposed granite sands. Our study sites looked in the summer of 1986 about the same as they had looked in 1985; yet when we looked at measurements of elevation and substrate taken over the two years we found substantial changes.

There seems to have been a major shifting of bed material. Fines, which we measure as particles less than a tenth of an inch in size, have been redistributed over the underlying substrate of gravel or cobble, changing the shape of most of the 55 transects we have established between Lewiston and Steiner Flat. It appears that the high flows also tended to clear fines from riffles, although a new influx of fines from tributaries continued to move in an almost dune-like pattern down through our study sites under the influence of the normal flows which followed the high water.

Table 1 shows the changes in transect profile elevation between the summer of 1985 and the summer of 1986 at our five uppermost study sites. In the interest of data manageability, these changes are shown as the average of absolute elevation differences over the width of each transect. In reality, the differences in elevation over riffles, caused by a shifting of cobbles and gravel, was generally slight, a matter of a few tenths of a foot, while the difference over pool substrates would reflect the shifting of tons of sand, with down-cutting on one side and deposition on the other.

Figures 1-3 show differences in substrate embeddedness on three transects at our Bucktail site between 1985 and 1986. Embeddedness, shown on the Y-axis, is a measure of the extent to which dominant substrate materials are embedded in fines, expressed as a percentage. Figure 1 shows the embeddedness at a run, Figure 2 at a pool transect, and figure 3 at a riffle.

The run and riffle transects follow what seems to be the general pattern at all our sites, a decrease in embeddedness under runs and riffles following the high water of 1986. Figure 2 shows an increase in embeddedness in pool habitat, which is probably the result of deposition of transported fines following high flows.

Sediments are entrained at very high water velocities, continue to be transported at somewhat lesser velocities, and are deposited at yet lower flows, resulting in uncontrolled rivers in the gradual downstream of sand as bed-load through a relatively stable configuration of riffles and pools (Morisawa, 1968; Leopold et al, 1964). In the controlled upper Trinity, this process seems to have resulted between 1985 and 1986 in a cleaning of sand from many riffles, where velocities were high, and deposition in pools as flooding subsided.

Poker Bar Spawning Substrate Changes

In the late winter of 1986, shortly after the subsidence of tributary flooding and the end of a two-week-long emergency release of 6000 cfs from Lewiston Dam, an observer high on Brown's Mountain Road opposite the mouth of Grass Valley

Creek could see the creek bed and the river below it as a meandering strip of white sand washed down from the disturbed and highly erosive Grass Valley Creek watershed. The Trinity River above the creek mouth was dark green, where below it was covered with white decomposed granite sand. A year and a half later, the same observer could see the lower reaches of the creek still covered with sand, but the Trinity River below the creek was again green, the sand washed down somewhere around the bend.

During the same period, the appearance of our Poker Bar study site, two miles below Grass Valley Creek, changed perceptibly. Passing through it on raft trips to monitor spawning salmon or collect habitat preference data, we noticed a greater expanse of pure sand than we remembered; yet results of our 1986 flow-related habitat evaluation indicated that salmon spawning conditions may have improved in the reach between the two years.

To examine this further, we made an additional survey of substrate types at each transect during the summer of 1987, and compared the substrate suitability for chinook salmon spawning in 1985, 1986, and 1987. The suitability criteria we used were Category II substrate values as presented by Hampton (1987). Figures 4 through 7 show results at two upper transects, 1 and 2, and two lower transects, 8 and 9. The X-axes represent distance across the transects, and the Y-axes shows the suitability for spawning of each substrate mixture on the transects.

The figures show that the value of substrate for spawning increased greatly over the years at transects 1 and 2, and at transects 8 and 9 generally increased in 1986 and then decreased in 1987. At the same time, in intervening transects not depicted, the substrate value was low in all three years or showed patternless changes. Generally the [illegible] of pure sand substrates increased, reflecting an encroaching underwater sand-bar or dune that moved down the right side of the channel below transect 2 all the way to the bottom of the study site.

Riffle areas on all transects were improved by the high water of February, 1986. This improvement continued at the upper transects with normal release flows in late 1986 and in 1987. However, the sand washed out of the upper areas seems to have moved downstream into the lower riffle areas. So the dynamic process of riffle silting and flushing causes continual changes in habitat value as pulses of sand move downstream.

Table 1. 1985-1986 elevation change on 55 transects on the upper Trinity River. Changes are the average of the absolute values of elevation change up or down at profiling stations across each transect, measured in feet.

Cemetery Site

Transect	Change
1U	0.2
2U	0.4
3U	0.9
4U	0.9
1L	0.3
2L	0.5
3L	0.3
4L	0.3
5L	0.2
6L	0.3
7L	0.4
8L	0.4
9L	1.1

Bucktail Site

Transect	Change
1	0.2
2	0.2
3	0.3
4	0.3
6	0.6
7	0.9
8	0.5
9	0.1
10	0.2
11	0.2
12	0.4

Poker Bar Site

Transect	Change
1	0.1
2	0.3
3	0.4
4	0.5
5	1.3
6	0.2
7	0.2
8	0.2
9	0.1
10	0.3

Steelbridge Site

Transect	Change
1	0.8
2	0.4
3	0.5
4	0.3
5	0.2
6	0.4
7	0.6
8	0.4
9	0.2
10	0.4
11	0.6

Steiner Flat Site

Transect	Change
1	0.4
2	0.2
3	0.2
4	1.4
5	0.5
6	0.3
7	0.7
8	0.3
9	0.3
10	0.8

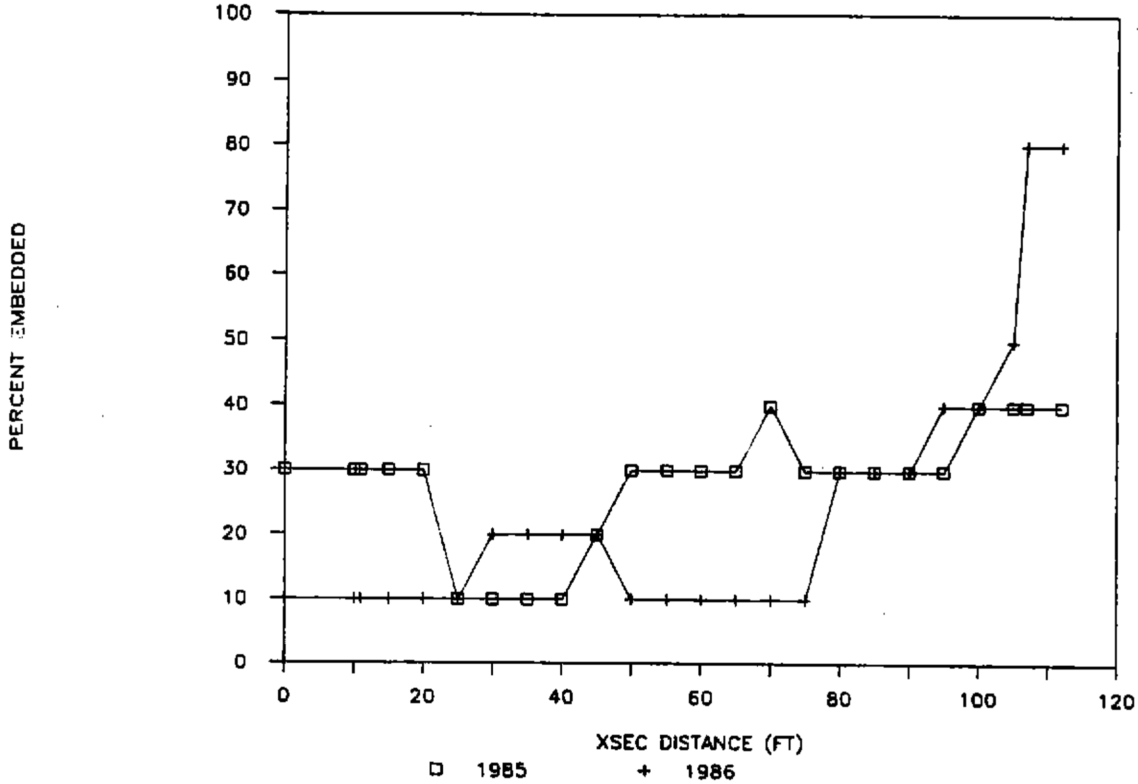


Figure 1. Change in substrate embeddedness, 1985-86, at a Bucktail riffle transect.

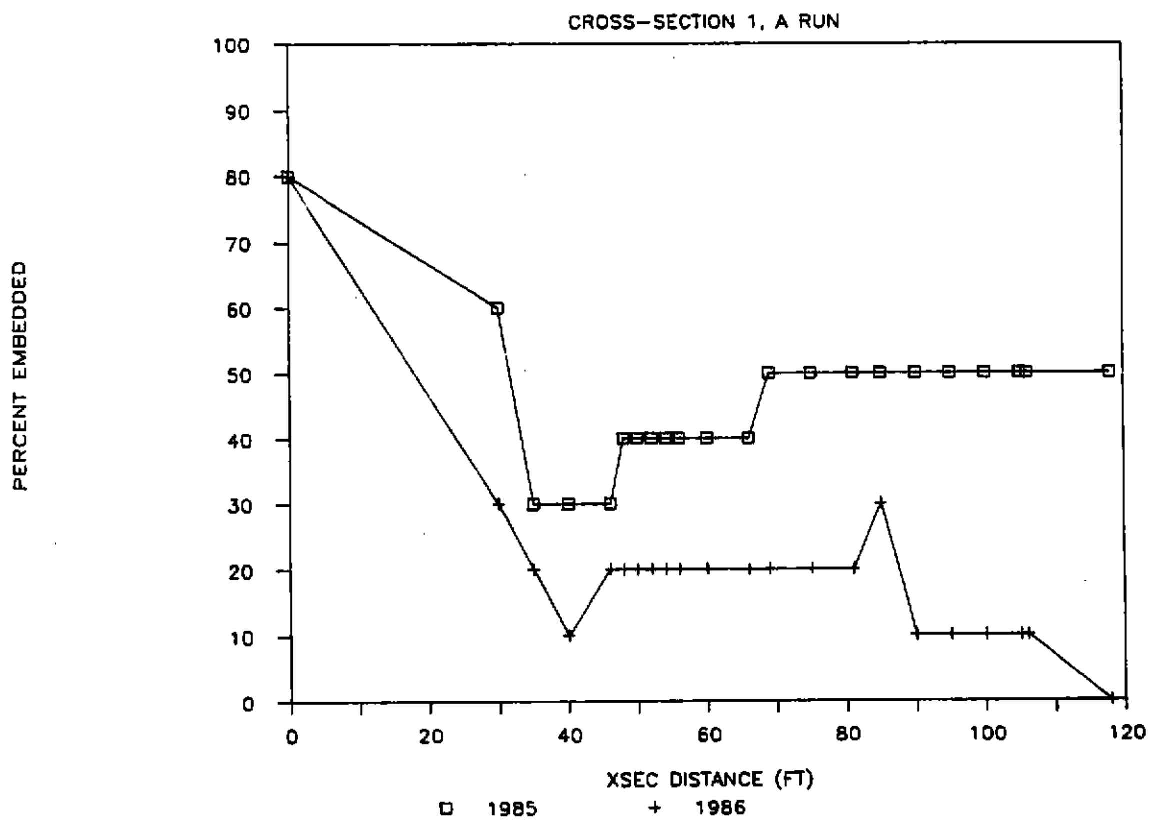


Figure 2. Change in substrate embeddedness, 1985-86, at a Bucktail run transect.

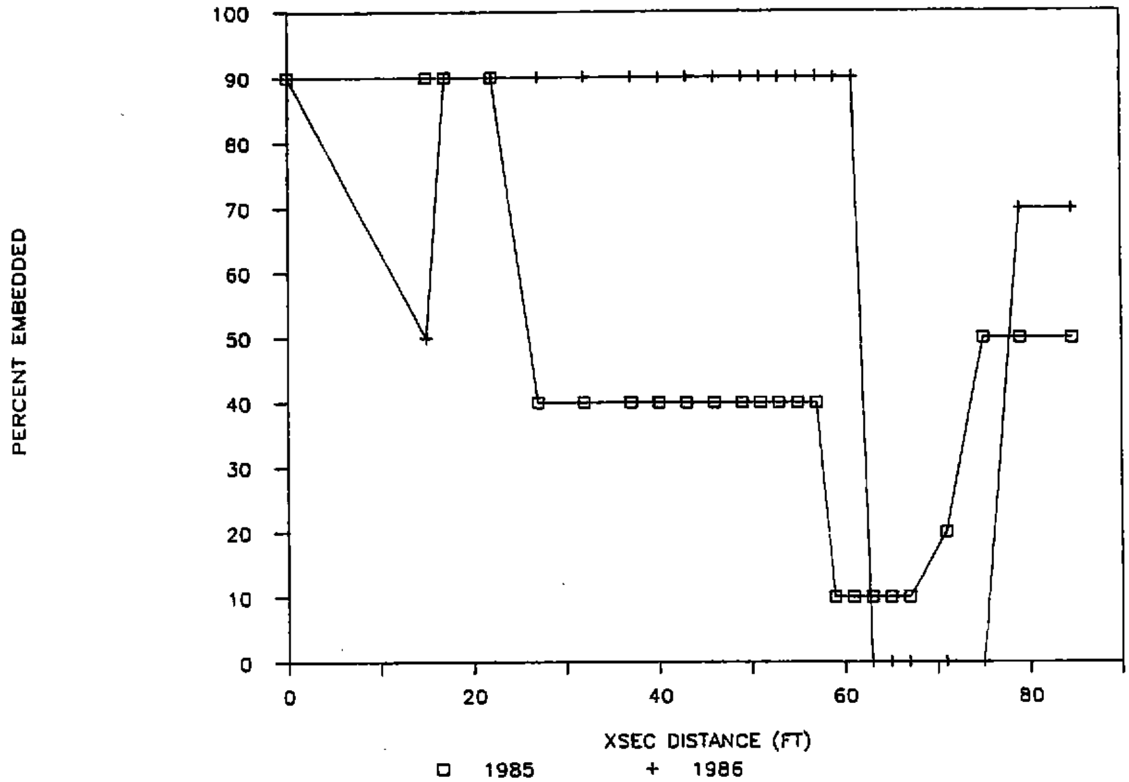


Figure 3. Change in substrate embeddedness, 1985-86, at a Bucktail pool transect.

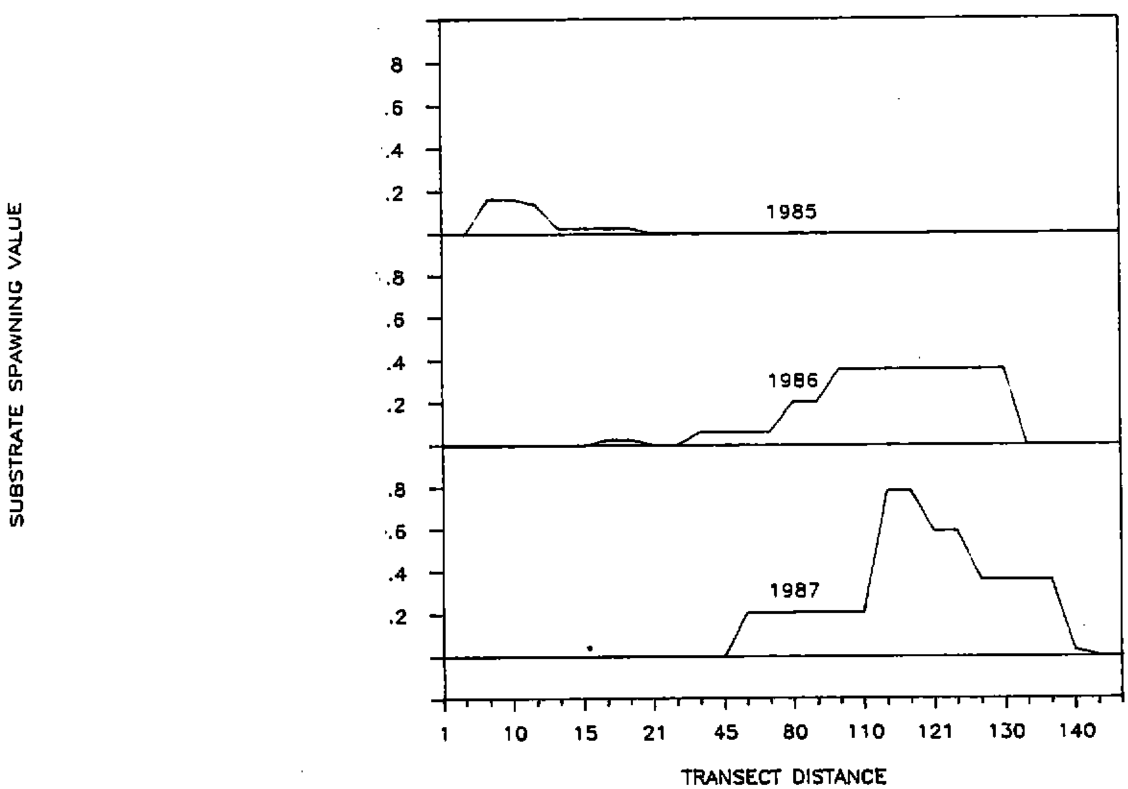


Figure 4. Change in substrate suitability for chinook spawning, 1985-87, at Poker Bar transect 1.

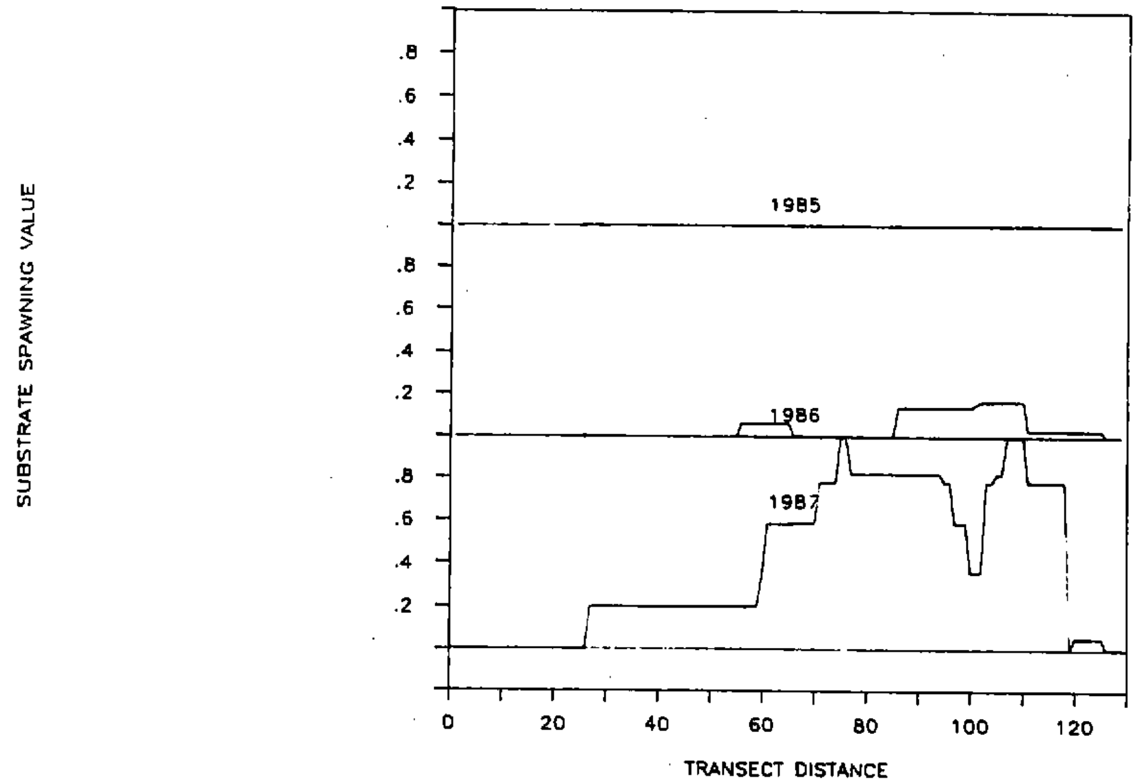


Figure 5. Change in substrate suitability for chinook spawning, 1985-87, at Poker Bar transect 2.

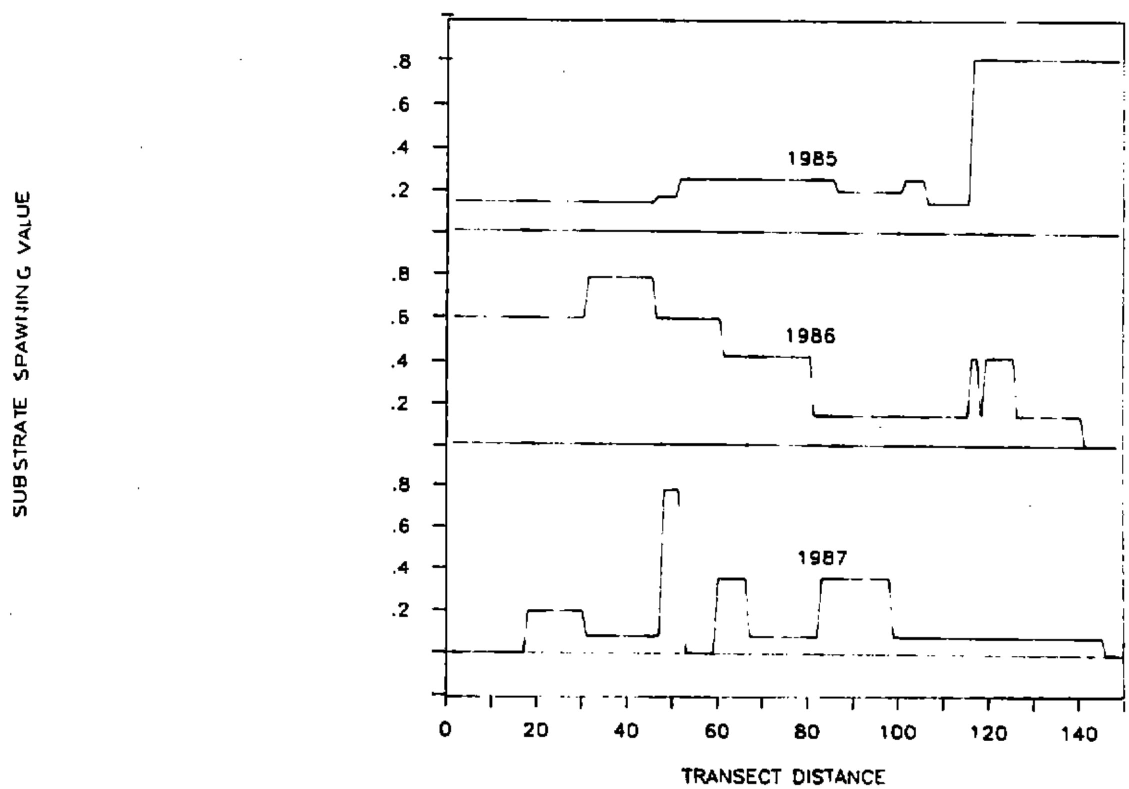


Figure 6. Change in substrate suitability for chinook spawning, 1985-87, at Poker Bar transect 8.

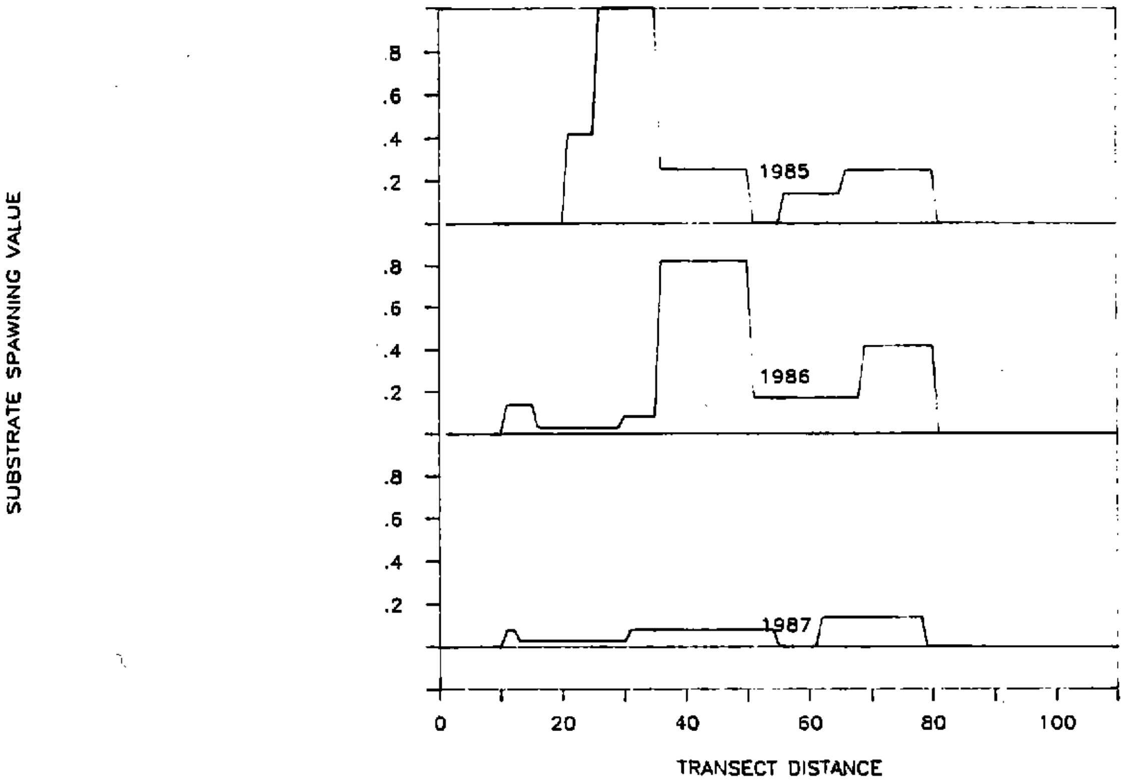


Figure 7. Change in substrate suitability for chinook spawning, 1985-87, at Poker Bar transect 9.

FLOW REQUIREMENTS FOR SIDE-CHANNEL MAINTENANCE

INTRODUCTION

The selective use of mainstem side-channels and backwaters by juvenile salmonids for rearing and as refuge areas is well documented in the literature (see for example, Bustard and Narver 1975; Hamilton and Buell 1976; Sedell et.al. 1982; Hartman and Brown 1987). During spring electrofishing surveys, when fry and juvenile salmonid populations are at their greatest, we have taken up to ten times more fish in side-channels than in the mainstem Trinity River.

In conjunction with our studies, biologists from Humboldt State University have been studying the importance of three upper-river side-channels to juvenile salmonid rearing habitat on the Trinity River. To supplement their data, and to increase our understanding of side-channels along the river we conducted a study of the major side-channels between Lewiston and Steiner Flat. Our objective was to determine the effect of river discharge on the general quantity and quality of side-channel rearing habitat.

METHODS

Data Collection

We surveyed the river by raft from Lewiston to a point 20 miles downstream near Steiner Flat, and chose six side-channels for their apparent value as rearing habitat (Table 1). These six side-channels represent most of the side-channel habitat within the surveyed reach.

We collected data from May through August of 1987. Data collection was planned to take advantage of scheduled flow releases from Lewiston Dam (Table 2) to observe changes in side-channel inflow that we expected to occur during each of these river flow regimes.

Data were collected so that a stage-discharge equation for the river at each side-channel could be developed, either through use of a computer simulation model or with a log-log stage-discharge regression. By measuring the water surface elevation of the river, we could estimate the Lewiston release required for inflow to the side-channel.

To measure river stage, transects were established across the Trinity River at each of the side-channel sites, with the

Table 1. Name and location of Trinity River side-channels

Side-channel Name	Location[1]
Salt Flat Bridge #1	RM 107
Salt Flat Bridge #2	RM 106.8
Bucktail	RM 105.1
Poker Bar	RM 102.5
Limekiln Gulch	RM 100.7
Indian Creek	RM 96

1/ RM = River miles upstream from mouth of Trinity River

Table 2. Flow releases at Lewiston Dam from May 1 through September 1, 1987

Date	Lewiston Release
May 1 - 16	800 cfs
May 17 - 21	500 cfs
May 22 - May 31	700 cfs
June 1 - June 30	700 cfs
July 1 - 31	600 cfs
August 1 - 27	400 cfs
August 28 - September 1	500 cfs

exception of the Poker Bar side-channel. The number of transects at each site varied from one to three, depending on the number necessary to determine the stage-discharge relationship of the river. One transect was always placed near the inlet of the side-channel. The complexity of the river at the Poker Bar location would have made transect location and modeling very difficult, so side-channel inflow versus river stage was described based on visual observations.

We measured water surface elevations at both ends of each transect for each of three target dam releases during the study period (700, 600, and 400 cfs). The mean water surface elevation at a transect was used as the stage value for a given discharge. All elevations were measured following standard surveying techniques (Trihey and Wegner 1981). We determined the bottom profiles for each transect by measuring the depth across a transect with a wading rod and then converting the depths to elevations by subtracting the depth from the mean water surface elevation.

Thalweg profile and water surface elevations were measured on each side-channel from the inlet to the outlet. Thalweg profiles were measured at the inlet, outlet, and the point controlling river flow into the side-channel. Additional measurements were taken at convenient locations or where there were obvious breaks in the profile. At each elevation point measured down the thalweg profile of a side-channel, the wetted width was measured.

Discharge into each side-channel was measured during each of the three target flow periods, following the mid-section method described by Buchanon and Somers (1969).

Data Analysis

River discharge data were obtained from the U.S. Geological Survey (USGS) (see Table 3) which maintains stage recording gages at sites at river mile 110.9 near Lewiston and at river mile 98.5 near Limekiln Gulch. Discharge data from the Lewiston gage were used for the Salt Flat Bridge and Bucktail sites, and Limekiln Gulch gage data were used for all other sites. USGS gage data available at the time of this report were preliminary values, but were not expected to change appreciably when published (W. Pete Shelton, Personal Communication).

The stage-discharge equation for each transect at the inlet to a side-channel was determined by either a water surface profile computer simulation or an empirical stage-discharge regression. The Service's WSP hydraulic simulation program (Milhous et al. 1984) was used to model transects at the Salt Flat Bridge, Limekiln Gulch, and Indian Creek sites. For the Bucktail site, we used the Service's WSEI4S computer

Table 3. Trinity River discharge at study site when side-channel inflow was measured, based upon USGS gage data.

Side-channel	FLOW 1	FLOW 2	FLOW 3
Salt Flat Bridge #1	720 cfs	660 cfs	325 cfs
Salt Flat Bridge #2	720 cfs	660 cfs	325 cfs
Bucktail	720 cfs	664 cfs	325 cfs
Poker Bar	711 cfs	652 cfs	321 cfs
Limekiln Gulch	690 cfs	637 cfs	321 cfs
Indian Creek	714 cfs	637 cfs	321 cfs

program (Milhous et al. 1984) which determines a logarithmic regression equation for a set of water surface elevations and discharges, and solves the equation for the stage corresponding to a given unknown discharge.

The wetted surface area between each side-channel thalweg measurement point was calculated as the average of the widths at each point multiplied by the distance between points. The areas between measurement points were summed to determine the total wetted width of each side-channel.

RESULTS AND DISCUSSION

Side-channel Descriptions

Brief descriptions of the character of each side-channel follow:

Salt Flat Bridge #1 - Habitat grades from pool and run in the upper 100 feet to a backwater pool. A well developed riparian canopy completely shades the upper end of the side-channel and opens up as the channel widens. A beaver dam approximately 100 feet downstream from the side-channel mouth controls the water surface elevation of the side-channel up to the inlet. The thalweg gradient is so low in this side-channel that it almost functions entirely as a backwater. See Figure 1.

Salt Flat Bridge #2 - The first 120 feet of the side channel is a riffle with some pocket water. The remainder of the side-channel is pool and run habitat. Riparian canopy completely encloses the side-channel which prevents it from receiving any direct sunlight during the summer. By the end of this study a beaver dam had been constructed at the downstream end of the side channel and the entire lower reach had become a standing pool. See Figure 2.

Bucktail - Habitat consists of a sequence of several riffles and broad, shallow pools throughout its length. It has no riparian vegetation and only minor growth of aquatic macrophytes when inundated. See Figure 3.

Poker Bar - This is the longest side-channel in the study. The upper 200 feet of the side-channel is a riffle and run section. The remainder consists of pool and run habitat. There is extensive riparian growth along both banks but the side-channel is still open to the sun. The pool and run section also has an extensive growth of cattails along the margins. A beaver dam 1100 feet down the side-channel controls water surface elevations for a distance of nearly 600 feet up the side-channel. See Figure 4.

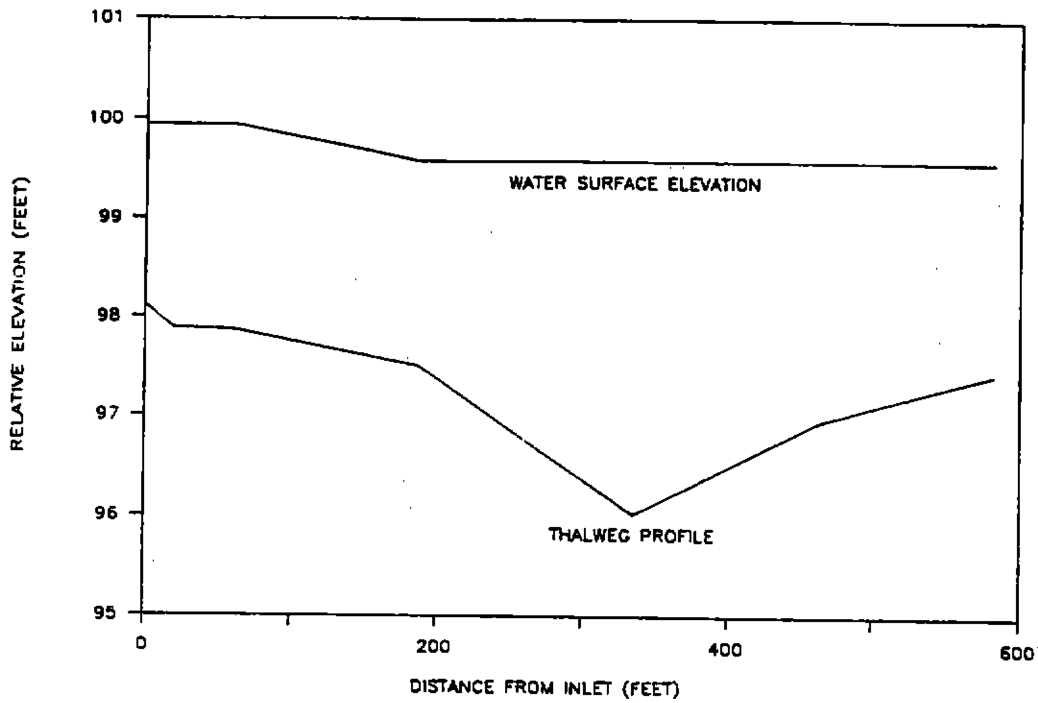


Figure 1. Salt Flat Bridge #1 side-channel thalweg profile and water surface elevations at Lewiston Dam release of 700 cfs (For actual Trinity River discharge at site see Table 3.).

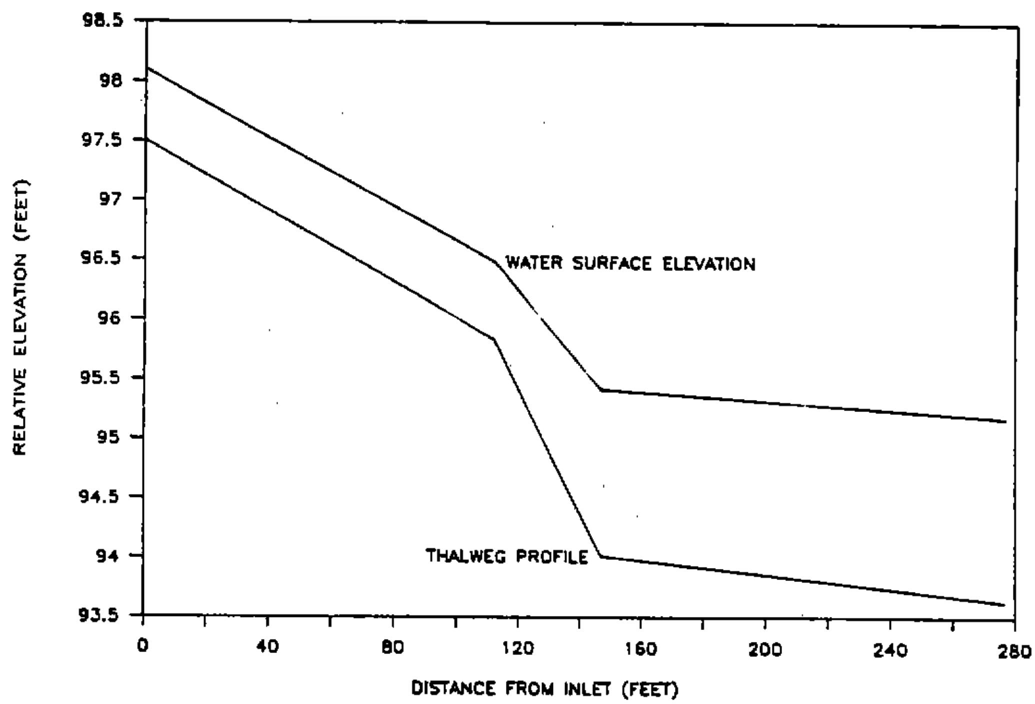


Figure 2. Salt Flat Bridge #2 side-channel thalweg profile and water surface elevations at Lewiston Dam release of 700 cfs (For actual Trinity River discharge at site see Table 3).

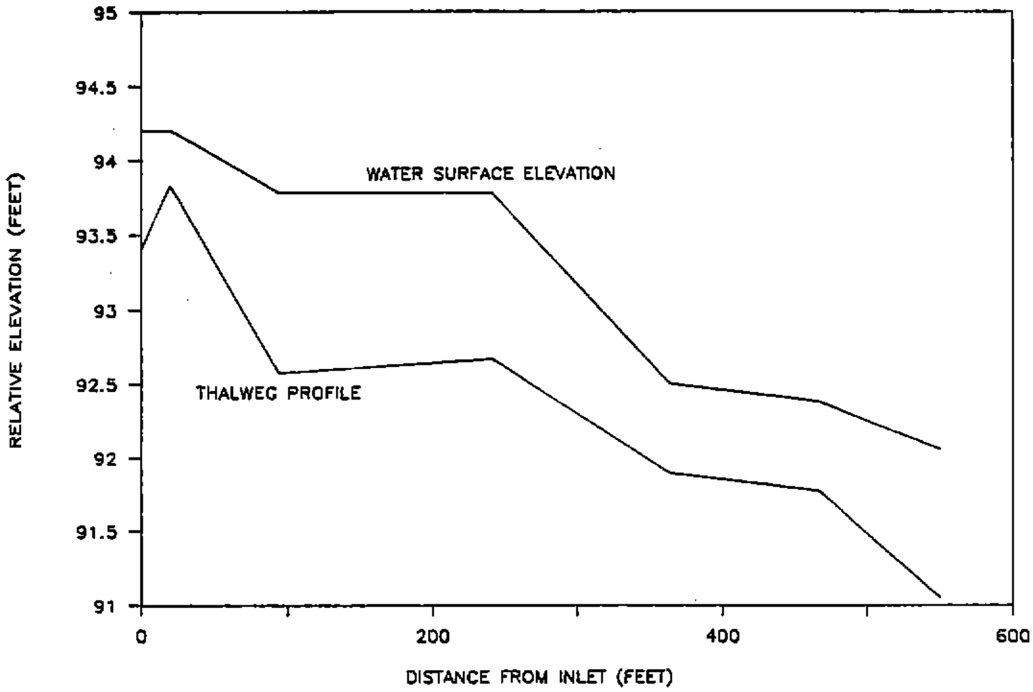


Figure 3. Bucktail side-channel thalweg profile and water surface elevations at Lewiston Dam release of 700 cfs (For actual Trinity River discharge at site see Table 3.).

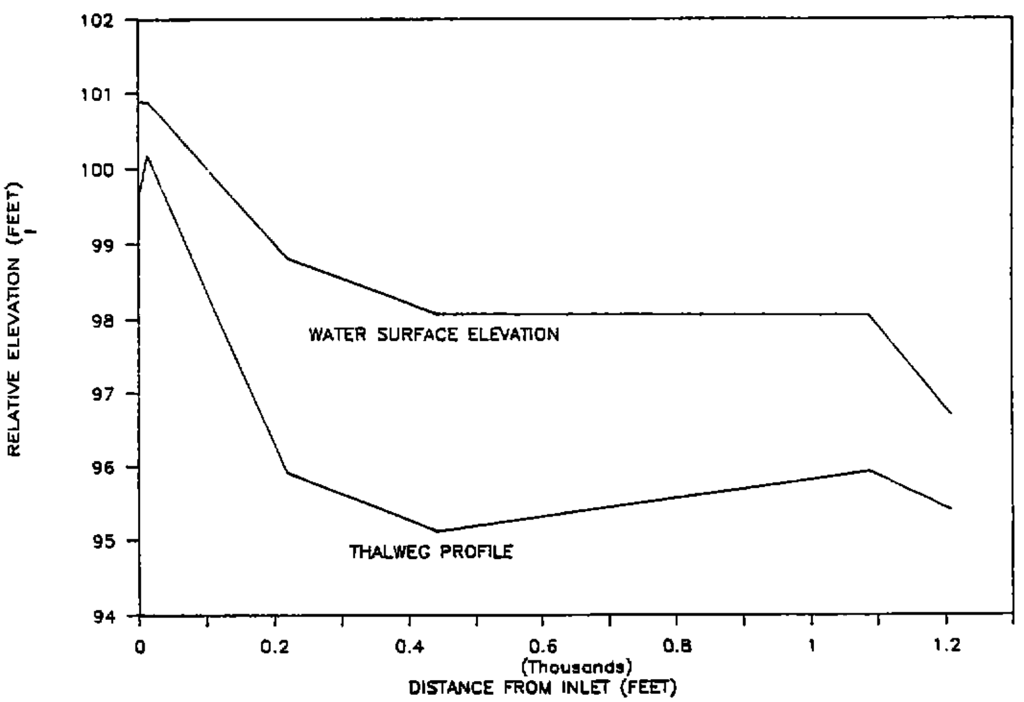


Figure 4. Poker Bar side-channel thalweg profile and water surface elevations at Lewiston Dam release of 700 cfs (For actual Trinity River discharge at site see Table 3).

Limekiln Gulch - A riffle and run section extends from the inlet to approximately 200 feet downstream. The remainder is a backwater pool. There is extensive riparian growth that completely shades the side-channel in the riffle and run section, but the canopy opens up as the side-channel widens downstream. See Figure 5.

Indian Creek - Pool, riffle, and run habitats alternate throughout its length. A well established riparian canopy completely shades the side-channel with the exception of a few small open areas. See Figure 6.

Effects of Changing River Discharge

Based on the stage-discharge relationships we determined for each site, side-channels begin receiving inflow over a range of river discharge varying from 35 to 550 cfs (see Table 4). The stage-discharge equations for the river at each side-channel site, except Poker Bar, were as follows:

Salt Flat Bridge #1 - $Q = 45.1383(STAGE-97.00)^{2.3901}$ (1)

Salt Flat Bridge #2 - $Q = 97.36855(STAGE-96.60)^{2.42218}$ (2)

Bucktail - $Q = 8.39725(STAGE-90.80)^{3.76493}$ (3)

Limekiln Gulch - $Q = 18.45679(STAGE-96.40)^{2.47157}$ (4)

Indian Creek - $Q = 58.09892(STAGE-97.60)^{3.0565}$ (5)

where Q = discharge, and
STAGE = mean water surface elevation at discharge.

Table 4. Thalweg gradient and Trinity River discharge initiating inflow at side-channels

Side-channel	Thalweg Gradient[1]	River Discharge[2]
Salt Flat Bridge #1	6	60 cfs
Salt Flat Bridge #2	74	75 cfs
Bucktail	27	550 cfs
Poker Bar	21	321-500 cfs
Limekiln Gulch	21	240 cfs
Indian Creek	14	35 cfs

1/ feet/mile

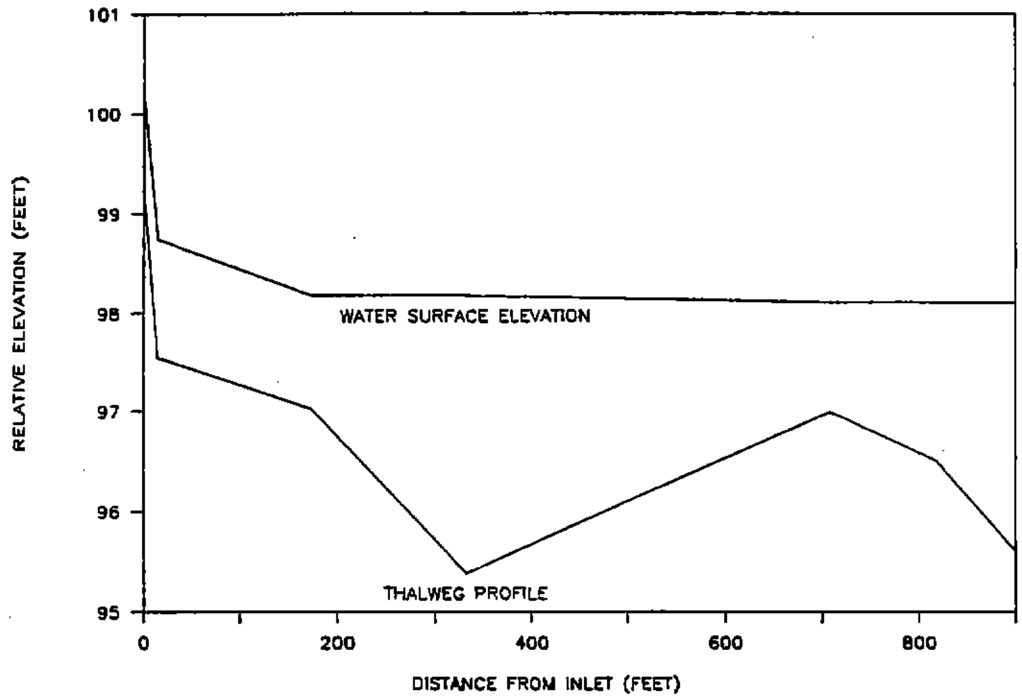


Figure 5. Limekiln Gulch side-channel thalweg profile and water surface elevations at Lewiston Dam release of 700 cfs (For actual Trinity River discharge at site see Table 3).

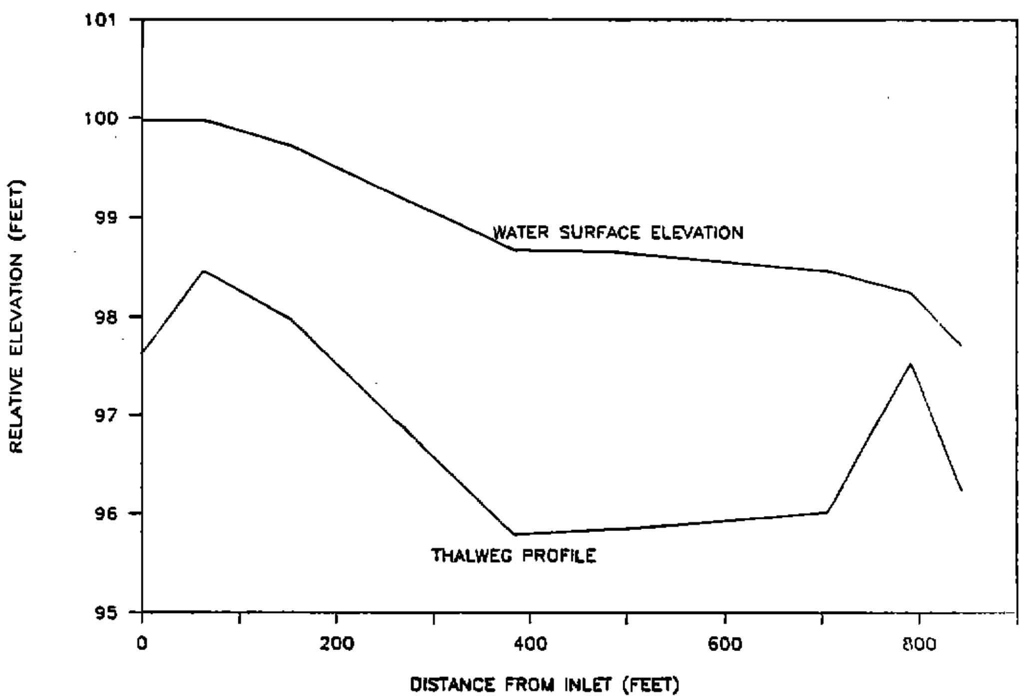


Figure 6. Indian Creek side-channel thalweg profile and water surface elevations at Lewiston Dam release of 700 cfs (For actual Trinity River discharge at site see Table 3).

Inflow decreased with decreasing river discharge at all side-channels, with the exception of Poker Bar (Figure 7). Between the June and July site visits a beaver dam blocked flow within a small channel of the river near the entrance of the Poker Bar side-channel causing the elevation of the small channel to increase. Thereby discharge to the side-channel increased even though river discharge had decreased. Indian Creek had the greatest inflow of all side-channels throughout the range of dam releases observed. At the lowest dam release of 400 cfs, Bucktail and Poker Bar had no inflow. Our observations at Bucktail agreed with the point of no inflow we predicted using a stage-discharge regression (Table 4.). Although inflow at Poker Bar had stopped at a dam release of 400 cfs, we observed that at a dam release of 500 cfs, such a small amount of water was entering the side-channel that no water was running from the outlet. Salt Flat Bridge #1 had no measurable inflow at a dam release of 400 cfs, but standing water remained throughout the side-channel.

Volume of side-channel inflow is influenced by three factors: 1) the elevation controlling inflow, as reflected by the river discharge at which inflow begins (Table 4), 2) the gradient of the side-channel (Table 4), and 3) the cross-section of the side-channel at the point controlling inflow. Side-channel cross-sections were not measured but the effect of inflow elevation and gradient are illustrated by side-channels at Salt Flat Bridge and Indian Creek. The Salt Flat Bridge #1 side-channel has little inflow, even though it starts to receive water at a low river discharge. Because of a low thalweg gradient, very little water is moving through the side-channel. In contrast, the Indian Creek side-channel receives inflow at a low river discharge and has a moderate thalweg gradient, and consequently has the greatest inflow of all the side-channels.

<u>Effect of Side-channel Inflow on Habitat Quantity</u>

Wetted surface area and depth provide a relative measure of the amount of habitat that may be available for rearing salmonids in the side-channels (See Figures 1-6 and 8). Magnitude of side-channel inflow did not necessarily reflect the wetted surface area or depth of a side-channel. Our measurement of wetted surface area within the side-channels at a Dam release of 700 cfs (Figure 7.) found that side-channels with relatively low inflow, e.g., Poker Bar and Salt Flat Bridge #1, can have a substantial wetted surface area. Side-channels with extensive pool area are able to maintain more habitat at lower inflow than those with greater riffle area. We did not measure wetted surface area or depth for dam releases other than 700 cfs. Generally, wetted surface area and depth decreased in all the side-channels as inflow decreased, albeit at very different rates. Indian Creek and Salt Flat Bridge #1 lost little in the way of surface area and depth as inflow decreased. Salt Flat Bridge #2 and Limekiln Gulch lost extensive amounts of habitat in the

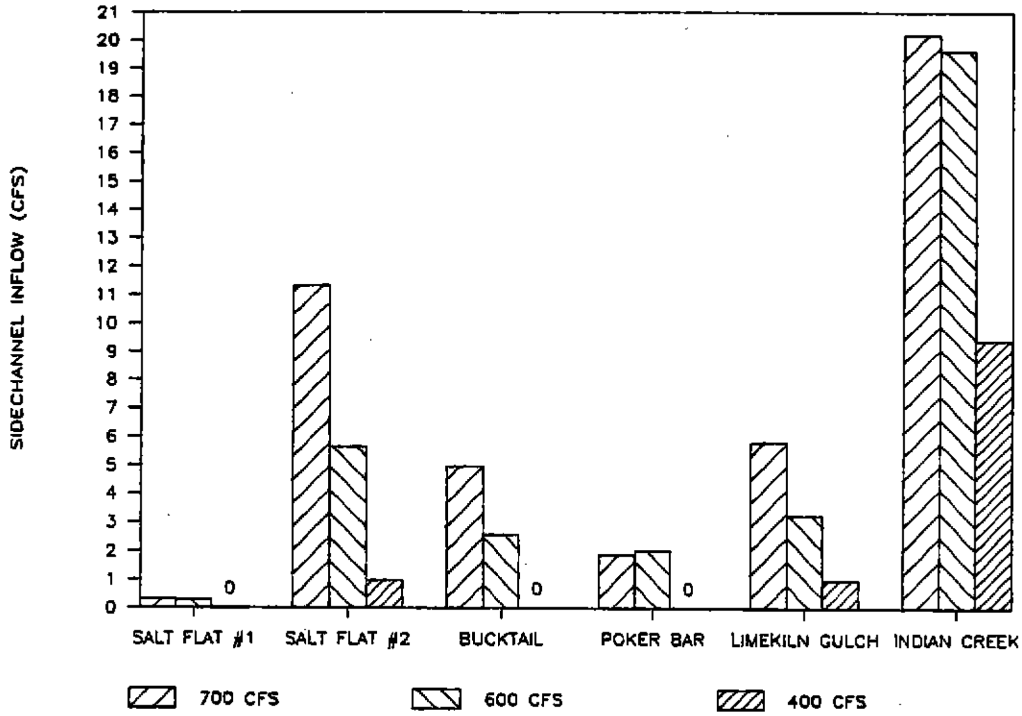


Figure 7. Inflow to Trinity River side-channels measured at Lewiston Dam releases of 700, 600, and 400 cfs (June, July and August, 1987) (For actual Trinity River discharge at each site see Table 3).

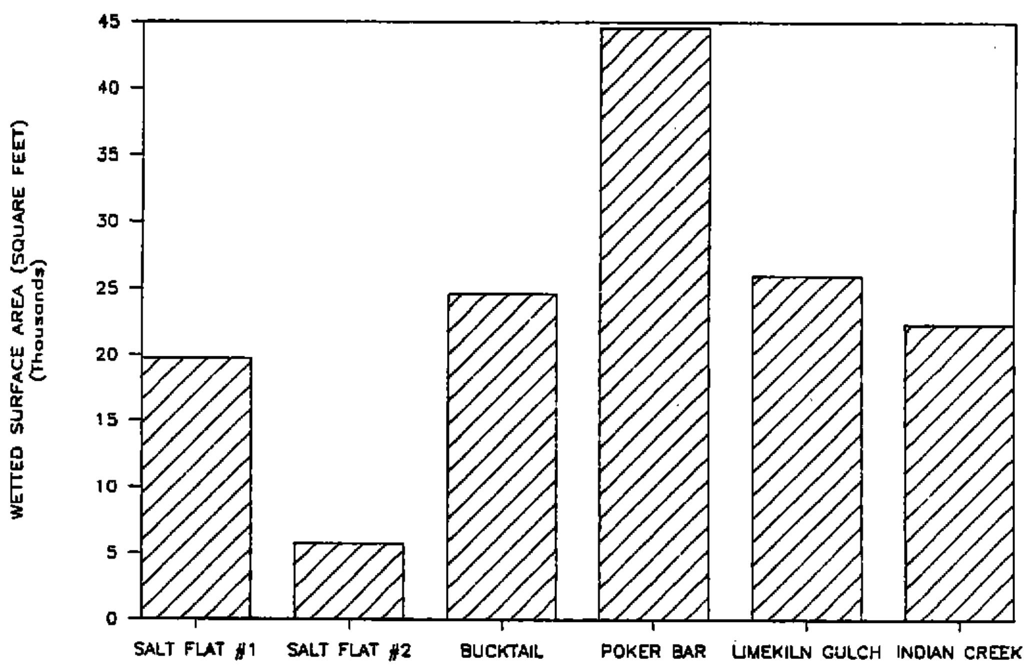


Figure 8. Wetted surface area of Trinity River side-channels at a Lewiston Dam release of 700 cfs (June 1987)(For actual Trinity River discharge at each site see Table 3).

riffle areas as flows decreased with moderate to minimal losses in pool or backwater areas. At a dam release of 400 cfs, Bucktail was completely dry and Poker Bar, although it contained standing water, had no connections with the main river and was uninhabitable by salmonids.

Although a quantitative measure of salmonid rearing habitat in each side-channel was not undertaken for this study, data collected during the 1986 Trinity River Flow Evaluation provides an example of the benefits that side-channels can provide in the system. That evaluation used the Fish and Wildlife Service's IFG-4/PHABSIM computer simulation programs (pages 14-25) to model salmonid rearing habitat. Two of the flow evaluation study sites have transects that cross side-channels. Those sites include the Bucktail side-channel investigated in this study and the Cemetery side-channel identified previously. The flow evaluation found that side-channels greatly contributed to the amount of fry chinook salmon habitat, as represented by weighted usable area (See Figures 9 and 10). Note that inflow at the Cemetery side-channel begins at a relatively low river discharge while inflow at Bucktail does not begin until a discharge of 550 cfs.

Effect of Beaver on Side-channel Habitat

Many of the side-channels along the Trinity River provide ideal habitat for beaver (Maser et al., 1981). Beaver ponds have been identified as productive salmonid rearing areas (Everest and Sedell 1984) and important refuges during the winter (Bustard and Narver 1975). On the other hand, beaver dams can also block migration of juvenile salmonids (Everest and Sedell 1984). Beaver could be making a contribution to fish habitat in Salt Flat Bridge #1 and #2, and the Poker Bar side-channels by maintaining higher water surface elevations at lower discharges. However, they have been known to de-water large portions of the Cemetery side-channel by dam construction and in the event of flow reductions, beaver dams, especially at Salt Flat Bridge #2 and Poker Bar, may increase the chance of fish being trapped.

Effect of Flow Change on Fish Stranding in Side-channels

During May the release at Lewiston Dam was reduced for a 5-day period, from 800 to 500 cfs, to facilitate installation of the Department of Fish and Game's Junction City weir. During that time all side-channels with the exception of Limekiln Gulch were monitored to determine if fry and juvenile salmonids had become stranded, or trapped and subjected to increased mortality. The dam release was reduced at a rate of 100 cfs per hour.

One day after flow was reduced, trapped chinook salmon fry were found in the Bucktail side-channel. Chinook fry and unidentified salmonid juveniles were also found trapped in

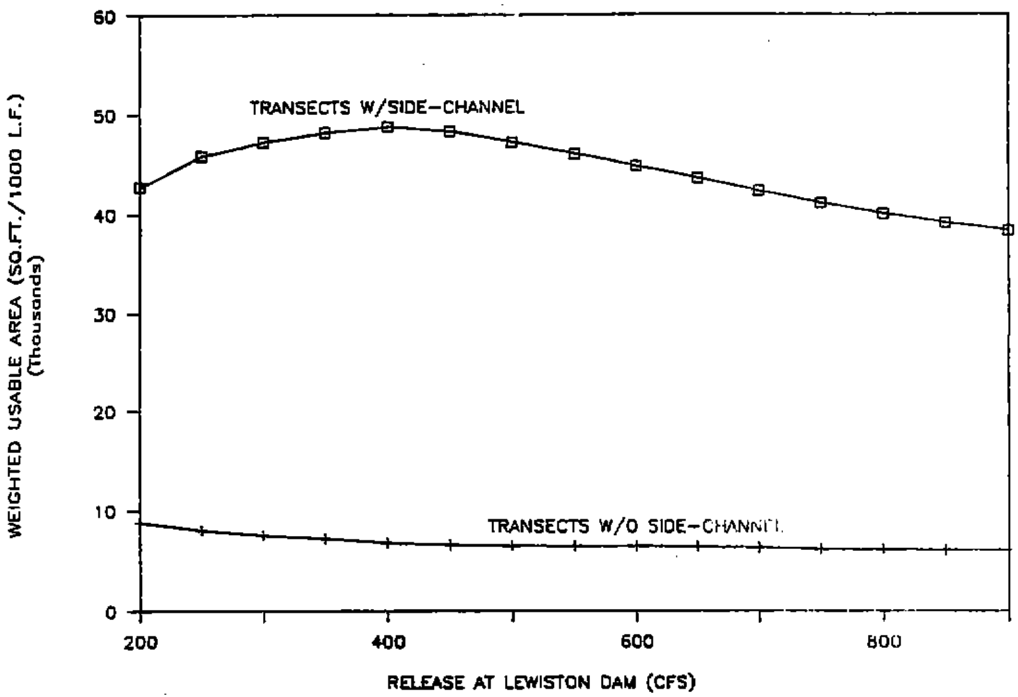


Figure 9. Fry chinook salmon habitat at Cemetery flow study site, Trinity River. Quantitative comparison of transects with and without side-channel habitat. Habitat modeled using IFG-4/PHABSIM computer programs. Habitat represented by weighted usable area (WUA); in square feet per 1000 lineal feet of stream.

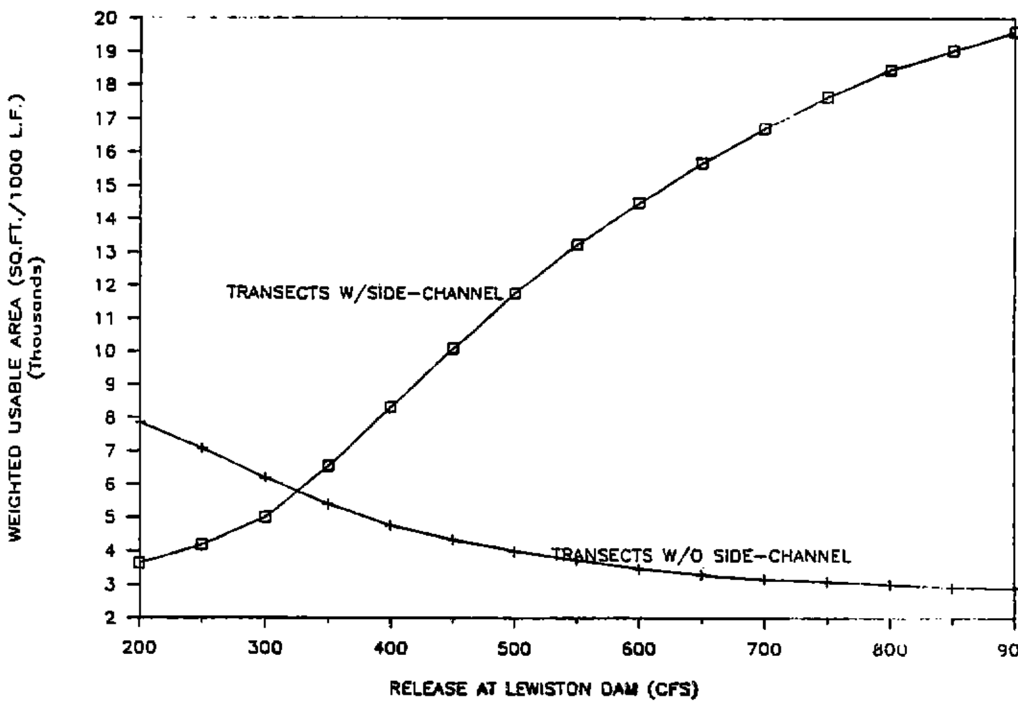


Figure 10. Fry chinook salmon habitat at Bucktail flow study site, Trinity River. Quantitative comparison of transects with and without side-channel habitat. Habitat modeled using IFG-4/PHABSIM computer programs. Habitat represented by weighted usable area (WUA); in square feet per 1000 lineal feet of stream.

the Poker Bar side-channel. No other side-channels produced conditions at this flow regime that would trap fish. Inflow to the Bucktail side-channel ceased during the flow reduction and isolated pools in the side-channel quickly became inhospitable to salmonids as the water evaporated and temperatures increased due to warm sunny weather. The lack of riparian cover at Bucktail contributed to these conditions. After two days all fry trapped in isolated pools had died. Although the actual cause of death was unknown, we suspect that a combination of high water temperatures, measured during mid-afternoon at 86° F.(stem thermometer), and reduced dissolved oxygen were to blame. The number of dead fish was estimated at between 50 and 100.

Salmonids at the Poker Bar side-channel survived through the flow reduction period presumably because a small inflow was still entering the side-channel; only the side-channel outfall was dry. Water temperatures measured at Poker Bar peaked at 76° F. A longer period of reduced flow may have also killed fish at Poker Bar either through prolonged stressful conditions or increased predation.

Few fish appear to have been killed by the flow reduction. However, future flow reductions during the spring, when fry and juvenile salmonids are occupying side-channels and river margins in high numbers, should be given full consideration before they are initiated. Potential for stranding and mortality could be affected by many factors including tributary inflow downstream of the dam, the difference between flows during the reduction, the time period of the reduction, weather conditions, the magnitude of the initial flow regime, and time of year. Development of a ramping rate that considers the morphometry of the river may be desirable, although Hamilton and Buell (1976) found that fry chinook and yearling coho salmon were reluctant to abandon their positions during a stranding test, despite falling water levels. The best approach would appear to be to avoid rapid flow reductions and to monitor areas that could strand fish during a reduction in flow. Avoidance of large flow reductions during the spring should also be considered.

Discharge for Maintenance of Side-channel Habitat

Our observations of the side-channels at a dam release of 400 cfs found that rearing habitat for juvenile salmonids was non-existent at Bucktail and Poker Bar, marginal at Salt Flat Bridge #2, and fair at Salt Flat Bridge #1, Limekiln Gulch, and Indian Creek. The side-channels at Bucktail and Poker Bar, based on the current stage-discharge relationship will require a minimum 600 cfs release at the dam to provide marginal rearing habitat, and releases higher than that will apparently continue to improve rearing habitat conditions (see Figures 9 and 10). Conditions in the other side-channels, although fair at a 400 cfs release, were much improved at a release of 600 cfs based upon a subjective evaluation considering changes in velocity and depth and how they influence space, cover, and food availability in the side-channels (See Reiser and Bjornn 1979).

Potential for Improvement of Side-channel Rearing Areas

In addition to the identification of side-channels as important rearing areas, biologists have also recognized the opportunities for modifying existing side-channels or constructing artificial side-channels in order to improve and increase the rearing areas for anadromous salmonids (See for example; Mundie and Mounce 1978, Parfitt and Buer 1981, Mundie and Traber 1983, Doyle 1984 and Everest et al., 1985) The Trinity appears to have potential for application of both of these techniques. For example, modification of the inlet and outlet at Poker Bar could extend the range of river flows over which the side-channel is accessible and usable. Construction of artificial side-channels, if feasible, should mimic the features of natural side-channels which make them most productive and attractive for rearing salmonids. The information presented in this study should assist in the identification of appropriate sites (e.g., optimum length and gradient) and design of artificial side-channels (e.g., inlet elevation and riffle/pool incorporation).

WATER TEMPERATURE MONITORING

INTRODUCTION

Water temperature monitoring in the mainstem of the Trinity River was conducted between Lewiston Dam and the confluence of the North Fork Trinity River. Monitoring was done to establish a data record and to provide a data base for future modeling of the system in an effort to predict instream water temperatures during different flow conditions.

SITES AND METHODS

The Trinity River from the North Fork to Lewiston Dam was divided into discrete subsections for purposes of temperature monitoring. Each subsection is defined by relatively similar hydrological conditions and segregated by a set of temperature recorders, one each at the upstream and downstream points. Each instrument location can be considered a "node" of the monitoring network, at least for the upper Trinity River, for future use in the Service's instream temperature model (SNTEMP). Tributaries were also monitored throughout the summer. It is felt that this procedure will provide data to allow the differentiation of the effects of mixing of water masses from other forms of heat exchange.

The actual distribution of temperature recorders is shown in Figure 1. Table 1 lists the monitoring locations, type of instrument used, recording interval, and duration of sampling. Four temperature recorders were operated in the Trinity River between Lewiston Dam and the confluence of the North Fork. These were downstream of Lewiston Dam, off Steel Bridge Road, at Evans Bar (near Junction City), and at Idaho Bar (approximately 1 river mile upstream of the confluence of the North Fork). Tributary water temperature monitoring sites were generally located as close to their confluence with the Trinity as possible.

The temperature recorders used consisted of a combination of Omnidata Datapod Model DP-112 temperature recorders, and Ryan Instruments Model J and TempMentor temperature recorders. The Datapod and TempMentor are capable of recording temperatures at an accuracy of 0.1 degree Celsius (C) and were set to record water temperature at 1 hour intervals. The Ryan Model J instruments are continuous temperature recorders. The Datapods recorded data on a nonvolatile storage medium called a data storage module (DSM). This prevents data loss in the event of flooding, power failure or other mishap. The stored data can be transferred to computer data files using a DSM

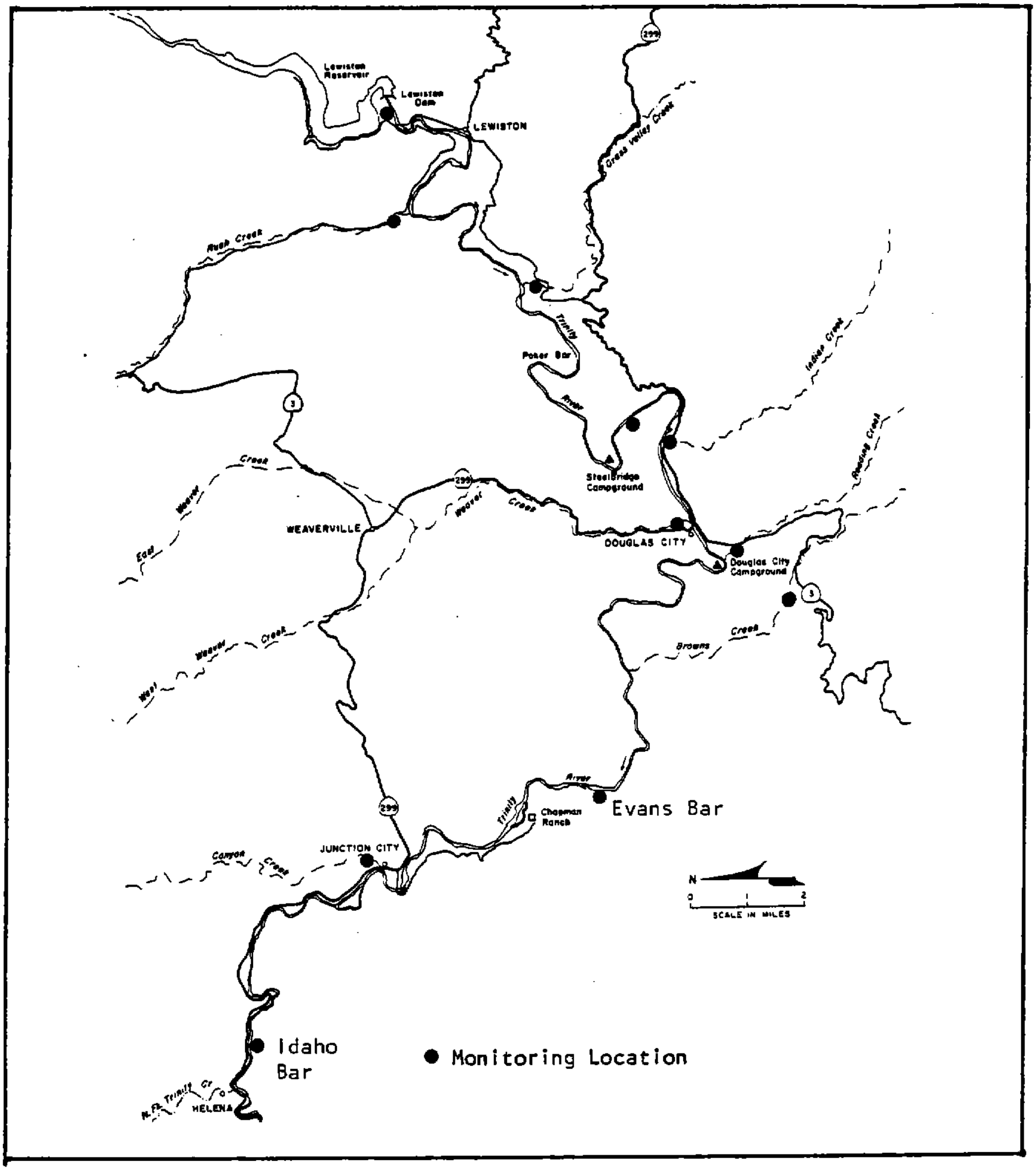


Figure 1. Distribution of temperature monitoring stations, Trinity River water temperature monitoring study, July 8 to September 15, 1987.

reader. The TempMentors recorded data on a built-in storage chip and was transferred to computer files through direct link of the instrument to a computer terminal. The Ryan Model J units recorded temperature data on a removable strip chart. All temperature recorders were sealed in water-resistant housings and placed in armored cases for deployment. The sealed units were then submerged at depths which kept

Table 1. Location of Trinity River water temperature monitoring stations during the summer of 1987.

Location Description	River[1] Mile	Type of Recorder	Recording Interval	Sample Period
Lewiston	111.4	Datapod	60 min.	7/8 - 9/15
Rush Creek	107.5[1]	Ryan J	continuous	8/4 - 8/24
Grass Valley Creek	104.0	Ryan J	continuous	7/8 - 8/4
Steel Bridge Road	97.5	Datapod	60 min.	7/8 - 9/15
Indian Creek	95.3	TempMentor	60 min.	8/25 - 9/15
Weaver Creek	93.8	Ryan J	continuous	7/8 - 8/4
Reading Creek	92.9	Ryan J	continuous	8/25 - 9/15
Browns Creek	87.9	TempMentor	60 min.	8/25 - 9/15
Evans Bar	85.0	Datapod	60 min.	7/8 - 9/15
Canyon Creek	79.1	Datapod	60 min.	7/8 - 9/15
Idaho Bar	73.0	Datapod	60 min.	7/8 - 9/15

[1] Location of the tributary confluence with the Trinity River.

them immersed over the range of river stages observed during the monitoring period and were chained to trees, boulders, or other immovable objects. Each unit was serviced at an interval of approximatly 30 days or less. For the Datapods this consisted of removing the DSM with its stored data and replacing it to continue the data record.

In order to calibrate the stream temperature model, adequate hydrological and meterological data are also necessary. For purposes of this monitoring effort established USGS stream gage stations at Lewiston and near Limekiln Gulch (Steel Bridge) were used. Mean daily discharge data are available from USGS for these stations.

Ambient air temperature was recorded at two locations adjacent to the Trinity River. One was at the Sawmill wildlife area near Lewiston and the other was at Evans Bar near Junction City. Daily air temperature extremes were recorded with minimum-maximumthermometers.

RESULTS

The temperature monitoring study resulted in the collection of a large amount of data for each of the four mainstem study sites and the six tributaries between Lewiston Dam and the North Fork Trinity River. These data define the response of the river and tributaries to flow and local weather conditions during the monitoring period.

Trinity River Temperatures

Mean daily water temperatures recorded for the four mainstem river monitoring sites are presented in Figure 2.

In general, mean daily temperatures increased downstream from Lewiston Dam, as would be expected. With the exception of the Lewiston site mean daily temperature patterns were fairly similar between sites. Temperatures at the Lewiston site remained fairly constant as would be expected close to the Dam. Hourly temperature records show that the daily temperature pattern followed a sinusoidal pattern. Maximum temperatures had a relatively short duration under this typical pattern. Figure 3 is a plot of the diurnal temperature pattern for August 18 (Lewiston), August 19 (Steel Bridge Road and Idaho Bar), and August 28 (Evans Bar). These dates were selected for illustration because they are the days when the maximum temperatures were recorded for each site. It is likely that the maximum temperature at the Evans Bar site would have been either on the 18th of 19th except that the recorder malfunctioned during this period so no temperature data are available. Figure 3 shows that the higher temperatures occurred during the period of 1700 to 1900 hours daily. This pattern was fairly typical for the mainstem Trinity River monitoring locations, except for the Lewiston site where the highest temperatures occurred slightly earlier in the day, from 1500 to 1700 hours.

Stream temperature profiles for the mainstem Trinity River for July 12, July 18, and August 19 are plotted in Figure 4. These dates were selected because they represent median, minimum and maximum temperature ranges during the monitoring period, respectively.

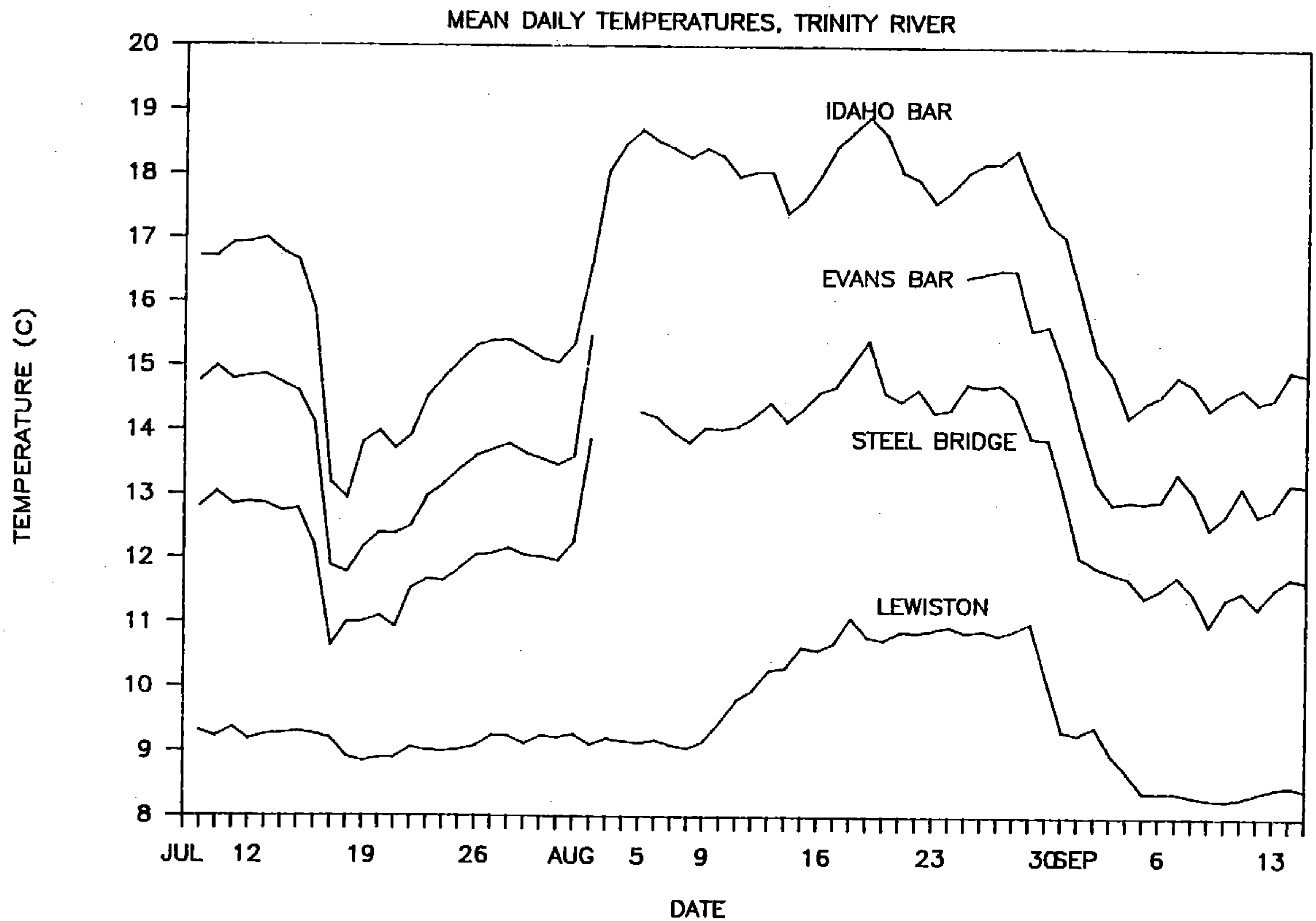


Figure 2. Mean daily water temperatures at the four mainstem monitoring sites on the Trinity River, 1987.

Tributary Temperatures

Temperature recorders in each of seven major tributaries to the Trinity River between Lewiston Dam and the North Fork were operated for a period of approximatley 21 days each with the exception of Canyon Creek. Canyon Creek was selected to be a control stream for estimating tributary temperatures. Therefore, temperatures were recorded in Canyon Creek using the same type of instrument (an Omnidata Datapod) as was used in the mainstem. Water temperatures in all tributaries were recorded at 1 hour intervals. The results of tributary water temperature data gathering from July 8 through September 15, 1987 are illustrated in Figure 5. For the most part, tributary water temperature patterns closely followed the temperature pattern observed in the mainstem Trinity River downstream of Lewiston Dam. Diurnal temperature fluctuation patterns were also similar as illustrated in Figure 6, except that the highest daily temperatures occurred during the period of 1400 to 1700 hours, slightly earlier than all but the Lewiston monitoring site on the mainstem Trinity River. Temperature profiles from upstream tributaries to downstream tributaries are illustrated in Figure 7.

DISCUSSION

Heat exchange of water with the environment is characterized by a number of mechanisms which act through the water surface. All natural water bodies dissipate heat to the atmosphere through back radiation, conduction, and evaporation, and heat gain through shortwave solar radiation and longwave atmospheric radiation (Edinger et al. 1974). This heat balance and the mixing with incoming water masses such as lateral groundwater flow and tributary inflows result in changes in detectable water temperature.

Local conditions such as ambient air temperature, cloudiness, wind speed, relative humidity, topographic and vegetation shading all affect the heat balance of a water body. In addition the azimuth (orientation) of the stream affects the duration of exposure to shortwave solar radiation and the width of the stream affects the amount of water surface available for heat exchange (back radiation, evaporation, solar radiation, etc.) (Theurer et al. 1984).

Although the water temperature monitoring presented here represents only summer conditions some insight can be gained as to possible seasonal effects. Water temperature data for the upper Trinity River reach, presented in the previous sections, clearly reflect trends associated with ambient air temperature (Figure 8). Ambient air temperature alone however may not be the only meterological factor influencing Trinity River water temperatures. Additional data is being obtained but is not available for this discussion.

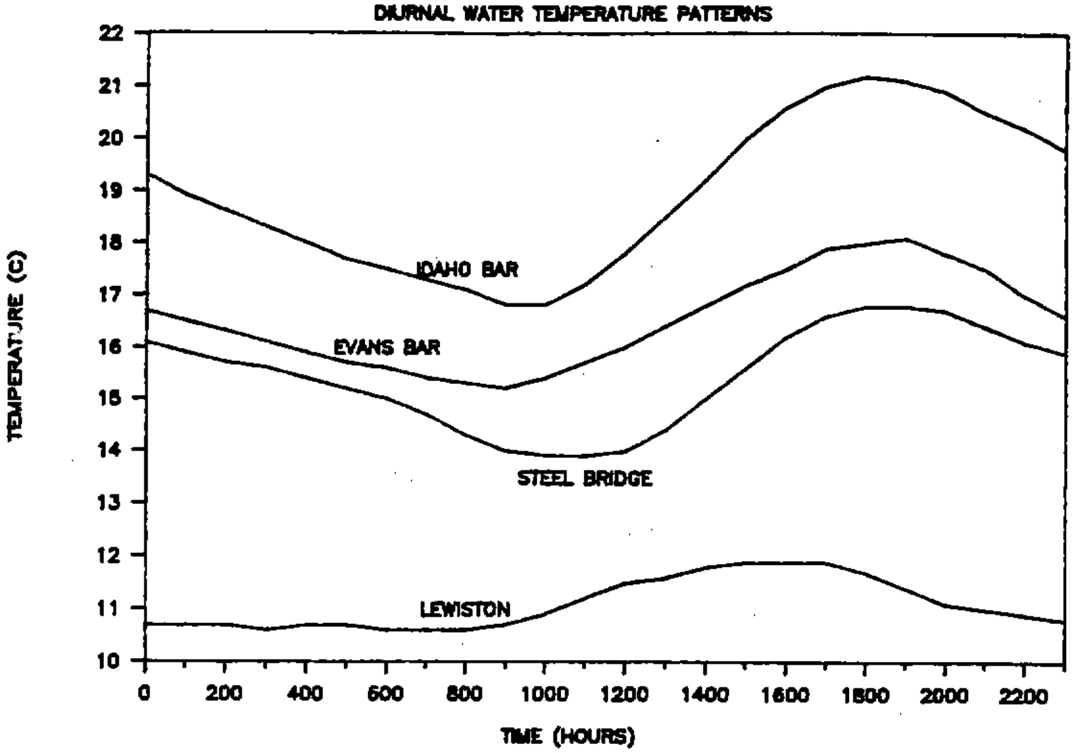


Figure 3. Diurnal water temperature patterns observed on the Trinity River, 1987.

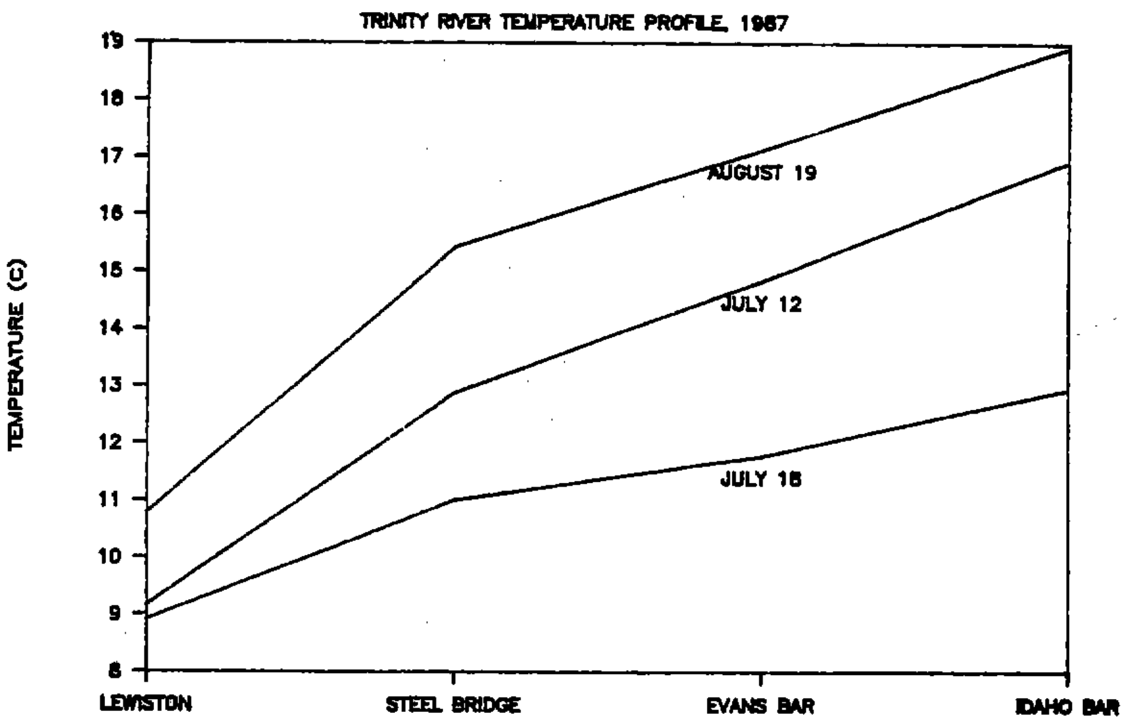


Figure 4. Temperature profiles of the Trinity River between Lewiston Dam and Idaho Bar (near the North Fork) for three temperature regimes during 1987.

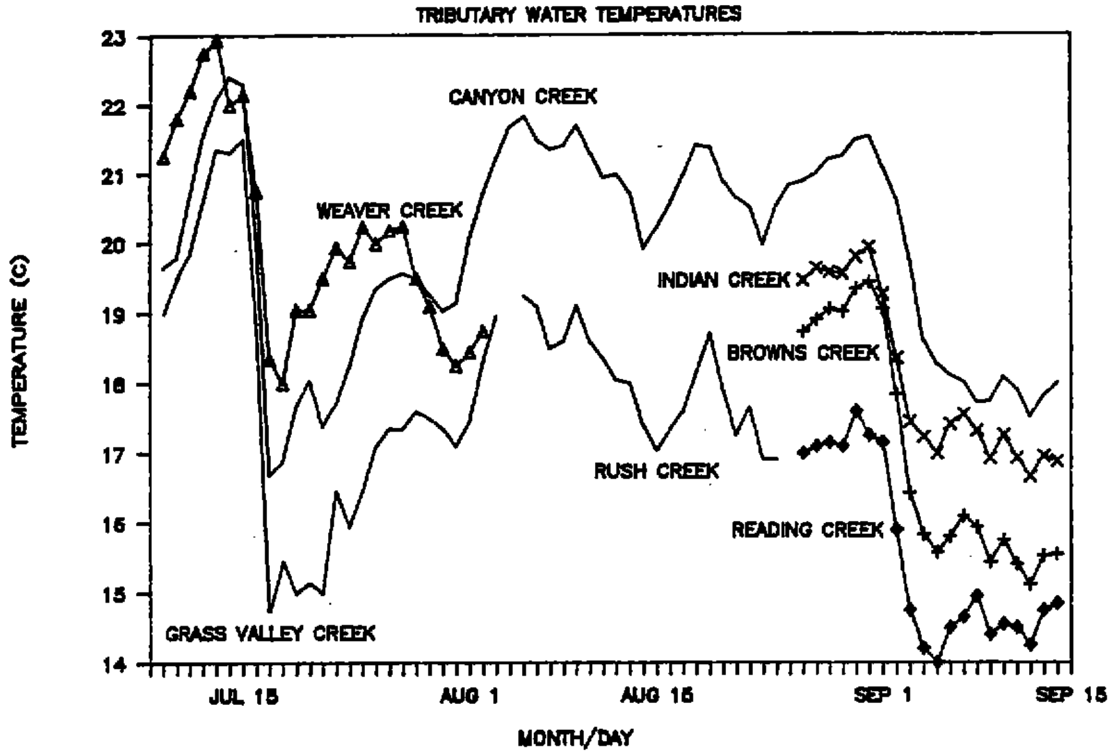


Figure 5. Mean daily water temperatures recorded at six tributaries to the Trinity River between Lewiston Dam and the North Fork.

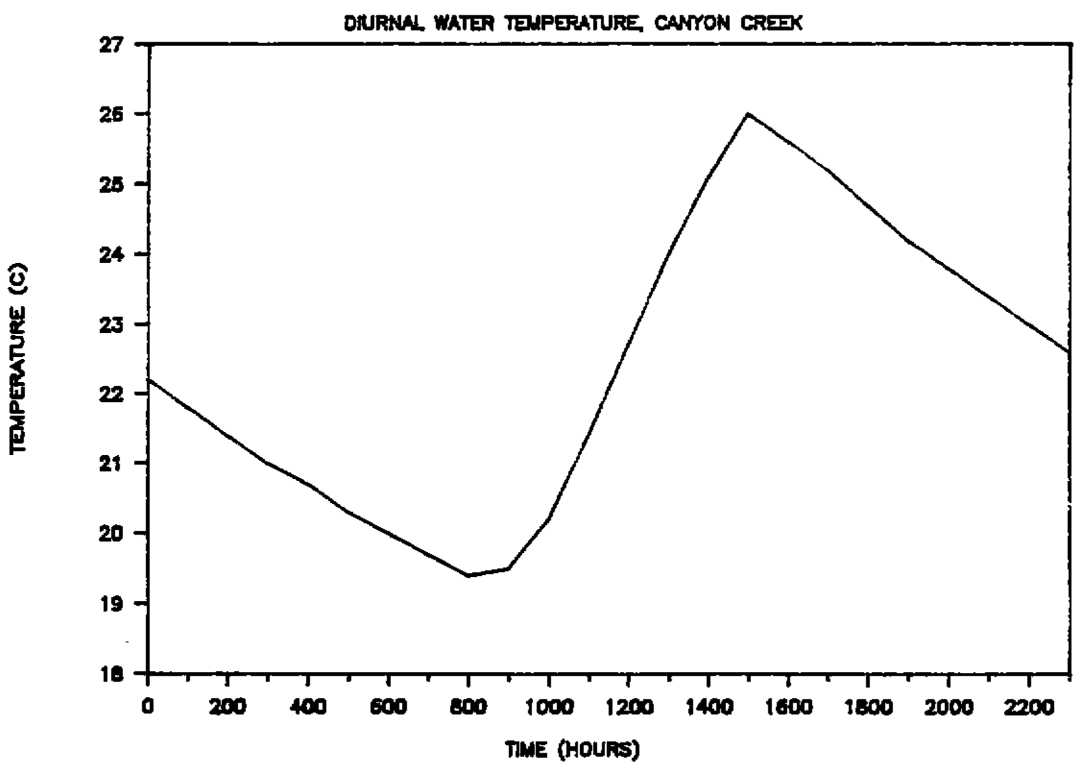


Figure 6. Diurnal water temperature pattern observed in tributary streams of the Trinity River. Measured from July 8 through September 15, 1987 in Canyon Creek.

An examination of diurnal temperature variation is important since the purpose of this study is to provide information for input to an IFIM analysis of the effect of temperature on fish habitat suitability. Daily mean temperatures are usually indicative of the median conditions recorded at a given location in a 24-hour period and may provide a good indication of longer-term temperature exposure. However, these do not necessarily provide adequate information on exposure to the shorter duration maximum temperatures observed. The importance of short duration exposure is related to the magnitude of the temperature, its duration, and the fish species short-term sensitivity. Maximum diurnal fluctuations observed in the mainstem Trinity River were in the range of 10.8 to 11.6 degrees C just below Lewiston Dam to 16.9 to 21.1 degrees C at Idaho Bar (Figure 3). Fluctuations observed in the tributaries were in the range of 19.5 to 26.0 degrees C (Figure 6). All exhibited a well-developed sinu soidal pattern with the exception of the Lewiston site on the Trinity River. This site was just downstream of the Dam and showed a relatively constant temperature curve, daily as well as over the longer term. This diurnal water temperature cycle is most likely driven by solar radiation. This is particularly apparent if the mean daily tributary temperatures are compared to the measured mean daily ambient air temperature. As as example Figure 9 compares mean daily water temperatures of Canyon Creek with mean daily air temperatures measured within the Trinity Basin.

Water temperature changes with various flow releases from Lewiston Dam were recorded based on USGS stream gage data from Lewiston and at Steel Bridge (near Limekiln Gulch) recorded during the monitoring period of July 8 through September 15, 1987. The overall effect of changes in releases depends on the stream reach, location, and actual discharge (Figure 10). It appears that at higher release levels, the range of variation of daily maximum water temperatures was substantially reduced and was consistently closer to the mean. Mean temperatures also tended to be less variable. The effect of the releases on temperature was also affected by local influences such as air temperature especially at the lower release levels. In general, it appears that changes in water temperature with various release flows, at least of from 650 cubic feet per second (CFS) to 300 CFS are between 3 and 4 degrees C.

While the alternate release flow aspect of this study may be extremely valuable in examining the affect of Lewiston Dam releases on downstream water temperatures, the true effects may be obscured by day-to-day variations in air temperature, cloudiness, humidity, etc. Figure 11 compares mean daily water temperatures within the Trinity River with air temperatures measured in the basin and stream flow as measured at the Lewiston gage. The next step in this water temperature study is to apply known data (water temperature, meterologi-

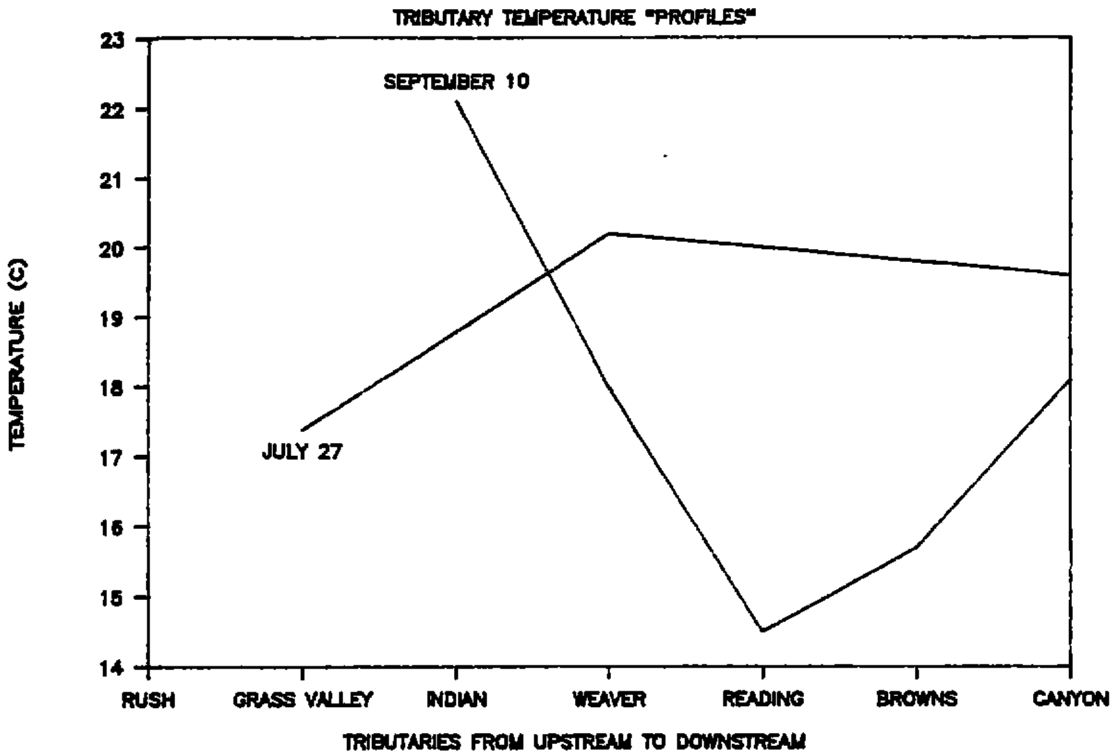


Figure 7. Tributary water temperature profiles from upstream tributaries to downstream tributaries, Trinity River water temperature monitoring study, 1987.

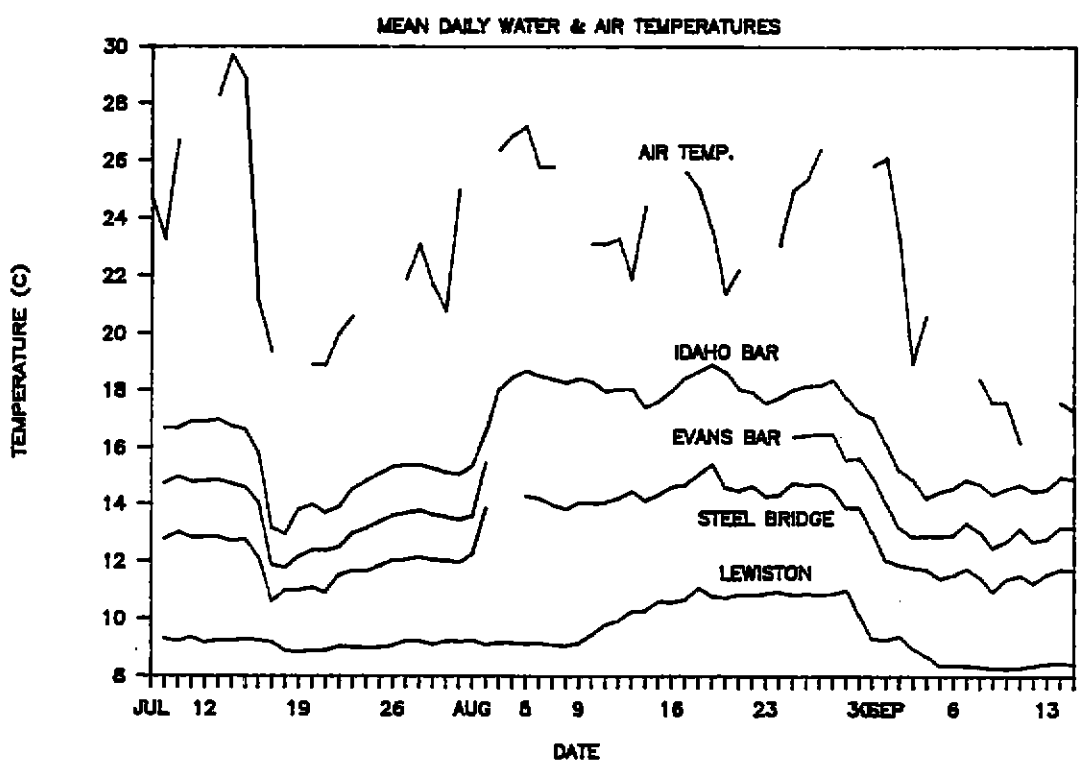


Figure 8. Trinity River water temperatures compared with ambient air temperatures in the Trinity basin during the summer of 1987.

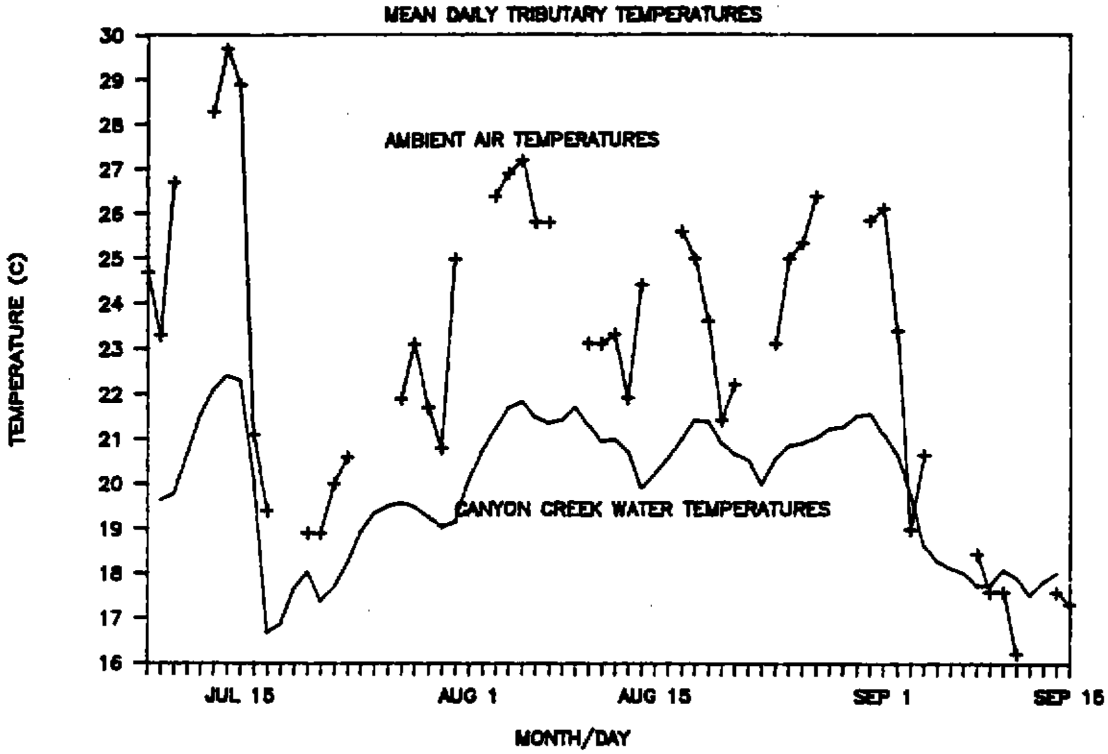


Figure 9. A comparison of mean daily water temperatures or Canyon Creek with mean daily air temperatures in the Trinity River basin during the summer of 1987.

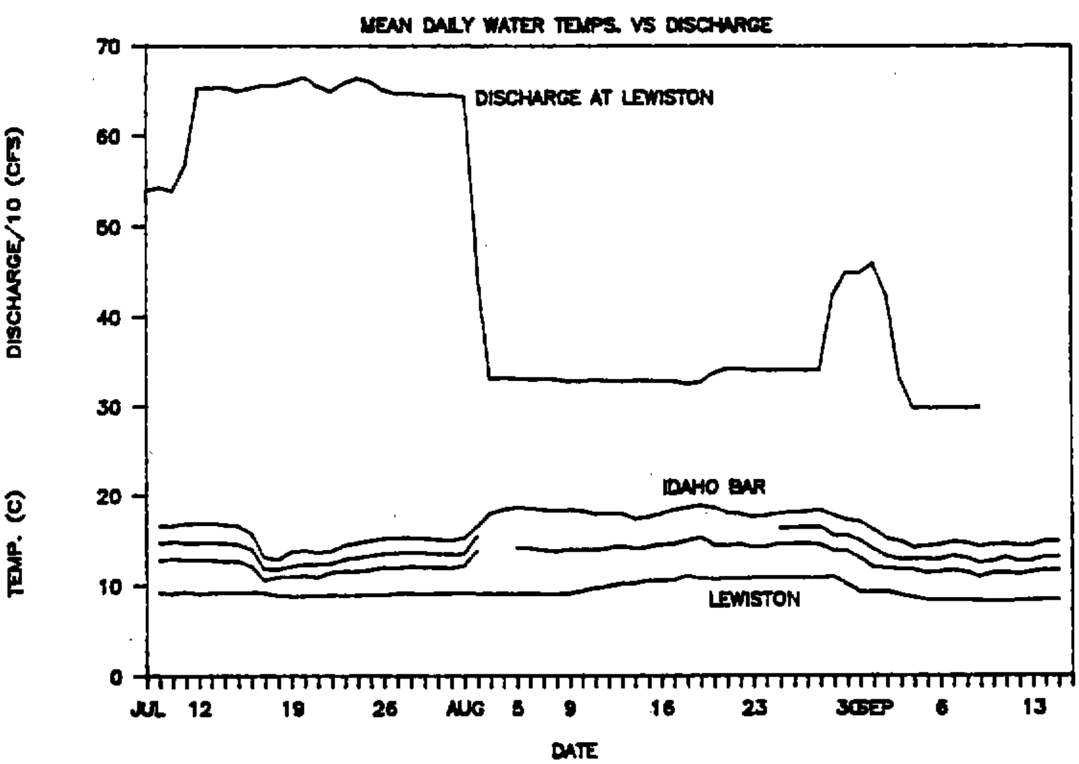


Figure 10. A comparison of mean daily water temperatures in the Trinity River with instream releases from Lewiston Dam during the period of July 8 through September 15, 1987.

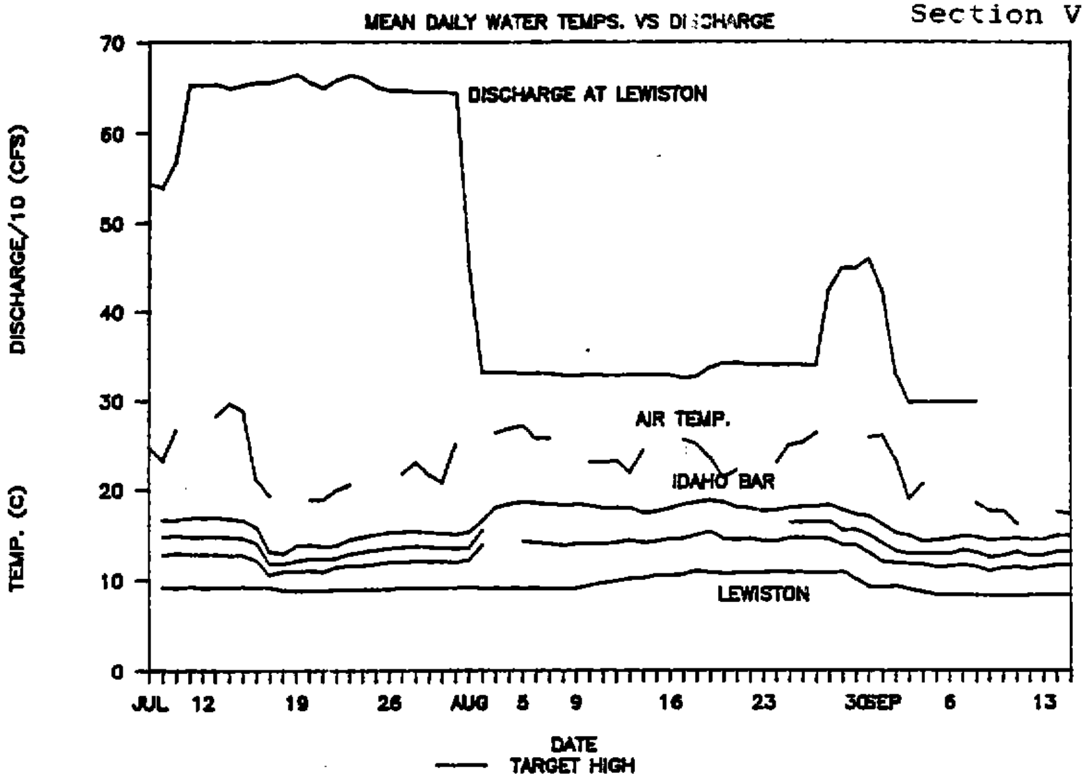


Figure 11. Mean daily water temperatures at four sites in the Trinity River compared to mean daily air temperatures within the basin and stream flow measured at the Lewiston gage.

cal, and hydrological) to the Service's instream temperature model (SNTEMP) which provides an analytical framework to isolate the effect of alternate release flows on stream temperatures under a variety of conditions.

FISH POPULATION CHARACTERISTICS AND LIFE HISTORY RELATIONSHIPS

The purpose of Task 4, within the 12-year Trinity River Flow Evaluation, is to describe fish population characteristics and life history relationships of the salmonid species present. The task has been subdivided into six parts, A through F. The goal of each of these subtasks is as follows:

4A: Habitat Use Monitoring - cooperative task designed to monitor fish responses to habitat rehabilitation or enhancement projects on the mainstem Trinity River.

4B: Fish Distribution Studies - includes development of habitat use indexes, population estimates and determination of downstream migration patterns.

4C: Egg and Juvenile Survival - goal is to determine egg and juvenile salmonid survival rates.

4D: Juvenile Salmonid Growth - describe growth patterns and characteristics of Trinity River salmonids.

4E: Invertebrate Studies - describe invertebrate species compositions and estimate production levels for the Trinity River.

4F: Juvenile Salmonid Food Habits - determine feeding habits and preferences for juvenile salmonids of the Trinity River.

The following report sections describe this year's efforts in each of these areas.

SPAWNING DISTRIBUTION

INTRODUCTION

In 1986, we made a number of river trips in the fall and early winter to find out where and when salmon were spawning, as an aid to planning our field population and growth monitoring. The results of these surveys are included below, as a contribution to the study that will be necessary to evaluate the year-to-year distribution of spawning habitat, and to determine changes in habitat as they occur.

Our surveys were conducted during raft trips through various sections of the Trinity River from Bucktail hole, at river mile 105, downstream to Tish Tang Creek on the southern boundary of the Hupa Indian Reservation. We covered all likely spawning areas, with special attention to bankside runs and the tops of riffles, and marked the location of isolated redds or mass spawning areas on aerial photographs. A total count of the number of redds present in each spawning area was also noted.

RESULTS

The dates and locations of each raft trip along with the total number of redds observed are shown in Table 1. The

Table 1. Date, section of river surveyed, and total number chinook salmon redds observed in the Trinity River, CA., 1986.

DATE	AREA SURVEYED	NUMBER OF REDDS
11/17/86	Bucktail Hole to Steelbridge Campground	443
11/26/86	Steelbridge Campground to Douglas City	177
10/27/86	Douglas City Campground to Calif. Dept. Fish Game Weir	134
11/27/86	Calif. Dept. Fish Game weir site to Junction City Campground	99
11/24/86	Del Loma to Cedar Flat	119
11/25/86	Willow Creek to Tish Tang Campground	21

major spawning areas within our survey boundaries are mapped in Figure 1. Only those those habitat areas where at least 10 redds were observed were considered as major spawning areas.

DISCUSSION

Spawning areas in the upper Trinity River, between Lewiston Dam and Bucktail Hole, were mapped during other studies conducted in the Trinity River Flow Evaluation Study.

California Department of Fish and Game estimated that 91,088 adult chinook salmon spawned naturally in the Trinity River upstream from Willow Creek in 1986. The large escapement of adult salmon resulted in extensive spawning within habitat areas where spawning had not been observed in recent years. Although not shown in Figure 1, scattered spawning was observed as far down-river as Tish Tang Creek. The capture of button-up fry chinook salmon during our growth study sampling in these lower sites, as well as snorkel observations at Hayden Flat, indicated the capability of these lower habitats to produce fry salmon when seeded.

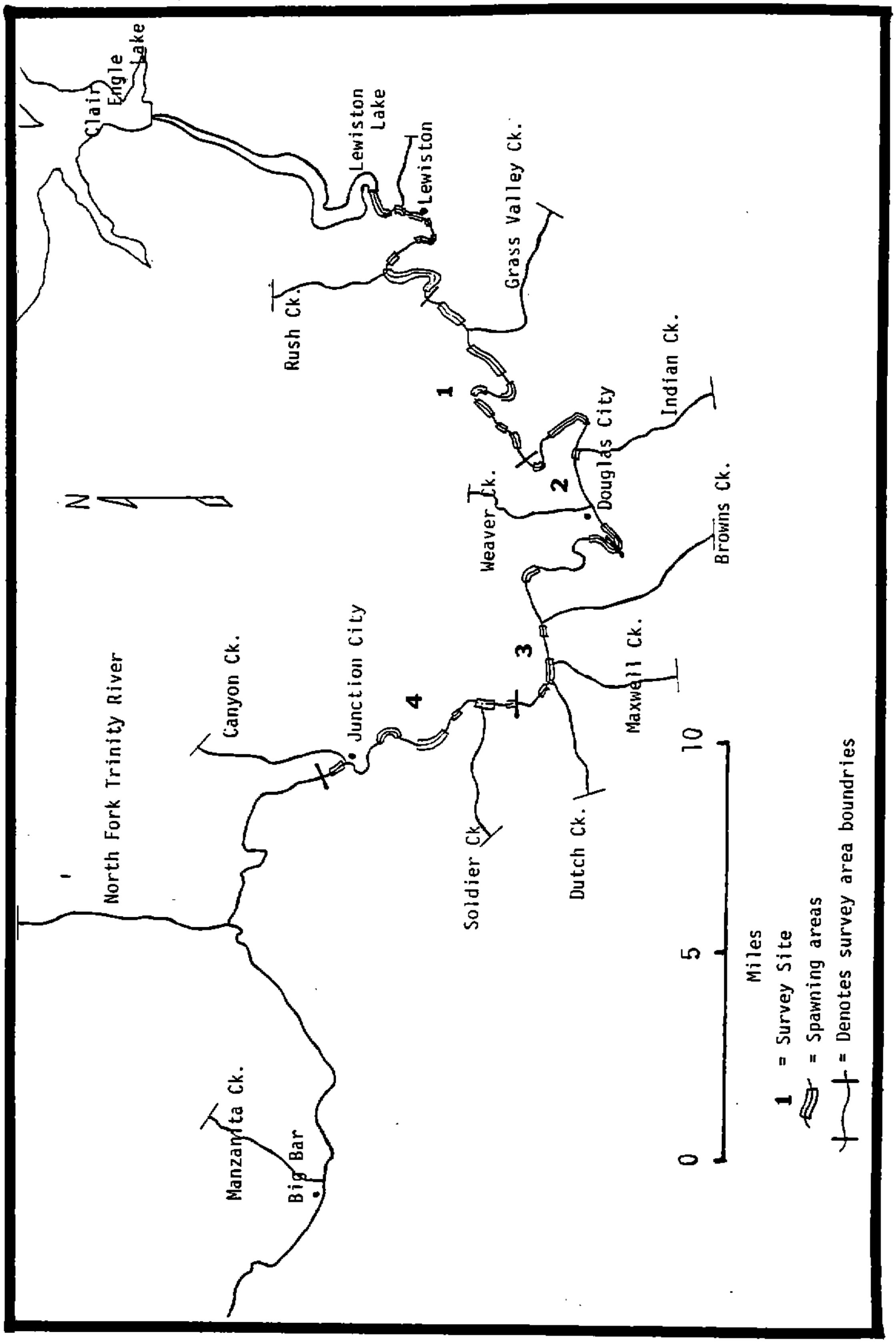


Figure 1. Spawning areas used by chinook salmon in the Trinity River, CA., 1986.

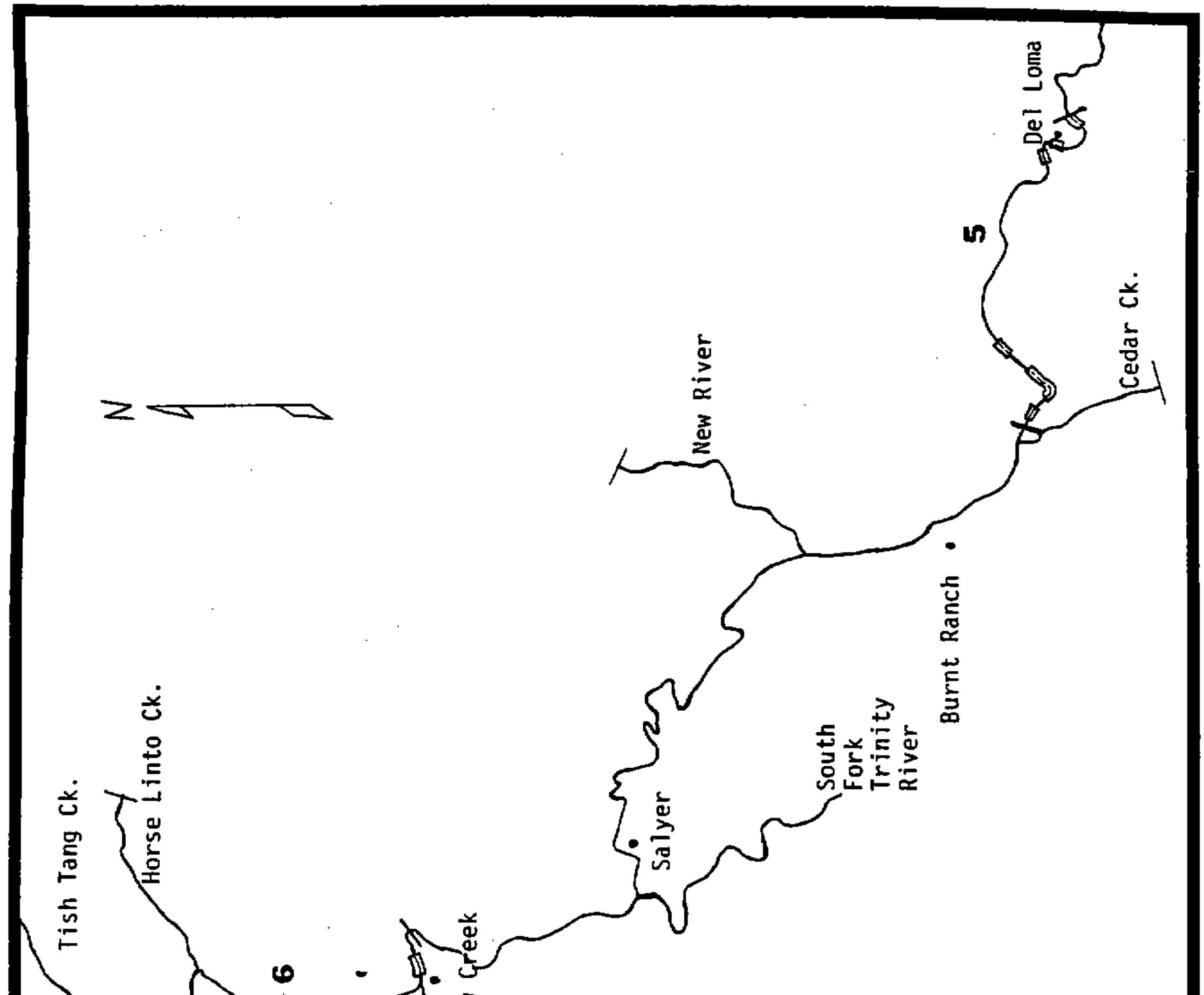


Figure 1. Continued

JUVENILE POPULATIONS

METHODS

In 1987, we continued our underwater observations of juvenile salmonids at the Cemetery, Steelbridge, Steiner Flat, and Junction City study sites. We made observations at the same locations used in 1986, with an additional single-location site below the North Fork at Hayden Flat, and used essentially the same diving and data-reduction methods (USFWS, 1986). Since we found in 1986 that observations made ascending a rope along the bank allowed coverage to midstream, we discontinued cross-river transect observations except on an occasional basis to confirm our observations from the edges.

This year's excellent water visibility allowed us to start observations before fry emergence. We saw no fish at our uppermost site during reconnaissance surveys on December 10 and January 26. On February 20, we saw several small schools of chinook fry along the river margins at the site, and on March 11 we started the observations reported in Figures 1 through 5. We saw only a few coho salmon and steelhead fry or young juveniles this year, and have not reported these sporadic observations.

Figures 1 through 4 show 1987 and 1986 data for each site, and Figure 5 shows a comparison of 1987 data for the four sites combined. Note that the x-axes, showing the date of observation, are not to scale, although observations are of course arranged in the correct time sequence.

RESULTS

It is evident that in 1987 there were substantially more juvenile chinook salmon in the river than there had been the previous year, and that the increase in populations extended at least to Junction City. The first chinook from Trinity River Fish Hatchery, undersized fish stressed by poor conditions in the raceways, were not released until May 5, so our counts through May are entirely of naturally-spawned fish. Normal hatchery releases started on May 26, so our counts from June onward include any hatchery fish we may have encountered.

In the three upper sites, increased chinook densities occurred in all habitat types, but were greatest over gravel bars, and, once fish had grown to about 55 mm, in faster water away from the river's edges. The increase at Junction City occurred in eddying, deep water along a bedrock bank, similar to sample areas at Steelbridge and Steiner Flat that did not show such large population gains, so it probably directly reflects the extension of spawning in 1987 to the lower river.

On May 11 we made an additional observation of the gravel bar habitat at the Cemetery site, setting up a grid with three 100-foot ropes arranged longitudinally down the bar and spaced to allow observation of strips of the entire sample area by three divers ascending the ropes simultaneously. Covering an area 34 feet wide from midstream to the river bank for two repetitions, we counted an average of 1073 juvenile chinook in 3400 square feet, or about eleven chinook per linear foot of river edge. These observations substantiated estimates made over the gravel bar during our regular sampling, and also indicated the high value of gravel bar habitat, even in the absence of cover, to rearing chinook.

This year we added observations at the Forest Service campground at Hayden Flat, just below Del Loma in the middle section of the river. Here we swam a 473-foot strip of edge habitat, consisting in approximately equal proportions of cobble bank, cobble bank bordering a backwater, and sand shoal. We did this because we saw numerous chinook redds immediately upstream from this area, and elsewhere in the middle river down to the highway bridge at Cedar Flat, and wanted information on the success of this spawning. Results are shown in Figure 6. The fish here were small in comparison to the downstream migrants which appeared midstream in this area around late May, and were evidently holding and rearing where we saw them. Our previous diving and electrofishing below Junction City had not indicated the presence of rearing fry and early juvenile chinook, and we assumed that these fish were produced by local spawning, which in the previous year had not been significant.

FINDINGS

Several things are noteworthy about these results.

First, there were from about four to eight times as many fry and juvenile chinook in our observation sites in the spring of 1987 than there were in 1986. River flows may have had a large effect on this, because the high water during the emergence period of 1986 may have washed many fry downstream, and the comparatively high water after mid-March in 1987 provided better rearing habitat in some areas. But the great increase in spawning escapement in the fall of 1986 was probably a major cause. The increase indicates that rearing habitat has been under-utilized, and that, as common sense would indicate, an increase in spawning escapement leads to an increase in fry production.

Second, in 1987 the majority of naturally rearing fish migrated out of the upper sampling areas between mid-April and early May. Substantial numbers of fish, however, continued to rear in the river through early August.

Third, our chinook observations followed the estimates of fry and juvenile chinook habitat provided by our Instream Flow Incremental Methodology studies at the four sample sites (see Figures IV.1.1 and IV.1.2, page 17). Since fish are mobile, and fish populations are never static, it is probably impossible to confirm a direct relationship between available habitat and fish production, and this has spawned an often esoteric controversy among fishery biologists on the usefulness of hydraulic habitat modeling (for example, see EPRI, 1986). It is encouraging to note that, given the necessary methodological imperfections in monitoring species that are constantly moving through an environment that is constantly changing, the rearing chinook we saw in the Trinity River in 1987 stayed where the model showed the most usable habitat area to be.

Fourth, even with this year's dramatic increase the natural production implied by our counts is small in relation to hatchery production. The average of our highest population counts at the upper three sites, 3.31 chinook per linear foot of river edge, would produce about 1.4 million fry if it occurred in the 40 miles of river between Lewiston and the North Fork, compared to about ten million hatchery fry released this year.

We made a literature search this year and found that references on observed area densities of rearing chinook are unavailable, so we do not know how the Trinity compares with other rivers. All available numeric population data to date is from migrant trapping, usually of mixed natural and hatchery stocks, which provides no indication of local habitat use.

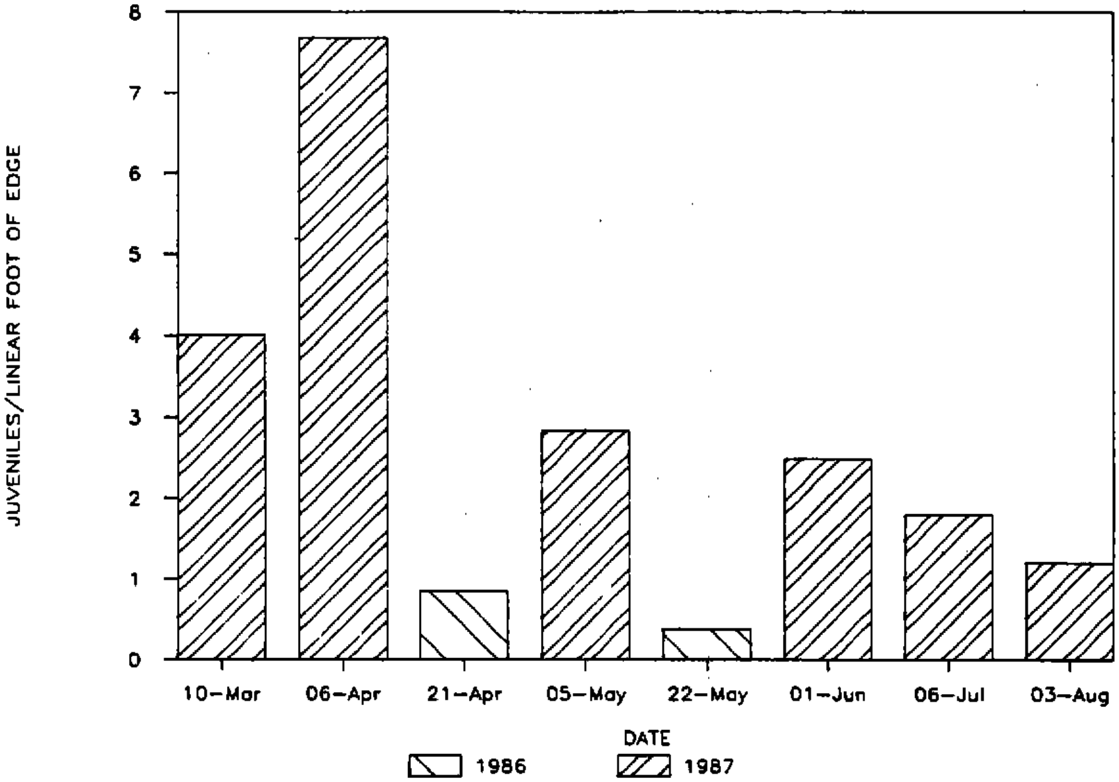


Figure 1. Chinook rearing populations at Cemetery site, 1987-1987.

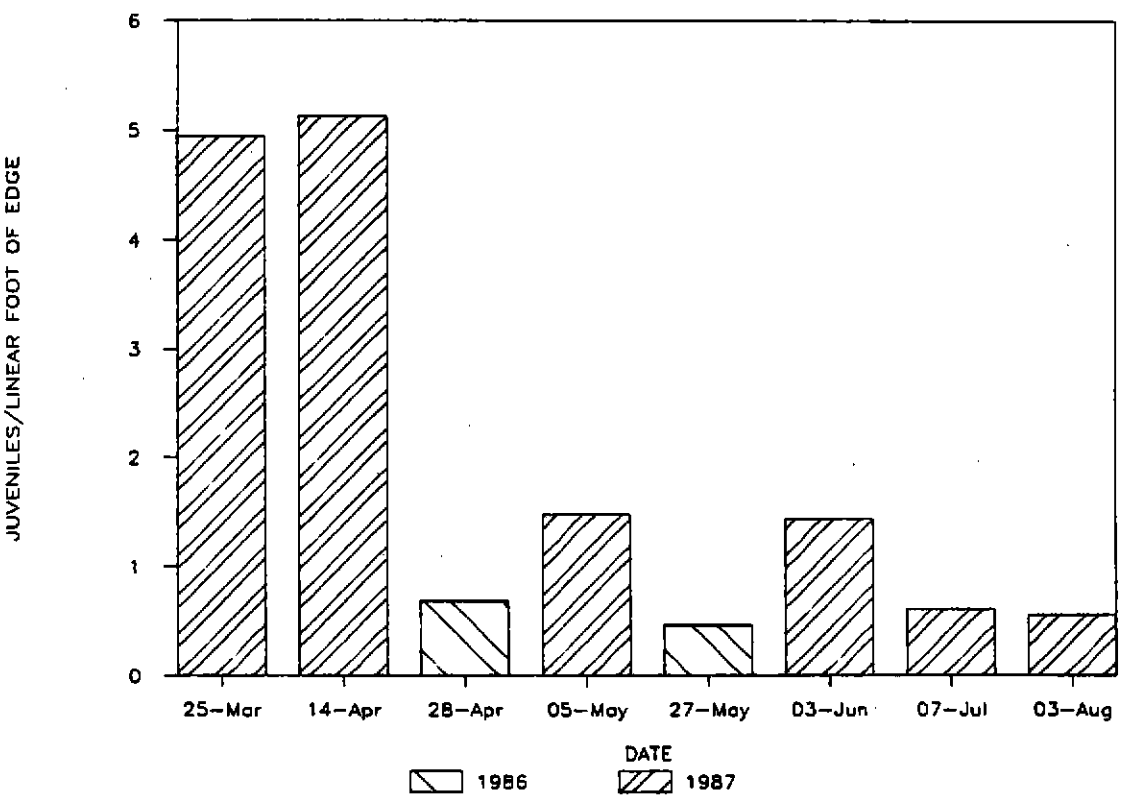


Figure 2. Chinook rearing populations at Steelbridge, 1986-1987.

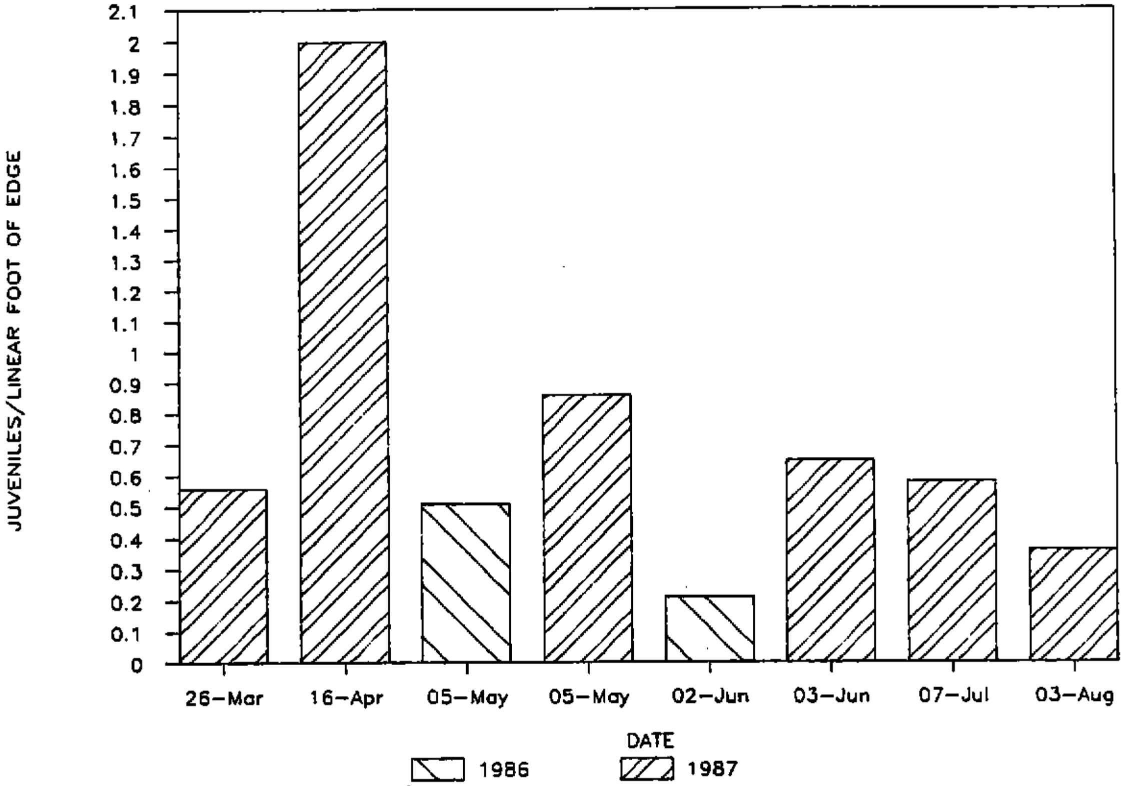


Figure 3. Chinook rearing populations at Steiner Flat site, 1986-1987.

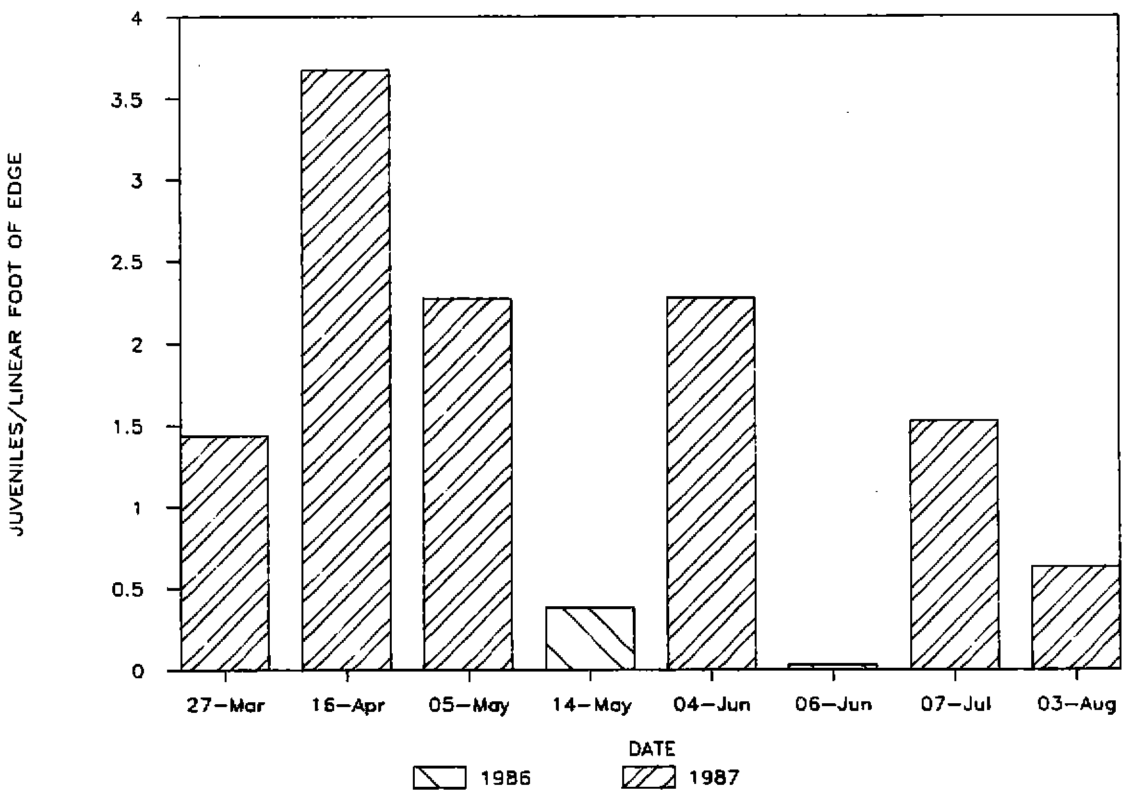


Figure 4. Chinook rearing populations at Junction City, 1986-1987.

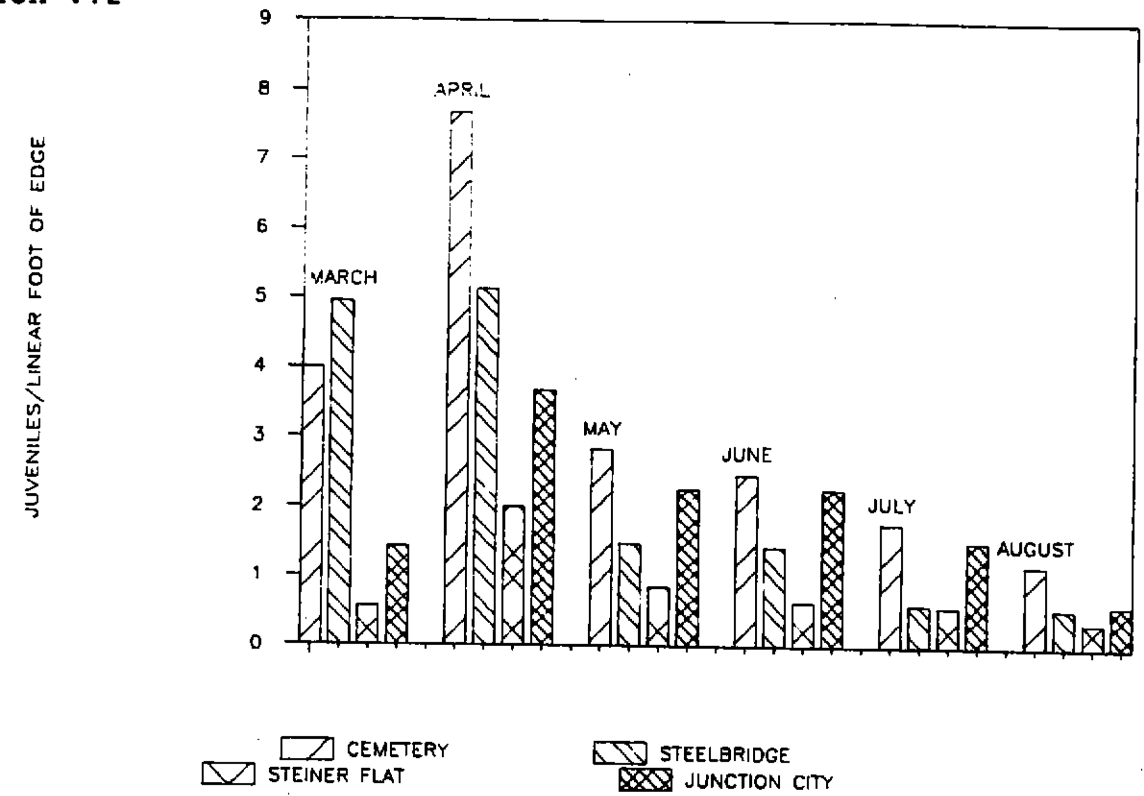


Figure 5. Chinook rearing populations at four sites above the North Fork Trinity River, 1987.

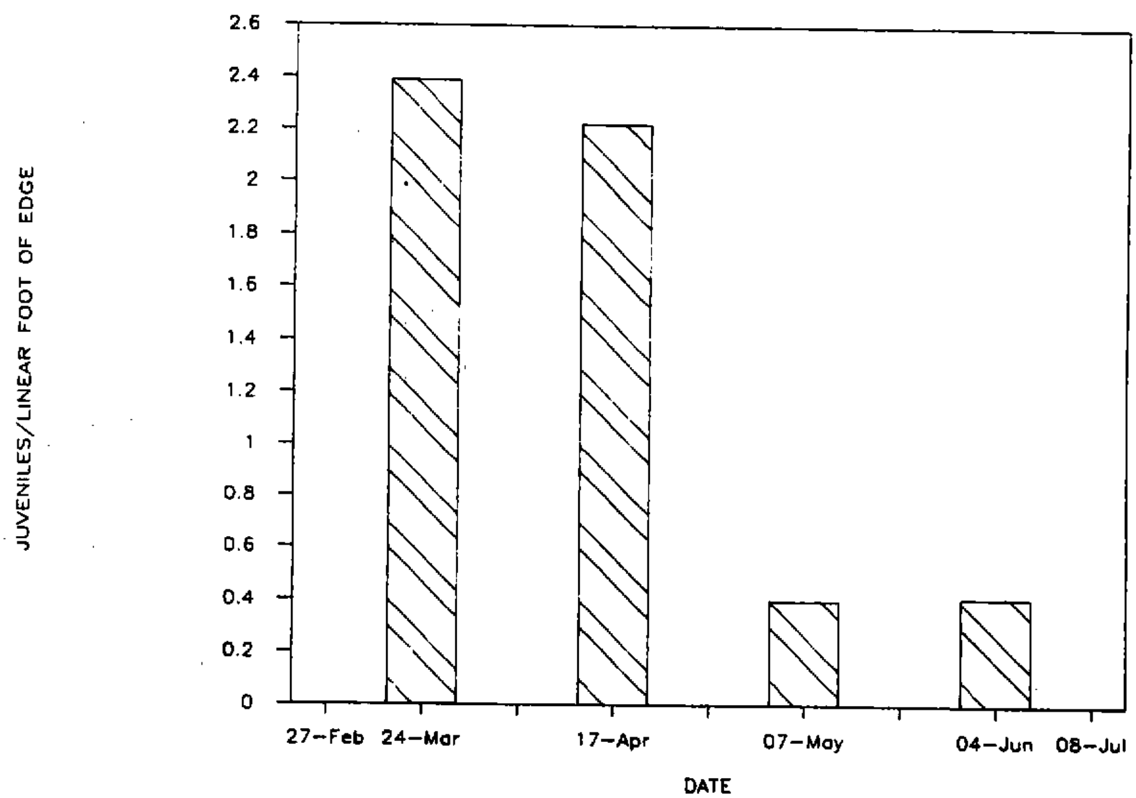


Figure 6. Chinook rearing population at a site near Del Loma in the Trinity River, 1987.

FRY EMERGENCE AND SURVIVAL

To add to our knowledge of the survival of salmonid eggs, in-gravel sac-fry, and young juveniles, we devoted a moderate portion of our 1987 resources to trapping emerging fry, and we increased our monitoring of early life stages to include middle-river areas where substantial spawning occurred for the first time in many years.

TRAPPING METHODS

As in 1986, we maintained a riffle trap in the tail-race of the Sawmill site hatchery rearing ponds, where the extent of spawning was known, and production could be measured from a limited area. However, the use of the rearing ponds for incubation of hatchery stock, and leakage of hatchery fish into the tail-race at the earliest stages of development, rendered the effort useless.

We also set riffle traps at the top and bottom of a small, semi-isolated side-channel located at the Cobb property on the left bank of the river about a quarter of a mile below Rush Creek, just below the outfall from the new Ambrose rearing ponds. This side-channel is 15 feet wide and 125 feet long from its divergence from the main river to a riffle that marks its end. There is some intermixing of flow between the main channel and the side channel through its lower 50 feet, and fish can pass between the two systems.

Although the situation for sampling production was far from perfect, the manpower cost of a small-scale trapping study was low, so prior to fry emergence we set a riffle trap at the top end, and one at the lower end of the side-channel. Our purpose was to use the upper trap catch as an indication of the number of fry entering the side-channel, and the lower trap catch as an indication of the number of fry produced by any spawning that occurred within the channel.

TRAPPING RESULTS

Chinook salmon spawned heavily in the lower half of the channel in October and November, and in the third week of February brown trout spawned at the apron of the lower trap, spilling chinook eggs and gravel into it. Despite the confusion of superimposed spawning, it was still evident that the site had accommodated four to five chinook redds. Emergent chinook fry began to appear in the trap in January.

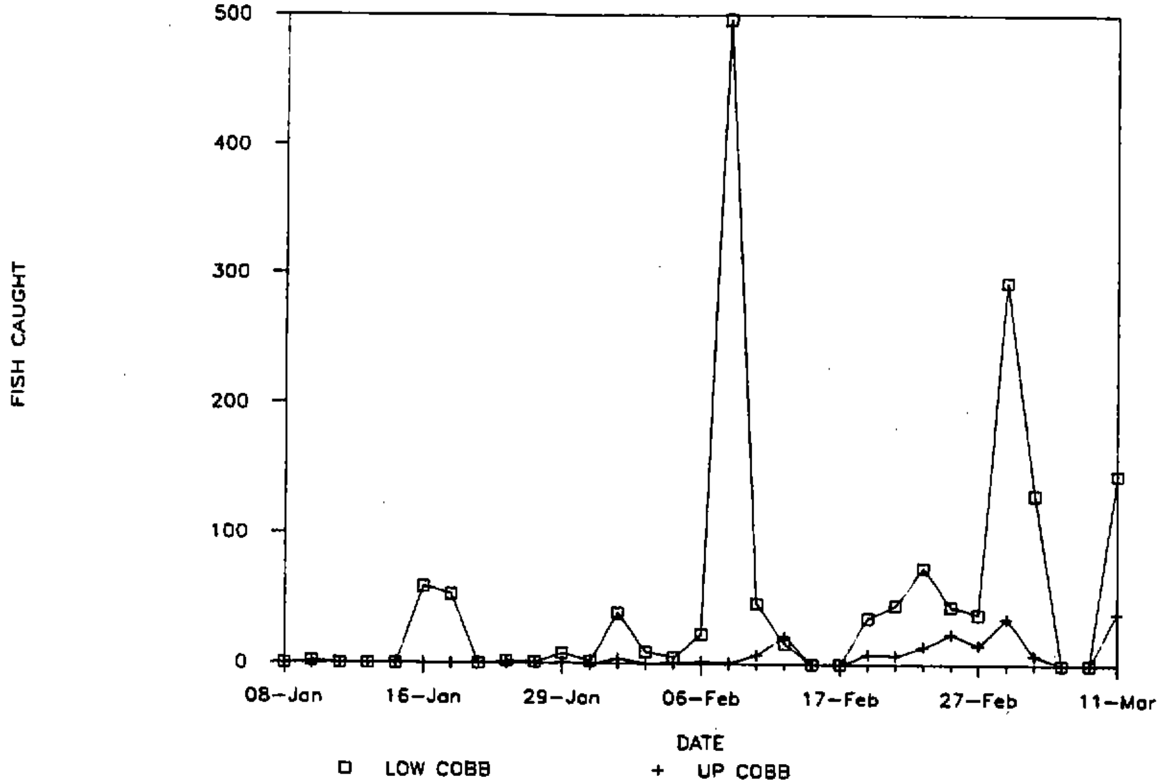


Figure 1. Chinook fry caught over five-day periods in two riffle traps in the upper Trinity River during the 1987 emergence season.

The numbers of chinook caught over five-day periods from early January until mid-march, when it became obvious that substantial numbers of fry from the Ambrose ponds had started leaking into the main river, are shown in Figure 1. Introduction of fry to the Ambrose ponds was completed on March 13, and the catch before that consisted of naturally-produced fish.

A total of 1573 chinook fry were caught in the lower trap, and 191 were caught in the upper trap, for a difference of 1382. If we assume that any lateral movement into or out of the sampling area was random, and that the traps were 100 percent efficient for the fifth of the side channel they spanned, this number is a conservative minimum estimate of the average number of fry produced by each of the five redd areas in the side channel.

Our IFIM estimation of weighted usable spawning area (pages 14-25) extrapolated by study reaches, indicates that there are 685,914 square feet of usable spawning area above the North Fork. At a conservative estimate of 100 square feet per redd, this is enough for 6859 redds, or about 9.5 million fry at 1382 per redd.

Nine and a half million fry would result in population densities over five times the highest average density of chinook fry we found in our population sampling (pages 65-

70), and over twice the highest density we counted in any one area. The discrepancy could be accounted for by the lack of precision in feasible sampling methods, or by immediate downstream migration by a substantial proportion of emerging fry; or it could be that chinook production in the upper Trinity River under current conditions is limited by a lack of adequate fry rearing habitat.

DIVE METHODS

We observed intensive spawning in the area between Del Loma and Cedar Flat on November 24, 1986, with the highest density of redds at the right edge of the run above the Forest Service campground at Hayden Flat. To get an idea of whether this middle-river spawning was successful, we started a series of mask and snorkel observations in a 473-foot length of evidently good chinook rearing habitat at the top end of the campground, just below the area of most-intensive spawning use. The site consisted of equal proportions of cobble run with low velocities near the bank, cobble run bordering a still back-water, and sandy pool shoaling to the water's edge.

We sampled by drifting downstream adjacent to the bank, maintaining a count of the numbers of fish observed; we also swam the length of the backwater, quartering back and forth to observe its entire area. After sampling the edge, we swam down the main channel to the beach at the lower end of the campground, passing through a cobble run and riffle, and two large eddying pools. Water clarity was good, at least ten feet, during all dives.

DIVE RESULTS

During a reconnaissance swim on February 27, we saw no chinook in the area. On March 24, we counted 806 chinook fry, [illegible] percent of them in the back-water. On April 17, May 7, June 4, and July 8, we counted 748, 128, 133, and zero chinook fry respectively, all of them holding and feeding in the slower-velocity areas adjacent to the bank (see page 65, paragraph 3).

The fry we saw along the 473-foot edge area were generally smaller throughout the spring than those we observed rearing at our population observation sites in the upper river. The Hayden Flat fish ranged from an estimated average length of 40 mm in the first observation to 55 mm in the last, compared to an estimated 45 to 65 mm in the upper river. We never saw fry in the main cobble channel adjacent to the edge site, or in the run and riffle below. During our May and June surveys, we saw substantial numbers of chinook juveniles averaging about 70 mm in length in the pools below the riffle, and supposed that these were migrants from upper river populations and from hatchery releases.

The fall of 1986 was the first time we observed substantial chinook spawning below Junction City, and it had not occurred for many years. In the 1985 rearing season we never saw chinook fry in potential rearing habitat below the North Fork, nor did we catch them in our electrofishing and seining surveys. Therefore, it may be reasonable to assume that the fry we saw at Hayden Flat were produced by spawning in the area, and that in the past the concentration of limited spawning populations in the upper river led to an under-utilization of lower river rearing habitat.

DOWNSTREAM MIGRATION

In 1986 we continued to monitor riffle traps set near the river's edge to obtain additional information on migration timing. We also made a series of night mask and snorkel counts to see if this was a feasible means of monitoring the downstream migration of chinook juveniles.

TRAPPING METHODS

We set a two-by-three-foot box trap, fed by a three-foot wide eighth-inch mesh fyke net, on a gravel bar in the Steelbridge Road area, and checked it at two- to three-day intervals from early January until this fall. We also fished several three-foot metal ramp traps in side channels and riffles adjacent to the Ambrose and Cobb properties just below Rush Creek, and a similar trap in the outfall of the outpost hatchery rearing ponds at the old sawmill at the end of Cemetery Road in Lewiston. The Cobb traps provided useful data until mid-March, when they began to catch fry escaping from the new Ambrose rearing ponds (page 72). The sawmill or cemetery trap proved useless, since chinook eggs from the hatchery were incubated there, and fry probably began leaking out of the ponds concurrently with natural emergence.

TRAPPING RESULTS

The chinook catch from the Steelbridge trap is shown in Figure 1. Fry began appearing in the second week of January, and and continued to be numerous until mid-May, when many downward-moving fish had moved offshore into swifter water. From January 9 to July 14, a total of 2345 young chinook were caught, with insignificant numbers appearing after that.

On April 10 we made night-time mask and snorkel and bank-side observations around the trap and for several hundred feet upstream, and saw no major movement of fish down the edges of the river, although almost all of a heavy chinook fry population was concentrated within five feet of the bank. We saw many more chinook than were caught in the trap. It appears that chinook fry, prior to mid-May, tend to drift imperceptibly down the river edges, holding focal positions that end up lower in the river each morning.

Counts of other fishes caught are shown in Figures 2 and 3. The low numbers of steelhead correspond to observed lower populations in the river. However, steelhead, along with coho salmon, and brown trout do not generally migrate downstream as fry, and so are not as susceptible to trapping.

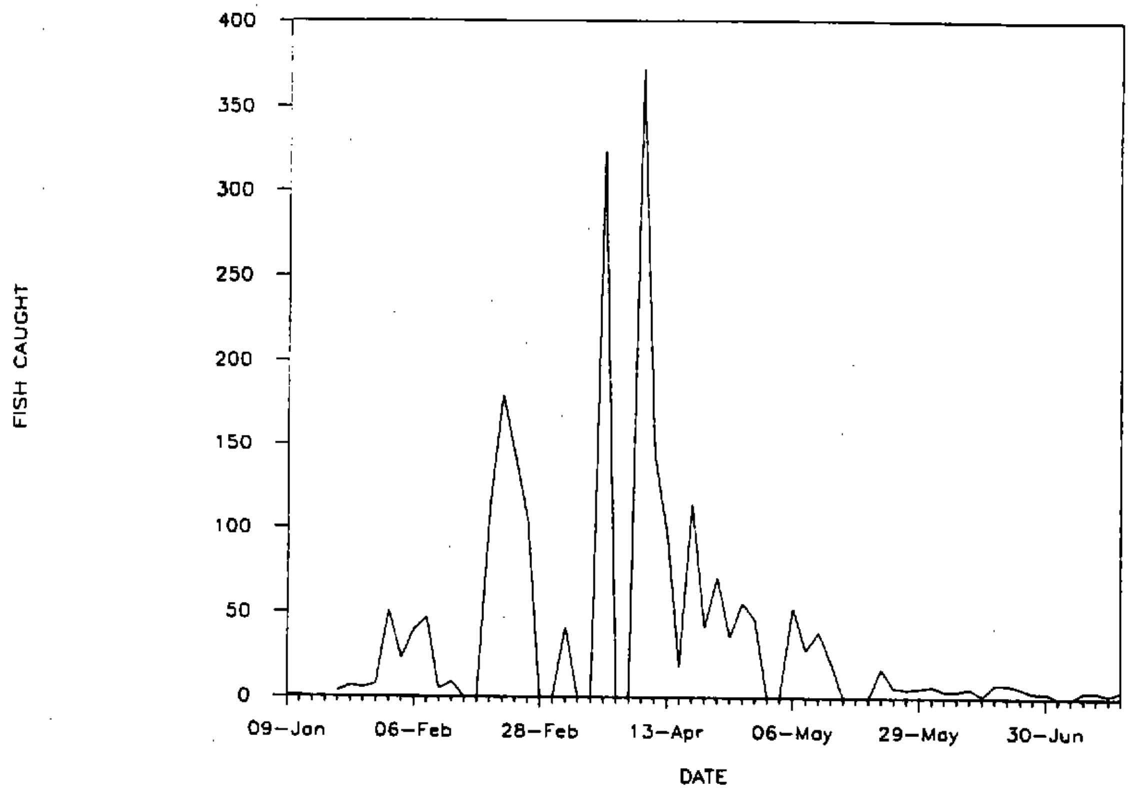


Figure 1. Chinook caught over five-day periods in a trap at Steelbridge, winter to mid-summer, 1987.

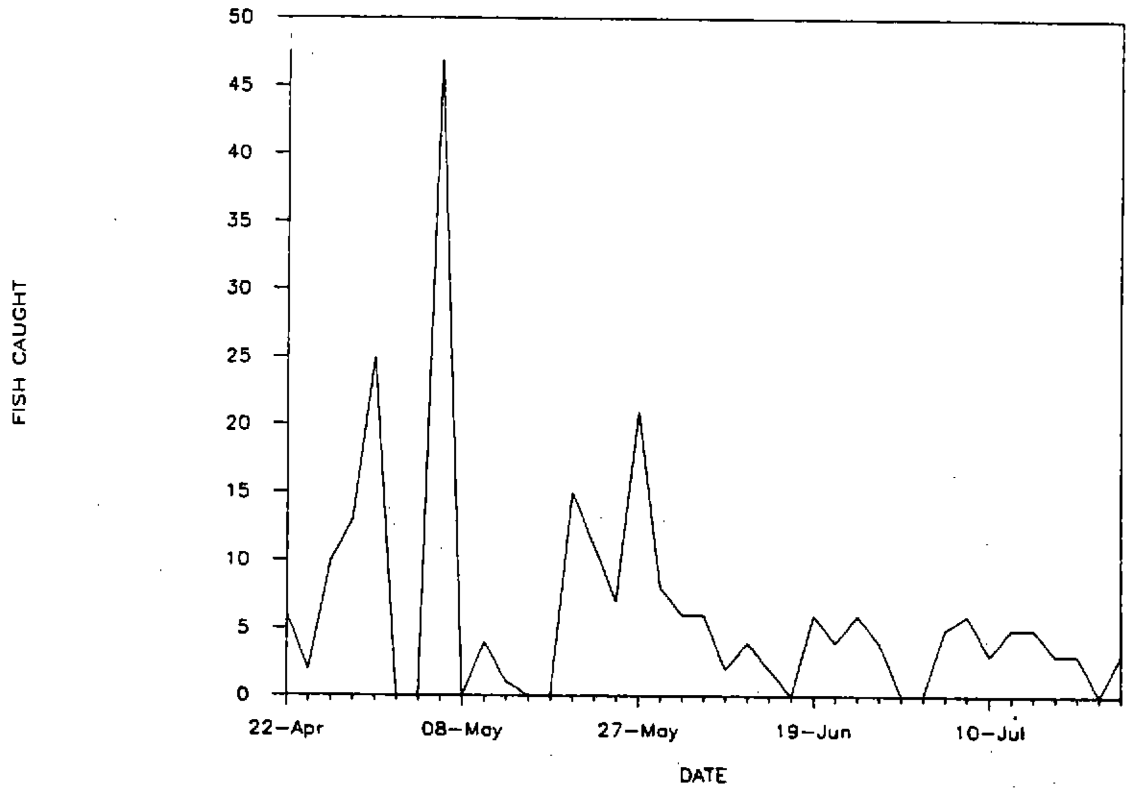


Figure 2. Steelhead caught over five-day periods in a trap at Steelbridge, winter to mid-summer, 1987.

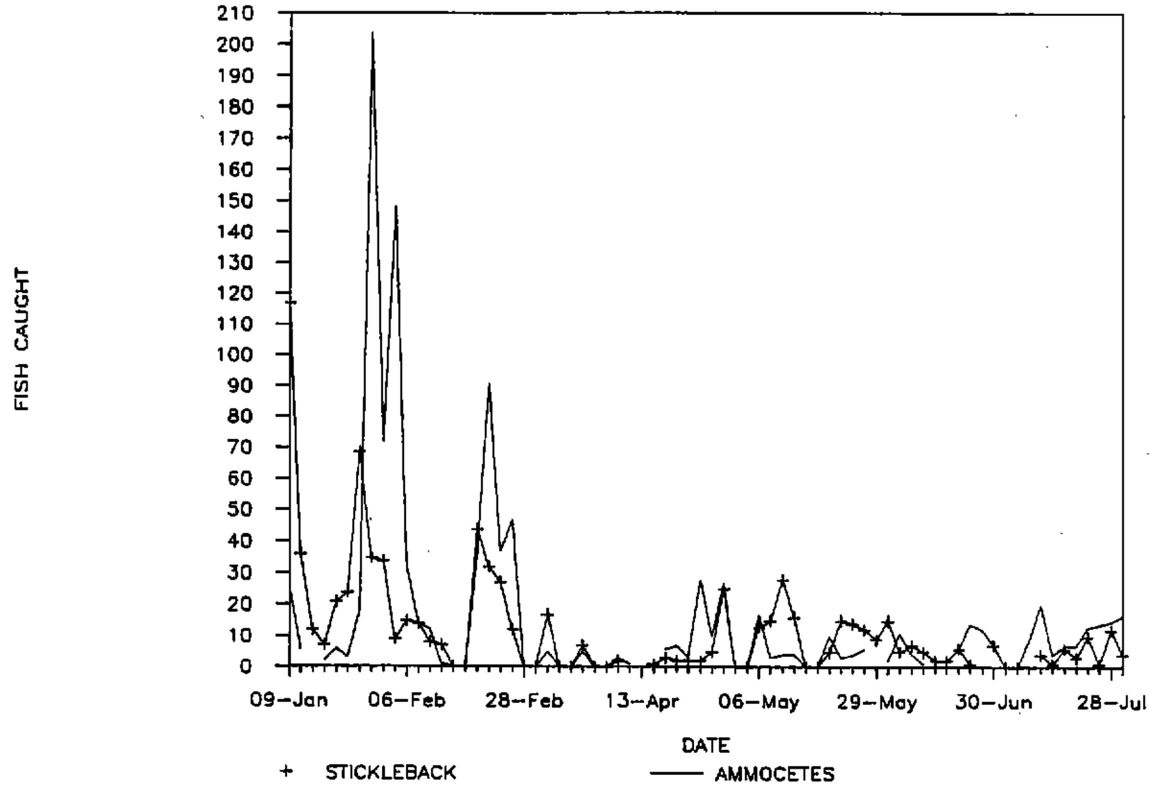


Figure 3. Lamprey larvae and stickleback caught over five-day periods in a trap at Steelbride, winter to mid-summer, 1987.

Two species showing up consistently in all our traps were larval lampreys and three-spine sticklebacks. Lampreys, native to the Trinity, constantly dribble downstream through the system, as we noted last year. The sticklebacks, which were introduced to the upper river accidentally in recent years, show up in bunches in our traps, probably because they often move in schools. Their number seems to be growing in the upper river, compared to the past two years. Anyone diving in the area will encounter vast numbers of them, and it is obvious that they are doing well.

DIVE METHODS

On the night of June 24, 1946, fishery biologists James Moffett and Stanford Smith anchored a raft at Lewiston and by lantern light counted 47 juvenile chinook moving downstream through a ten-foot wide section across the Trinity River (Moffett and Smith, 1950). From this they estimated 188 downstream migrants per minute across the entire river, which would be about 67,680 in the six hours of darkness in late June. This seems to indicate that naturally reared Trinity River chinook once migrated out en masse, and we wondered in 1987 if the phenomenon still occurs.

Lacking the resources for a full-scale trapping study, we decided to repeat Moffett and Smith's method in 1987, using under-water observation, and repeating counts to get an idea of sampling variability. Our method was to tension a static rope across the river with climbing gear and rescue pulleys, and have divers cling to it while counting fish crossing the beam of a hand-held underwater spotlight. Each count was made by two or three divers observing for five-minutes periods, for as many repetitions as seemed reasonable in the cold water.

DIVE RESULTS

We first tried this method on April 11 from 9:00 to 10:00 pm at a run adjacent to the residential area along the right bank at Steelbridge road. The river here was fairly homogeneous, running about 2.5 to 3.5 feet deep, with a moderate current, and affording visibility of about six feet. We saw no fish while hanging from the transect rope, but both margins of the river for several hundred feet up and down-stream had heavy densities of chinook fry, holding at depths from about four feet where banks were steep to about an inch at shoaling edges. The densities seemed comparable to the highest seen in day-time population sampling, around eight to ten fish per foot of bank.

The chinook, which ranged in size from sac-fry of about 34 mm to 60 mm juveniles, clustered within five feet of the river bank. In the the faster water beyond the influence of the edge there were hatchery steelhead measuring up to about ten inches, and in pockets of still water there were a few three- to four-inch coho. Three-spine sticklebacks were lined up along the bottom in the shear zones at the edges of the main current. Almost all the chinook held close to or on the bottom, moving only when a light was flashed on them, and showed no tendency to move downstream.

The next time opportunity to make night observations was June 3, again at the Steelbridge site. By then, over 2.4 million hatchery chinook had been released at Lewiston. The edge populations were greatly diminished, but many chinook were coming downstream at the speed of the current. Evidently, many of the naturally rearing fish had either left the area, or were moving out during the night to join the migrating swarm of hatchery juveniles. Six five-minute were made by two divers each. Counts ranged from 12 to 54 fish, and averaged 29. With six feet of visibility, the count extrapolated to the entire transect was 31,500 over the approximate seven hours of darkness.

Once it became apparent that there was no way to distinguish hatchery-reared from naturally reared fish, we realized that we were making a a one-night examination of a migration that might not be consistent over several nights. The hatchery fish had been released in batches of 176 to 567 thousand, and the numbers of migrants probably varied widely from night to night, so that any natural pattern could be masked by the clumped release distribution. We decided to continue sampling as far downstream as possible, where the spatial distribution would be more even, and where an estimate of how many hatchery chinook might be surviving the upper river could be made. So the next night count was made at Evans Bar, 25 miles below Lewiston, on June 11. Any fish passing this site had also passed the reaches considered most affected by recent habitat degradation, and had a good chance of making it to the ocean.

The river at Evans bar flows in a trapezoidal channel, and on June 11 was 2.5 to 3.5 feet deep, with a velocity of 3.4 to 3.8 feet per second. We made thirty five-minute counts, in sampling periods starting at 10:00 pm, 11:47 pm, 2:00 am, and 4:00 am.

The mean number of fish counted per foot of transect was 14.7, plus or minus 3.5 at the 95 percent confidence level. Extrapolating to the 85-foot river width, this equated to about 90,000 fish over the six hours of darkness, give or take 24 percent.

We had thought that chinook might migrate downstream mostly at dusk and dawn, but our observations showed this to not be the case. A Kruskal-Wallis Test (Sokol and Rohlf, 1981) showed no significant differences in the populations observed during each sampling period.

At Evans Bar we confirmed an observation we had made at Steelbridge the previous week, that downward migrating chinook all kept to within about six inches of the surface. Thus, a floating inclined-plane trap would be an effective way of sampling seaward migration.

We also made two seine hauls, at 9:30 pm and 1:00 am, at a cove above the transect site, but with inconclusive results. Our purpose was to determine the relative numbers of hatchery and natural fish in the migration, but no size patterns were evident among the 102 chinook caught in the two hauls, and no marked fish were found.

Three more night counts were made at Evans Bar. On July 1, starting at 10:00 pm, we made ten individual counts and estimated approximately 30,000 juveniles crossing the transect. On July 23, we counted a total of nine fish in six counts, for an estimated 918 fish overnight. On August 8, we observed for eight five-minute periods and estimated about 2800 fish crossing the transect, some of them probably coho that had been released by the hatchery.

FINDINGS

From May 6 to June 28 approximately ten million chinook fingerlings were released from the Trinity River Fish Hatchery and from the Sawmill and Ambrose rearing ponds, and an unknown number of naturally-spawned fish went downstream with them. Dividing by a liberal 60 migration days, there would have been an average of about 166,000 hatchery fish moving out per night, if they all survived the upper river. Our high estimate, a sample taken under good conditions at the height of the release season, was 90,000.

We have never seen many dead juveniles in the river, and observed incidents of predation are extremely rare, so the fate of the uncounted thousands of hatchery fish is unknown. The spatial distribution we observed in sampling, while bi-modal and clumped within modes, was not so clumped as to indicate wide variations in migration densities, but instead indicated that once night falls the fish tend to spread out and move down at random.

Two possibilities, other than mass mortality or errors in observation, exist. The first is that fish migrate down following some influence we did not take into account, such as the phase of the moon, or some temporal key. The second is that they continue to migrate through daylight hours, but manage to avoid traps and observation. We have seen some hatchery fish migrating downstream during day observations. They keep in tight schools, and move swiftly between eddies and edge pockets, where they hold for a moment before moving on. This daylight migration has never appeared significant compared to the large numbers of hatchery fish that hold in pools, but perhaps this is because it is difficult to see.

In 1946, the one year for which we have data, a mass down-stream migration of natural chinook juveniles occurred in June. Comparison of hatchery releases with our observations does not indicate that a similar phenomenon occurred in 1987. It seems that natural fry production, following the intensive spawning of the fall of 1986, was low compared to what the river produced when it was relatively pristine.

JUVENILE SALMONID GROWTH

INTRODUCTION

In 1987, we continued to sample juvenile trout and salmon throughout the river to determine their growth patterns, as an aid to understanding population characteristics and life history patterns of Trinity River salmonids. Sampling, which began in January of 1986, is expected to continue throughout the term of the Trinity River Flow Evaluation.

STUDY SITES

Nine study sites were selected on the Trinity River from Lewiston downstream to Tish-Tang Two study sites, Cemetery and Bucktail, are located on the upper river above Grass Valley Creek. Three study sites, Steelbridge, Steiner Flat, and Junction City, represent the upper river below Grass Valley Creek. The middle river section is represented by a single study site at Del Loma. The lower river segment begins below the confluence of the South Fork Trinity River and is represented by a study site at Tish Tang just south of the Hoopa Valley.

METHODS

At each study site fish were collected with a Smith-Root DC backpack electroshocker. Sampling was always conducted in an upstream direction in riffle or run microhabitats within each study site. One person operated the electroshocker, while a second person followed behind to capture shocked fish with a dip net. Once captured, fish were anesthesized with methyl-tricaine sulfate, measured for forklength and weighed on a dietetic 500 gm scale. No data was collected on clipped fish or any fish believed to be of hatchery origin. At the beginning of the study fish were weighed on a triple beam balance to the nearest 0.1 gram. A cardboard wind shield was used to shelter the balance from adverse weather conditions; however, this proved to be ineffective in many cases, and the triple beam balance was used only on a limited basis under ideal conditions.

Scale samples were mainly taken from the area on the right side between the lateral line and posterior end of the dorsal fin of a representative number of fish (figure 2). Scales were removed by gently scraping a scalpel toward the anterior of the fish, and were then placed on wax paper and inserted into coin envelopes for later analysis.

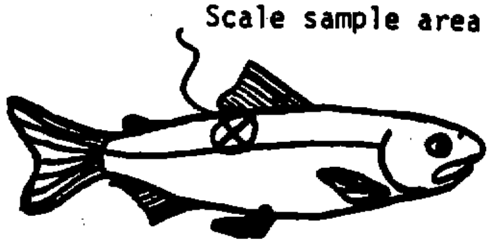


Figure 1: Area where scale samples were taken during growth sampling of juvenile salmonids on the Trinity River, CA. 1986.

Age class determinations for juvenile steelhead and brown trout were made from length frequency histograms and were verified by scale analysis. Instantaneous growth rates in length (Bagenal 1978) were calculated for steelhead and brown trout on a seasonal basis for each age class as follows:

$$G = \frac{\log_e \bar{L}_2 - \log_e \bar{L}_1}{\Delta T}$$

where: G = Instantaneous rate of length increase

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

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

ΔT = The change in time in years

Fulton's condition factor was calculated for juvenile steelhead and brown trout in order to detect possible changes in fitness or robustness through the changing seasons. The following formula was used:

$$K = \frac{10{,}000\ W}{L^3}$$

where: K = Fulton's Condition Factor
W = Weight in grams
L = Forklength in millimeters

RESULTS

Since growth sampling began in January of 1986 a total of 5,738 juvenile trout and salmon have been collected through July of 1987. A breakdown of the total numbers of each species collected is shown in Table 1.

Table 1. Total number of juveniles, by species and sample year, captured in growth sampling from January 1986 to April 1987, Trinity River, California.

	Sample Year	
species	1986	1987
Chinook Salmon	892	1105
Coho Salmon	320	65
Steelhead Trout	1293	1283
Brown Trout	443	337
Total	2948	2790

Table 2. Mean fork lengths of 1986 and 1987 chinook salmon broods by study site and date, Trinity River, CA 1986-87.

	STATION						
DATE	2	3	5	7	9	10	13
1986							
J	39.0		32.7				
F	39.9	37.5	39.6	39.0	38.9	39.6	
M	40.2	40.2	42.3	44.0	45.4	40.5	
A	48.1	42.4	43.8	43.4	41.9	45.4	
M	61.0	59.7		61.3			
J	79.2	79.8	76.7		69.7	48.4	
1987							
J	36.3	37.0	35.4	35.5		37.6	36.5
F	37.7	38.3	44.5		35.0	37.3	38.8
M	38.1	41.3	39.2	42.0	39.1	39.6	
A	44.9	44.4	46.0	45.9	42.9	45.1	43.1
M	48.3	43.0	45.9		54.8	50.5	56.1
J	64.0	52.1	51.0	56.3	63.7	61.2	66.3
J	61.8	60.3	65.4	62.7	55.3	55.0	47.2

The large escapment of adult chinook salmon to the Trinity River during 1986 resulted in much greater fry rearing during the spring of 1987. Increased spawning in lower river habitats during 1986 resulted in a much higher use of lower river rearing areas by juvenile chinook salmon as well. Table 2 provides a breakdown of mean fork lengths of juvenile chinook salmon by date and sample site for both the 1986 and 1987 broods. Figure 2 presents a comparison of mean fork lengths between 1986 and 1987 broods in their respective rearing seasons.

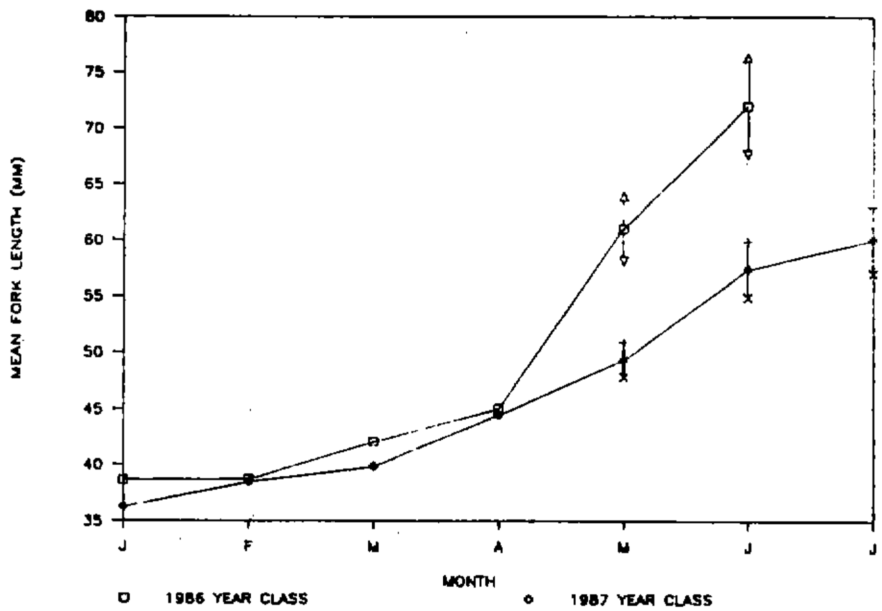


Figure 2. Comparison of mean forklengths (95% CI) of juvenile chinook salmon, between 1986 and 1987 year classes from January to July of their respective years in the Trinity River, CA.

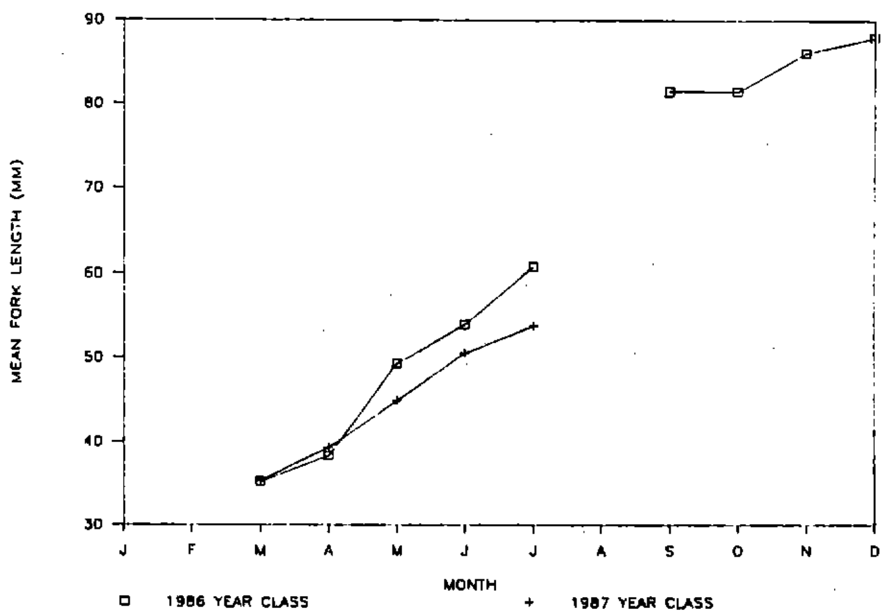


Figure 3. Growth comparison between 1986 and 1987 year classes of coho salmon in the Trinity River, CA.

The total number of adult coho salmon spawners in 1986-1987 was down from the 1985-1986 spawning season. Trinity hatchery recieved 7,648 adult coho in 1985-1986 compared to 2,902

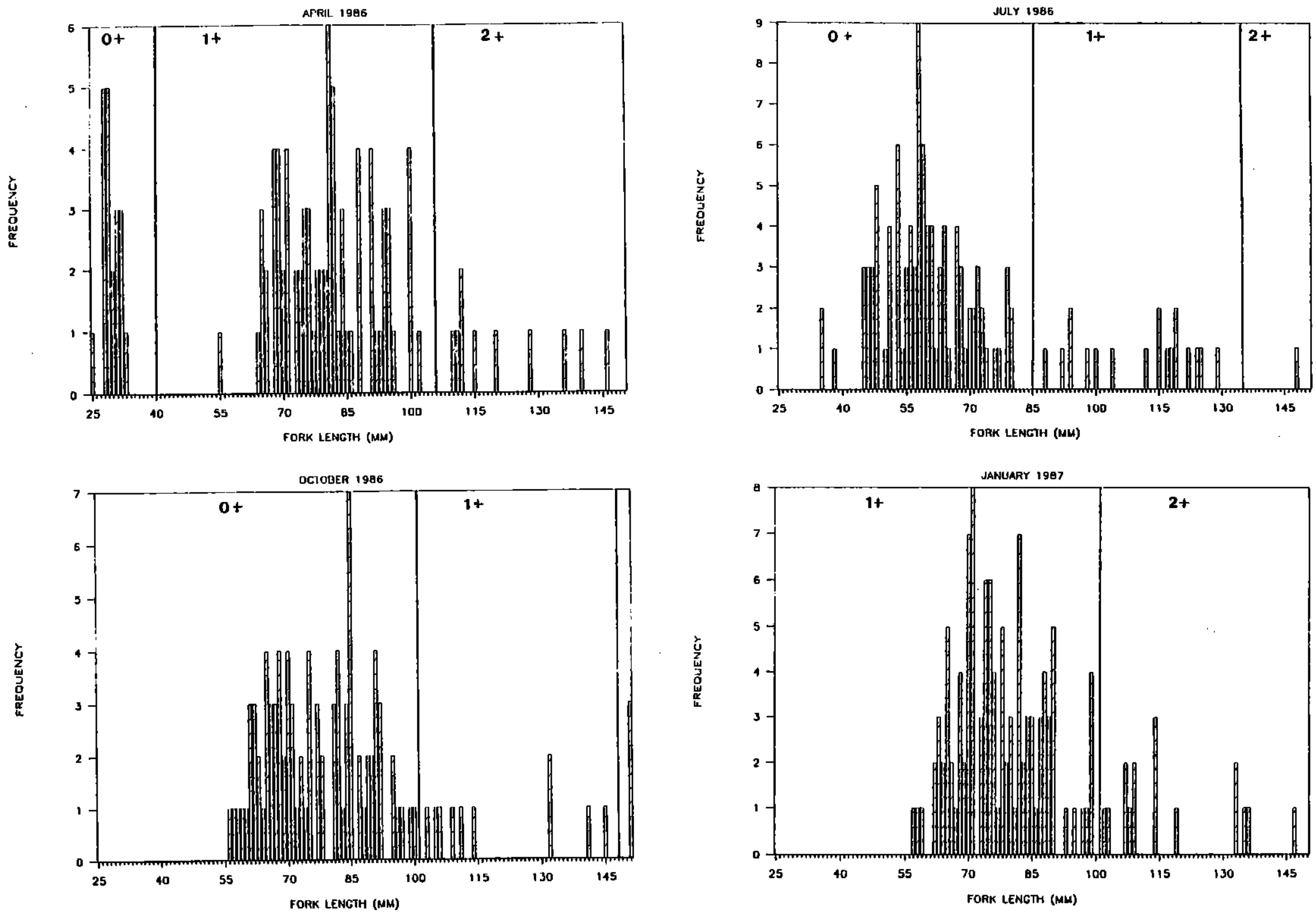


Figure 4. Length frequency histograms and age class delineations for steelhead trout of the Trinity River, CA.

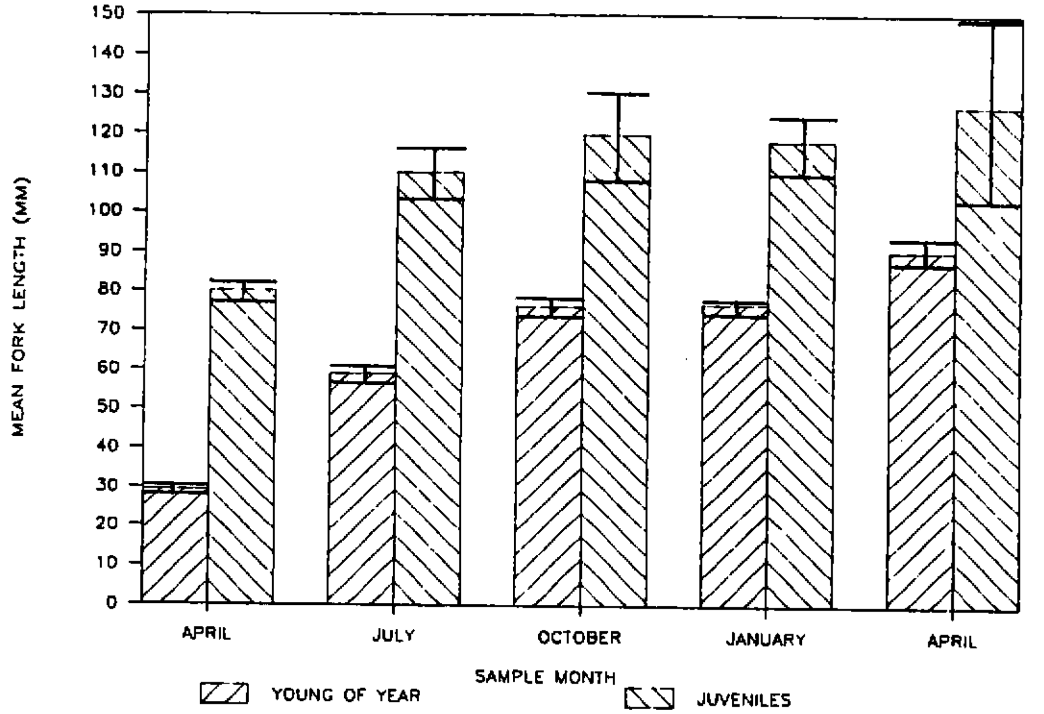


Figure 5. Mean forklengths (95% CI) of juvenile steelhead trout sampled over a one-year period in the Trinity River.

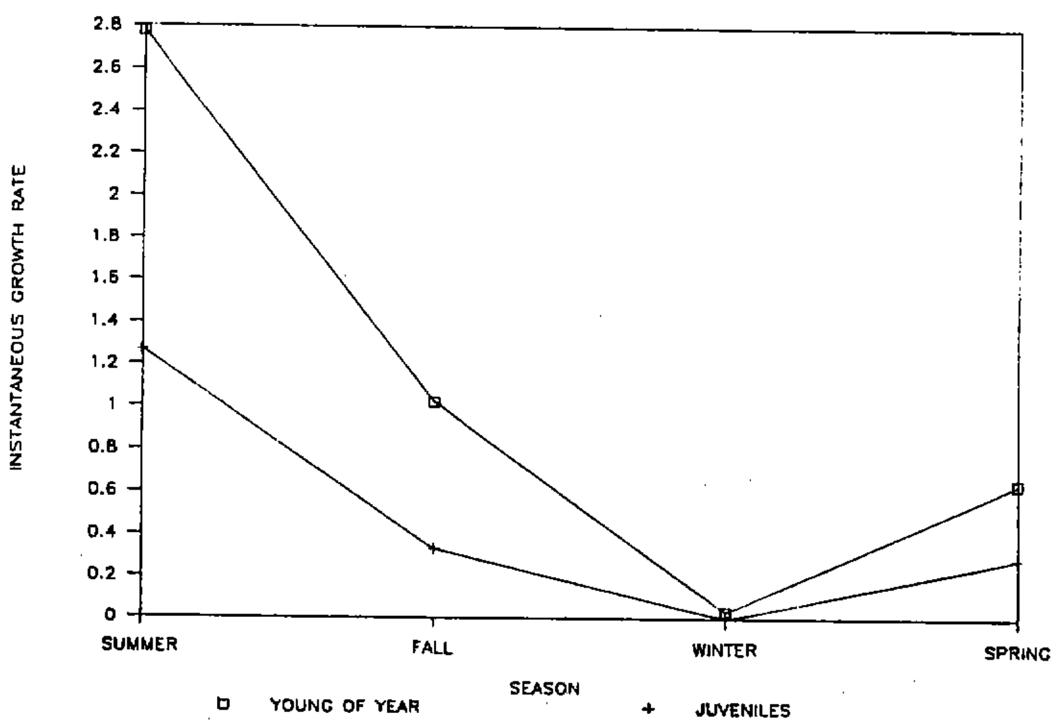


Figure 6. Instantaneous growth rates in length for young-of-year and one-plus steelhead in the Trinity River.

adult coho salmon in the 1986-1987 season. In-river spawning was noticably lower as well. As a result of lower spawner numbers fewer fry coho salmon were captured during the 1987 sampling period. In 1987 fry and juvenile coho salmon were captured only in the upper-most study sites at Cemetery and Bucktail. Figure 3 presents a comparison between mean fork lengths of 1986 versus 1987 brood year classes.

Juvenile steelhead trout are found throughout the river and were captured at all study sites. Fry steelhead first appeared in April of both 1986 and 1987. Data was analyzed on a seasonal basis which included the months of April, July, October, and January. Length-frequency histograms with age class delineations for each month are presented in Figure 4. Figure 5 presents mean forklengths for both 1985 and 1986 brood years over one year of sampling beginning in April of 1986. Instantaneous growth rates in length for the same time period are presented in Figure 6. Mean estimates of Fulton's condition factor, also for the same time period, are presented in Figure 7.

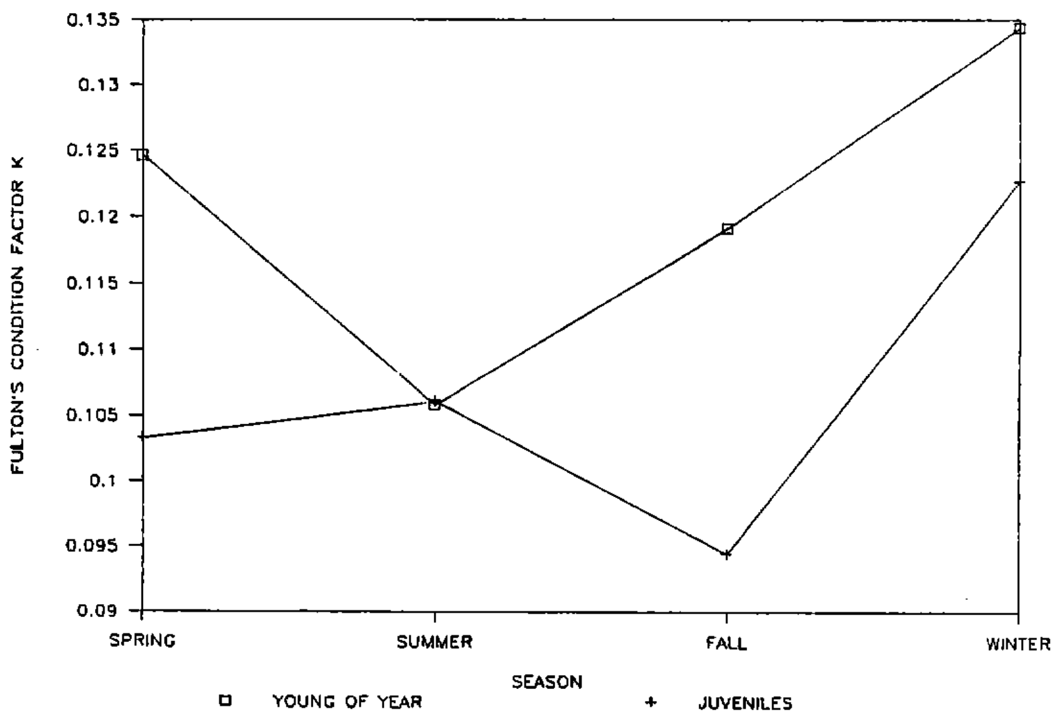


Figure 7. Average condition factors for young-of-year and juvenile steelhead trout in the Trinity River over one year of sampling.

In 1987 juvenile brown trout were found only in the upper river above the confluence of the North Fork Trinity River. In 1986 one juvenile brown trout was captured at Del Loma. During our monthly sampling the greatest number of juvenile brown trout were consistently captured at the upper-most site

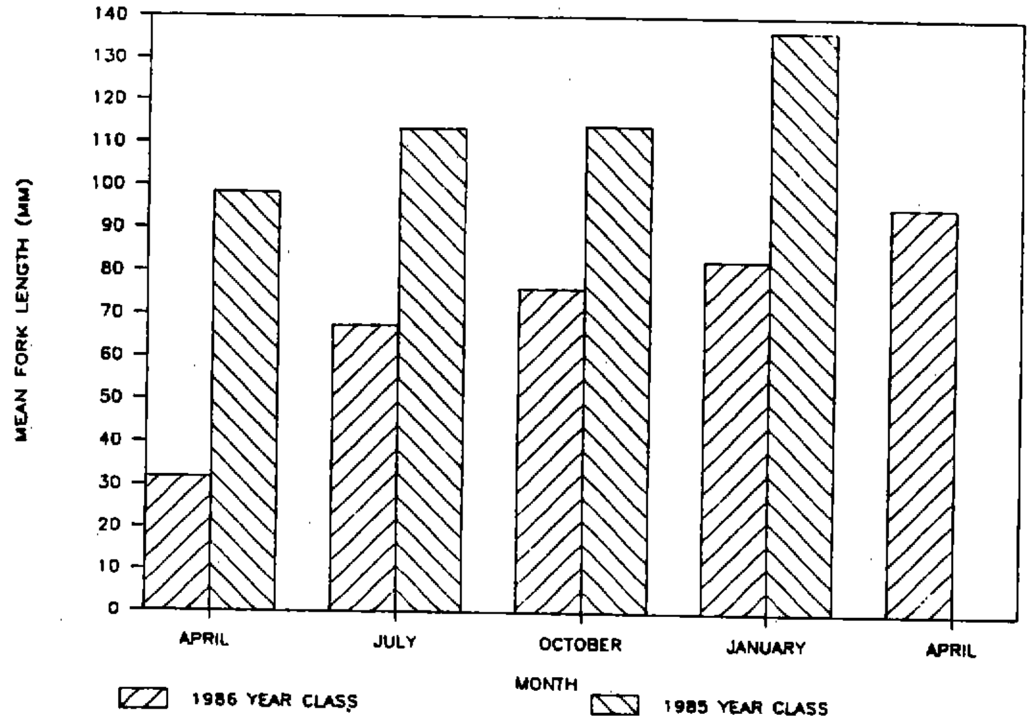


Figure. 8 Mean forklengths of juvenile brown trout sampled over a one-year period in the Trinity River.

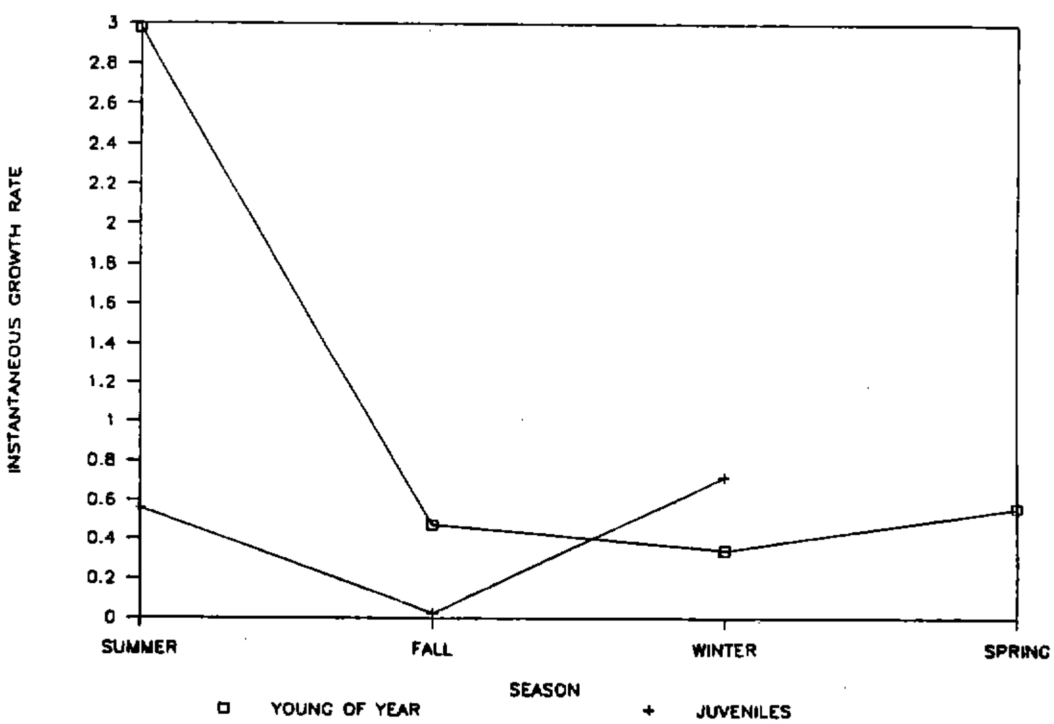


Figure 9. Instantaneous growth rates in length for juvenile brown trout in the Trinity River.

at Cemetery. In 1987, the first brown trout fry was collected in February with the peak swim up occurring in March. Mean forklengths of brown trout age classes sampled from April of 1986 to April of 1987 are presented in Figure 8. Instantaneous growth rates in length for each age class are presented in Figure 9.

DISCUSSION

Juvenile chinook salmon exhibited reduced growth in 1987 compared to the 1986 year class. In 1987, fry chinook salmon emerged from spawning gravels from January until as late as May. The presence of these late emerging fry seemed to have little affect on the overall mean forklengths that were observed as is noticable in the 95% confidence intervals present for that year class. The larger individuals that form the upper range in length for the 1987 year class were at least 6 mm shorter than than those larger individuals from the 1986 year class. This slow growth rate of the 1987 year class may have been caused by several environmental factors.

Reduced water temperatures could be one explanation for slower growth in 1987. However, examination of water temperatures taken during each sampling effort do not indicate any unusual temperature differences between 1987 and 1986. Temperatures taken at the time of sampling are not totally reliable as indicators of mean river temperature, because the measurements are made at varing times and locations dependant on our sampling schedule. An accurate temperature model would provide more conclusive answers as to the possible changes in river temperatures from year to year, providing better insight to temperature-related effects on growth.

Densities of juvenile chinook salmon were four to eight times greater in 1987 than in 1986, based on direct underwater observations made above Steiner Flat (pages 65-71). The greater chinook densities present in 1987 may have begun to exceed the carrying capacity of either the available rearing habitat or invertebrate habitat available at that time. If full production levels of naturally produced chinook salmon are to be established in the Trinity River, it appears that increases in rearing habitat need to be accomplished to accommodate the juvenile chinook salmon that are already produced within available spawning areas.

In 1987 only 65 fry and juvenile coho salmon were captured in our growth samples. The reduced number of coho spawners in the 1986-87 season compared to the previous year may account for the lower numbers of juvenile coho salmon captured. Since the habitat types that are sampled are not optimum rearing habitats for juvenile coho salmon, next year new sample sites will be added to our effort, which should increase our effectiveness. These areas will include more slow water habitat types, side channels and backwaters, where coho tend to be more prevalent.

Coho salmon growth in 1986 and 1987 was similiar during the early part of the rearing season in March and April. However, from May onward growth of the 1987 year class slowed compared to the 1986 year class. Competition from the abundant populations of juvenile chinook salmon for similiar foods may have had an adverse effect upon feeding behavior of juvenile coho salmon in those habitat types that were sampled. Sampling of more representative coho salmon rearing habitats next year should provide better results for comparison.

Growth of juvenile steelhead trout through the year followed a fairly typical pattern. The greatest increases in length occurred from spring to summer, while practically no growth occurred during the winter season when water temperatures were below 45 degrees F. It is interesting that the condition factors were the highest for each age class during the winter. These high condition factors correspond with our food study which found that the mean total weight of food ingested by juvenile steelhead was also higher in the winter samples. It is probable that food items eaten under these cold conditions may be digested over a longer period because of reduced metabolism rates. It should be noted that sampling is done at varying times of the day, and some fish were collected during morning hours when feeding activity is assumed to be high while other fish were collected in mid-day and may not have had full stomachs. This inconsistency probably had some effect on the resulting condition factors.

Table 3. Lengths of steelhead trout in September in northern California streams.

Source	Date	Location	Year	Age	Length
This study	1987	Trinity River	1986	0	72
				1	113
USFWS	1987	Grass Valley Ck.	1987	0	72
				>= 1	130
Pennington	1986	Manzanita Ck.	1974	0	70-80
Barnhart et. al.	1983	Browns Ck.	1979-1982	0	>= 98
Reeves	1979	E. Fork of N. Fork Mad R.	1977	0	61
Cross	1975	Singley Ck.	1969-1970	0	65
				1	105-125
Burns	1971	N. Fork Casper Ck.	1967-1969	0	51-54
				1	106-123

Lengths of juvenile steelhead trout in the Trinity River compare favorably with lengths of juvenile steelhead trout found in other northern California streams (Table 3). By comparing one-year-old steelhead trout in April of 1986 (1985 year class) with one-year-old steelhead trout in April of 1987 (1986 year class) it appears that the 86 year class is slightly ahead of the 85 year class. Rearing conditions for one-plus juvenile steelhead trout may have been improved by the large numbers of fry chinook salmon available as food during the winter and spring seasons. No food stomach analysis was made in 1987 to validate this, but juvenile steelhead trout were often observed actively preying on fry salmon near rearing pond effluents.

Brown trout fry exited the spawning gravels from February to March in 1987, about one month before fry steelhead. Growth comparisons between the two species were similiar for the 1986 year class (Figure 10). Instantaneous growth rates in

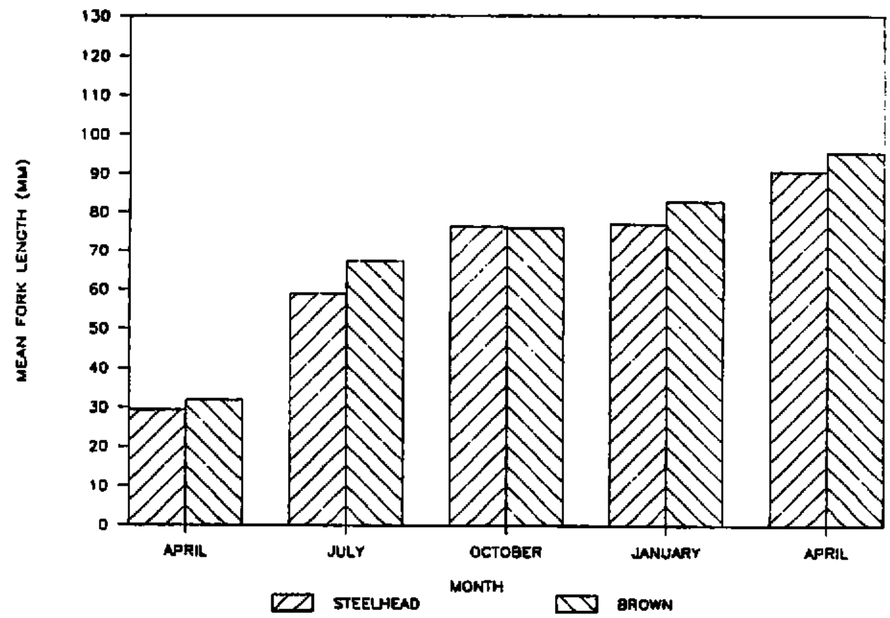


Figure 10. Growth comparison between 1986 year classes of steelhead and brown trout in the Trinity River, CA.

length for the 1986 brown trout year class followed the same patterns as the growth described for steelhead trout. Instantaneous growth rates for the 1985 brown trout year class show a higher increase in length during the winter season. Lack of data prevented any estimates for instantaneous growth rates for the spring rearing season.

INVERTEBRATE STUDIES

INTRODUCTION

The importance of benthic macroinvertebrates as a food source for anadromous salmonids has been well documented (see Becker 1973, Jenkins, et al. 1970, Johnson and Johnson 1981, and Johnson and Ringler 1980). Reservoirs are known to alter benthic invertebrate communities in many ways, depending upon water release management (Walburg, et al. 1981). The purpose of this study is to determine the overall health and productive capabilities of Trinity River invertebrate populations in established field study reaches. The health of invertebrate populations will be assessed by monitoring the diversity, standing stock, and production of aquatic macroinvertebrates.

METHODS

Sampling Sites

We chose riffles to index invertebrate population health because this habitat type is known to support maximum diversity and production. Five study riffles have been selected at locations representative of the different reaches of interest. The Cemetery site was chosen to represent riffle habitat immediately downstream of the reservoir. Sites at Bucktail and Steelbridge represent riffle conditions above and below Grass Valley Creek, respectively. Sites at Steiner Flat and Del Loma represent riffles with increasing distance, and probably, decreasing influence, downstream from the reservoir.

Sampling Procedure

Macroinvertebrates were collected with a modified Hess sampler 27 inches high and 14 inches in diameter, with a sampling area of 1.07 square feet. Net mesh size used in the sampler is 500 microns.

We collected five replicate samples at each of the five study sites, on ten occasions over the course of one year. Samples were collected monthly beginning April 1986, through November 1986, and in January and March of 1987. Sampling locations on the study riffle were selected at random, and microhabitat measurements of depth, mean velocity, bottom velocity, and Brusven substrate type (page 138) were recorded. The modified Hess sampler was operated in depths ranging from 0.6 to 1.5 feet, and velocities up to 5.8 ft/sec. The sampler was used in substrate ranging from sand to 9" to 12" cobble.

Hess samples were condensed on a 500 micron sieve and stored in 70 % ethanol for lab processing.

Sample Processing and Analysis

Rose Bengal solution was used to stain the invertebrates pink to aid in separating them from detritus. After samples were stained, they were floated in saturated salt solution to separate invertebrates from sediment. The stained invertebrates were then hand picked from the supernatant, and the sediment fraction checked for remaining organisms.

Macroinvertebrates were identified under a dissecting microscope to the lowest identifiable taxa. Lengths and widths for each taxa and size class were estimated using an ocular micrometer. Volume was calculated assuming a cylindrical shape:

$$V = 3.14 \left(\frac{W}{2}\right)^2 \times (L)$$

where: V = volume of invertebrate
W = width of invertebrate
L = length of invertebrate

Volume was converted to dry weight by the equation 1 mm^3 = 0.1 mg (Cummins and Wuycheck 1971). Shannon-Weaver diversity index (Wilhm and Dorris 1968) was used to determine diversity per sampler. Diversity (H') is calculated as:

$$H' = -\sum_{i=1}^{s} \left(\frac{N_i}{N}\right)^2 \times \log^2 \frac{N_i}{N}$$

where: H' = Shannon-Weaver diversity of sample
s = number of taxa in sample
N = total number of organisms in sample
Ni = number of organisms of taxon i

Annual macroinvertebrate production will be estimated using the size - frequency method (Hynes and Coleman 1968) as modified by Hamilton (1969) and Benke (1979). Estimates of production, biomass, and diversity will be used in characterizing the health of macroinvertebrates in study riffles.

Preliminary Results

A preliminary taxa list of invertebrates collected from samples keyed to date is presented in Table 1, which also includes aquatic invertebrate adults that were collected incidentally while working on other tasks. Preliminary results for the April 1986 sample group indicate a general trend of increasing diversity with distance downriver (Table 2). However, mean biomass and total numbers of invertebrates per sample peaks at Bucktail (site 3), then declines with distance downriver.

To date, 25 samples have been keyed and 100 have been sorted, out of a total of 250 samples collected. Due to personnel and project constraints, we plan to process a seasonal sample set that has been selected from the complete sample set. This group of samples were collected in April 1986, July 1986, October 1986, and January 1987, corresponding to sampling dates for our food study. A final report in April 1988 will incorporate the four sampling dates. We plan to process the remainder of samples as time permits over the duration of the flow study.

Estimates of production, biomass, and diversity will be used in characterizing the health of macroinvertebrates in study riffles. These estimates will be useful to monitor: 1) effects of differing flow regimes on macroinvertebrates; 2) sedimentation effects from tributaries such as Grass Valley Creek on downstream invertebrate populations; 3) downstream and seasonal changes in macroinvertebrate populations.

Table 1. Macroinvertebrates collected in the Trinity River by area and season.

Taxa	Location[a]			Season[b]			
	Low	Mid	Up	su	f	w	sp
ANNELIDA							
Hirudinea		cc	c			a[d]	a
Oligochaeta							
Lumbriculidae		a	a			a	a
ARTHROPODA							
Arachnida							
Hydracarina			r				a
Coleoptera							
Dytiscidae							
***Dytiscus* sp.**			r				1
***Hygrotus* sp.**			r				a
Elmidae							
***Ampumixis* sp.**			o				1
***Cleptelmis* sp.**		o					a
***Narpus* sp.**		c	c			1	1
***Optioservus* sp.**		c	c				b
Ordobrevia nubifera			r				1
Zaitzevia parvula		o					b
Histeridae			r				a
Haliplidae							
***Brychius* sp.**			r				a
Hydrophilidae							
***Hydrochus* sp.**			r			1	
Psephenidae							
Eubrianax edwardsi			r				1
Psephenus haldemani			r				1
Collembola			r			a	
Diptera							
Athericidae							
***Atherix* sp.**			o			1	
Blephariceridae							
***Blephariceria* sp.**			r	1			
Ceratopogonidae							
Ceratopogoninae		o					1
Chironomidae							
Tanytarsini			a				1
***Tanytarsus* sp. (not verified)**		a	a			1	1
Empididae		c	c			1	1
***Chelifera* sp**			c				1
***Hemerodromia* sp.**		c	c				1
Muscidae			r				1
Pelecorhynchidae							
***Glutops* sp.**			r				1

Table 1. Macroinvertebrates collected in the Trinity River by area and season (continued).

Taxa	Location[a]			Season[b]			
	Low	Mid	Up	su	f	w	sp
Simuliidae							
Simulium sp.		a	a			1	1
Tipulidae							
Antocha sp.			o				1
Dicranota sp.		c				1	1
Hexatoma sp.			o				1
Tipula sp.			r				1
Ephemeroptera							
Ametropodidae							
Ametropus sp.		o				n	
Baetidae							
Baetis sp.		a	a			n	n
Ephemerellidae							
Caudatella heterocaudata			r				n
Drunella coloradensis		c	c				n
D. doddsi			o				n
D. grandis			c				n
D. spinifera			o			n	
Ephemerella inermis		c	c			n	n
Timpanoga hecuba		r					n
Heptageniidae							
Cinygmula sp.		o	o				n
Epeorus (Ironopsis) sp.		c				n	n
(Iron) sp.		c	c				n
Rhithrogena sp.		a	a			n	n
Leptophlebiidae							
Paraleptophlebia sp.		o	o			n	n
Siphlonuridae							
Ameletus sp.		o	r			n	n
Isonychia sp.	r			n			
Tricorythidae							
Tricorythodes sp.		r					n
Lepidoptera							
Pyralidae							
Petrophila sp.		r					1
Megaloptera							
Sialidae							
Sialis sp.			r				1
Corydalidae							
Orohermes crepusculus			r	a			

Table 1. Macroinvertebrates collected in the Trinity River by area and season (continued).

Taxa	Location[a] Low	Mid	Up	Season[b] su	f	w	sp
Odonata							
Anisoptera							
Gomphidae							
Ophiogomphus sp.	o	o				n	n
Plecoptera							
Capniidae							
Capnia sp.		o	o			b	
Chloroperlidae							
Alloperla sp.		r					n
Kathroperla sp.			r				n
Sweltsa sp.			r				n
Nemouridae							
Amphinemoura sp.			r		b		
Soyedina sp.			r				a
Perlidae							
Calineuria californica			a			n	b
Claassenia sabulosa		a	a				b
Hesperoperla pacifica			o	b			b
Perlodidae		c	c				n
Chernokrilus sp.	o					a	
Cultus sp.		o	o			n	n
Isoperla sp.		o	c				b
Perlinodes aurea			o			a	
Rickera sp.			r				a
Skwala curvata			o			a	a
Skwala parallela			o			a	
Pteronarcyidae							
Pteronarcys californicus			c			n	b
Trichoptera							
Brachycentridae							
Brachycentrus sp.		a	a				l
Micrasema sp.		c	o				l
Glossosomatidae							
Glossosoma sp.			a			l	l
Protoptila sp.		r					l
Helicopsychidae							
Helicopsyche sp.			r			l	
Hydropsychidae							
Cheumatopsyche sp.		c	o				l
Hydropsyche sp.		a	a			l	l
Hydroptilidae							
Hydroptila sp.			c	l			
Leucotrichia sp.			r			l	
Lepidostomatidae							
Lepidostoma sp.		o				l	l

Table 1. Macroinvertebrates collected in the Trinity River by area and season (continued).

Taxa	Location[a]			Season[b]			
	Low	Mid	Up	su	f	w	sp
Limnephilidae							
Dicosmoecus sp.			o				l
Hydatophylax hesperus			r				l
Neophylax sp.			r				l
Onocosmoecus sp.			o			l	l
Philopotamidae							
Wormaldia sp.		o					l
Rhyacophilidae							
Rhyacophila sp.			a			a	
Sericostomatidae							
Gumaga sp.		r					l
Psychomyiidae							
Tinodes sp.			r				l
MOLLUSCA							
Gastropoda							
Hydrobiidae							
Amnicola sp.			o				a
Lymnaedae							
Lymnaea sp.			o				a
Planorbidae							
Gyraulis sp.			r				a
Pelecypoda							
Sphaeriidae							
Pisidium sp.			r				a
NEMATOMORPHA							
Gordiidae							
Gordius sp.	r					a	
NEMATODA		a					a

[a]Locations are defined as follows:
- Low...Weitchpec to South Fork
- Mid...South Fork to North Fork
- Up....North fork to Lewiston Dam

[b]Seasons are abbreviated as follows:
- Su....Summer
- F.....Fall
- W.....Winter
- Sp....Spring

[c]Rough Abundance per Location defined as follows: (Abundance determined by frequency sampled)
- a.....abundant
- c.....common
- o.....occasional
- r.....rare

[d]Lifestages are abbreviated as followed:
- n=nymph
- l=larva
- a=adult
- b=both adult and immatures

Table 2. Mean and standard deviation of diversity (Shannon-Weaver), biomass, and numbers for benthic invertebrates sampled in April 1986 at all sites.

SITE	DIVERSITY	SD	BIOMASS	SD	NUMBERS	SD
Cemetery	3.29	0.17	121.13	50.92	192.6	88.8
Bucktail	3.66	0.30	455.08	519.81	225.0	195.7
Steelbridge	3.77	0.14	84.49	67.62	77.6	18.7
Steiner Flat	3.90	0.05	116.58	91.80	107.0	39.5
Del Loma	3.48	0.34	41.03	14.07	51.4	8.3

JUVENILE SALMONID FOOD HABITS

INTRODUCTION

To better understand the relationship between juvenile salmonids and their habitat, it is of interest to determine use of available food supply. In sympatric populations of salmonids, limited food resources may result in competition. Fish species competing for limited food resources may therefore be limited in production. This study will investigate and quantify common salmonid foods, and the diet overlap between different species and lifestages of juvenile salmonids.

The objectives of this study are as follows:

1). To identify the preferred or commonly consumed foods of fry and juvenile salmonids.

2). To examine changes in feeding habits with river location and season.

3). To quantify the degree of diet overlap between different species and lifestages of juvenile salmonids.

METHODS

Field Sampling

Fish taken for stomach content analysis were a sub-sample of the fish collected for growth analysis (pages 81-91). Subsamples were taken from fish sampled at our Cemetery, Bucktail, Steelbridge, Steiner Flat, and Del Loma sites in April, July, October, and January, to correspond with benthic invertebrate sample sites and periods (pages 92-99).

At each site and time we collected five fry and five juvenile chinook salmon, coho salmon, steelhead trout, and brown trout for stomach content analysis. Fish were sampled between 0800 and 1600. They were anesthetized in methyltricaine sulfonate, their weight and length measured, and then fixed in 10 percent formalin. The fish coelom was incised to allow formalin to fix stomach contents.

Laboratory Analysis

Fish fixed in formalin were transferred to 70 percent ethanol for laboratory processing of stomach contents. Fish length and weight were recorded, and scales were taken before dissection. The stomach was dissected out of the fish, and contents between the esophagus and pyloric sphincter were removed for analysis. Fish food items were identified at 10X to 80X power under a Nikon SMZ-10 stereo microscope. We estimated food item lengths and head capsule width (or average width) to 0.1 mm at 10x power with an ocular micrometer. Volume of ingested invertebrates was calculated assuming a cylindrical shape:

$$V = 3.14 \left[\frac{W}{2} \right]^2 X \ (L)$$

where: V = volume of food item
W = width of food item
L = length of food item

Data Analysis

Many food items could not be completely measured, due to partial digestion, and only a head capsule width could be estimated. We developed head capsule width-length regressions from whole invertebrates to estimate volumes of partially digested organisms, as described by Bowen (1983). Volume was converted to dry weight by the equation 1 mm^3 = 0.1 mg (Cummins and Wuycheck 1971).

Fish subsampled for food analysis from the growth study were compared by forklength frequency histograms, and by the Kolmogorov-Smirnov goodness of fit test (Sokal and Rohlf 1981). We aged all food study juvenile brown and steelhead trout by examining scales on a microfiche reader. Some young-of-year brown and steelhead trout were aged to help clarify seasonal cut-off ranges between these fish and juveniles.

We regressed food item size with fish size to examine food size selectivity. We also regressed food weight with fish weight. Total food weight consumed was examined by time of day sampled and by season. All invertebrates and fish consumed by each species were summarized. Mean percent weight, the average of the weight percentage, of sixteen major food groupings were calculated for each species by season and site.

We calculated diet overlap amoung fish species and lifestages with the Schoener Index (Wallace 1981). The Schoener Index was calculated as follows:

$$\text{Overlap} = 1 - 0.5 \left[\sum_{i=1}^{n} \left| Pxi - Pyi \right| \right]$$

where: Pxi = proportion of food category i in the diet of species x

Pyi = proportion of food category i in the diet of species y

n = number of food categories

Food overlap was calculated for each species and lifestage by season using the Schoener Index based on the average of weight percentages for 16 major food categories. We defined the average of weight percentage as the average percentage that each food category contributed to the total weight of food in each stomach.

RESULTS

Sub-sample Comparison

Forklength frequency histograms for chinook salmon sampled for the food study are presented in Figure 1. Fish sampled in January 1987 that were over 78 mm forklength were assumed to be of hatchery origin, and not used in the food study. Kolmogorov-Smirnov nonparametric tests of chinook salmon cumulative forklength frequencies were significant in April (P = 0.05, D = 0.281), but not in January (D = 0.062).

Coho salmon forklength histograms are presented in Figure 2. Coho salmon cumulative forklength frequencies were significantly different between food and growth in April (P = 0.001, D = 0.323), but not for other months tested.

Steelhead trout forklength frequency histograms are presented in Figure 3. Kolmogorov-Smirnov nonparametric tests comparing cumulative forklength frequencies between steelhead trout food and growth sampled fish were not significantly different.

Brown trout forklength frequency histograms are presented in Figure 4. Kolmogorov-Smirnov nonparametric tests comparing cumulative forklength frequencies between brown trout food and growth-sampled fish were not significantly different.

Food Size Selectivity

Ratio and least squares linear regression estimates for invertebrate length versus head capsule width were calculated for 30 different taxa (Table 1). Ratio estimates were used to develop length versus head capsule width relationships for food organisms where significant regression equations could not be generated.

We examined food size selectivity by size of fish through regression analysis. Food item length regressed against fish forklength yielded significant ($P < 0.01$) relationships for each species (Table 2).

<u>Food Weight vs. Fish Weight</u>

Regression analysis of total food weight versus fish weight for chinook salmon was not significant (Figure 6). Coho salmon food weight increased linearly as fish weight increased (Table 3). Similar total food weight versus fish weight linear relationships were observed for steelhead and brown trout (Table 3, Figure 6).

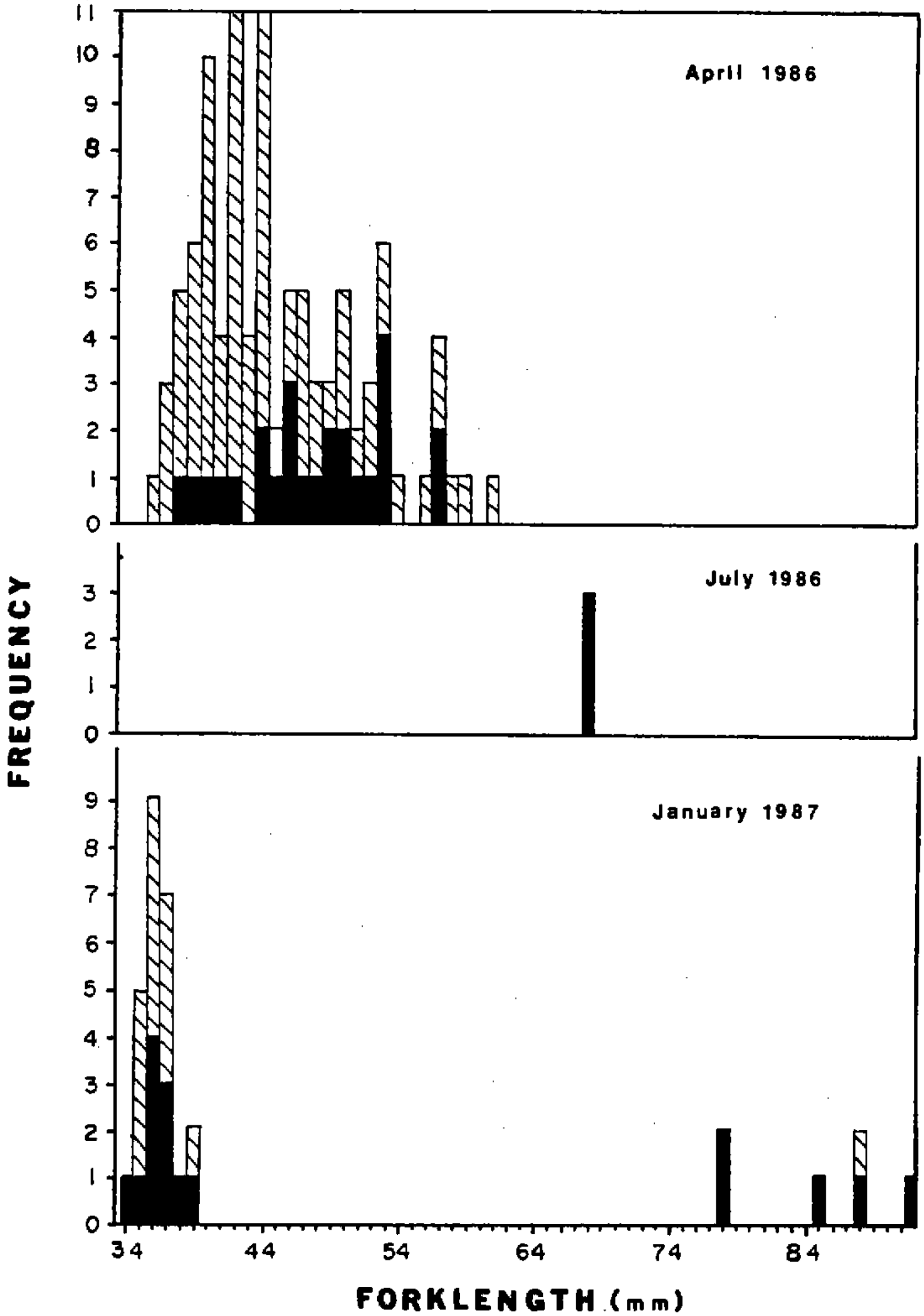


Figure 1. Forklength frequency histograms of chinook salmon sampled April 1986 - January 1987, at food study sites. Shaded bars are numbers of food study fish, and hatched bars are numbers of growth fish.

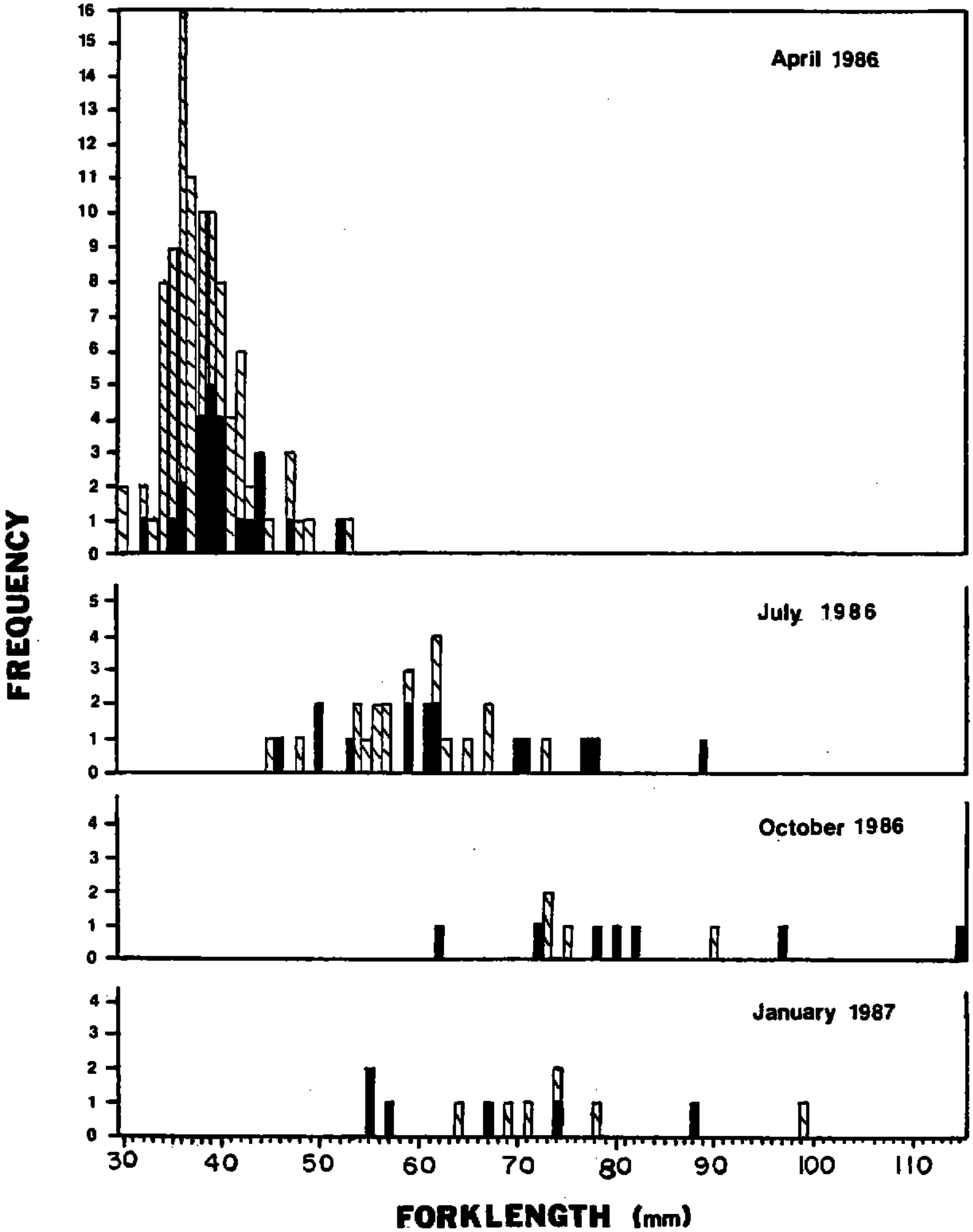


Figure 2. Forklength frequency histograms of coho salmon sampled April 1986 - January 1987, at food study sites. Shaded bars are numbers of food study fish, and hatched bars are numbers of growth fish.

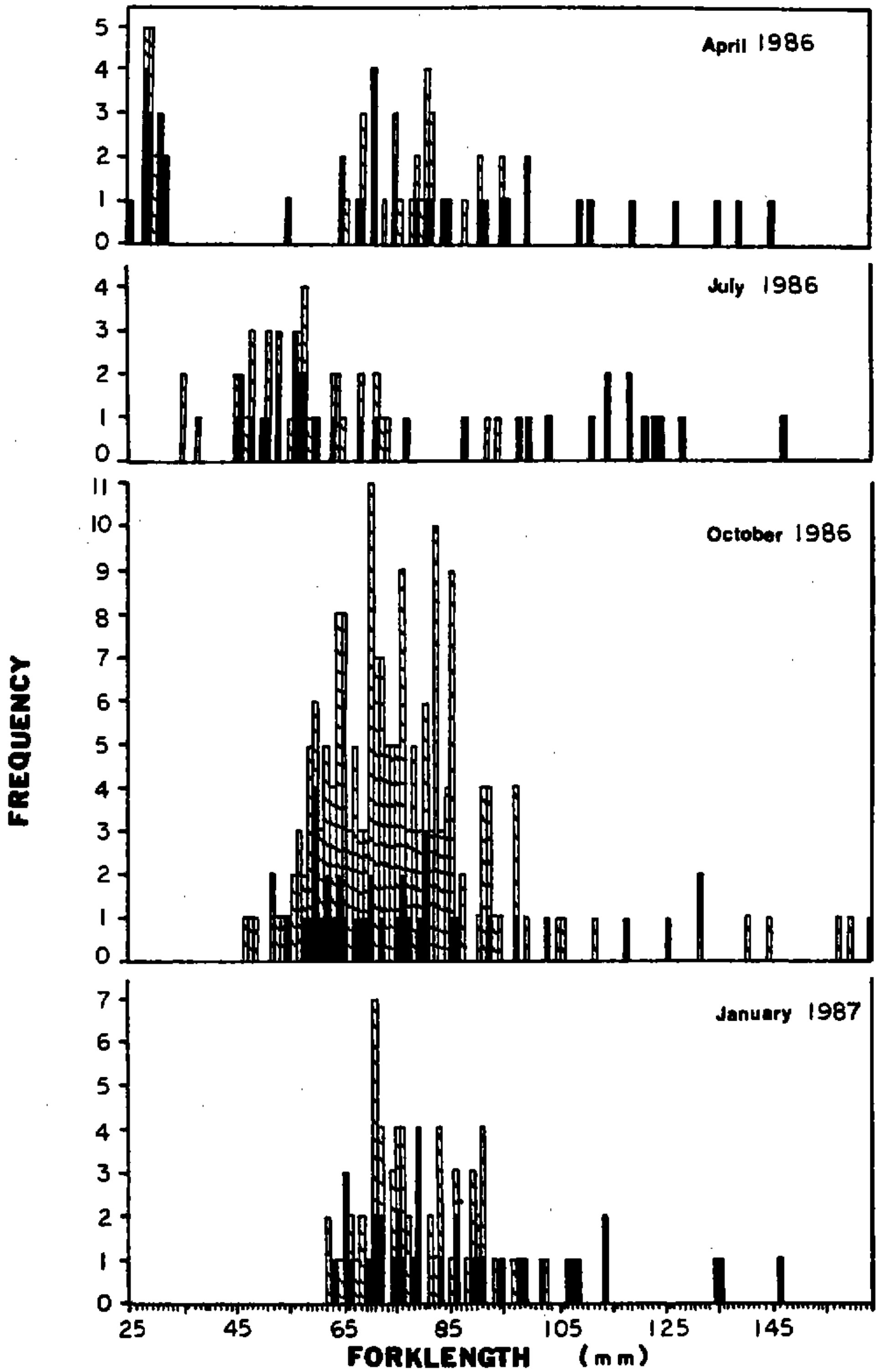


Figure 3. Forklength frequency histograms of steelhead trout sampled April 1986 - January 1987, at food study sites. Shaded bars are numbers of food study fish, and hatched bars are numbers of growth fish.

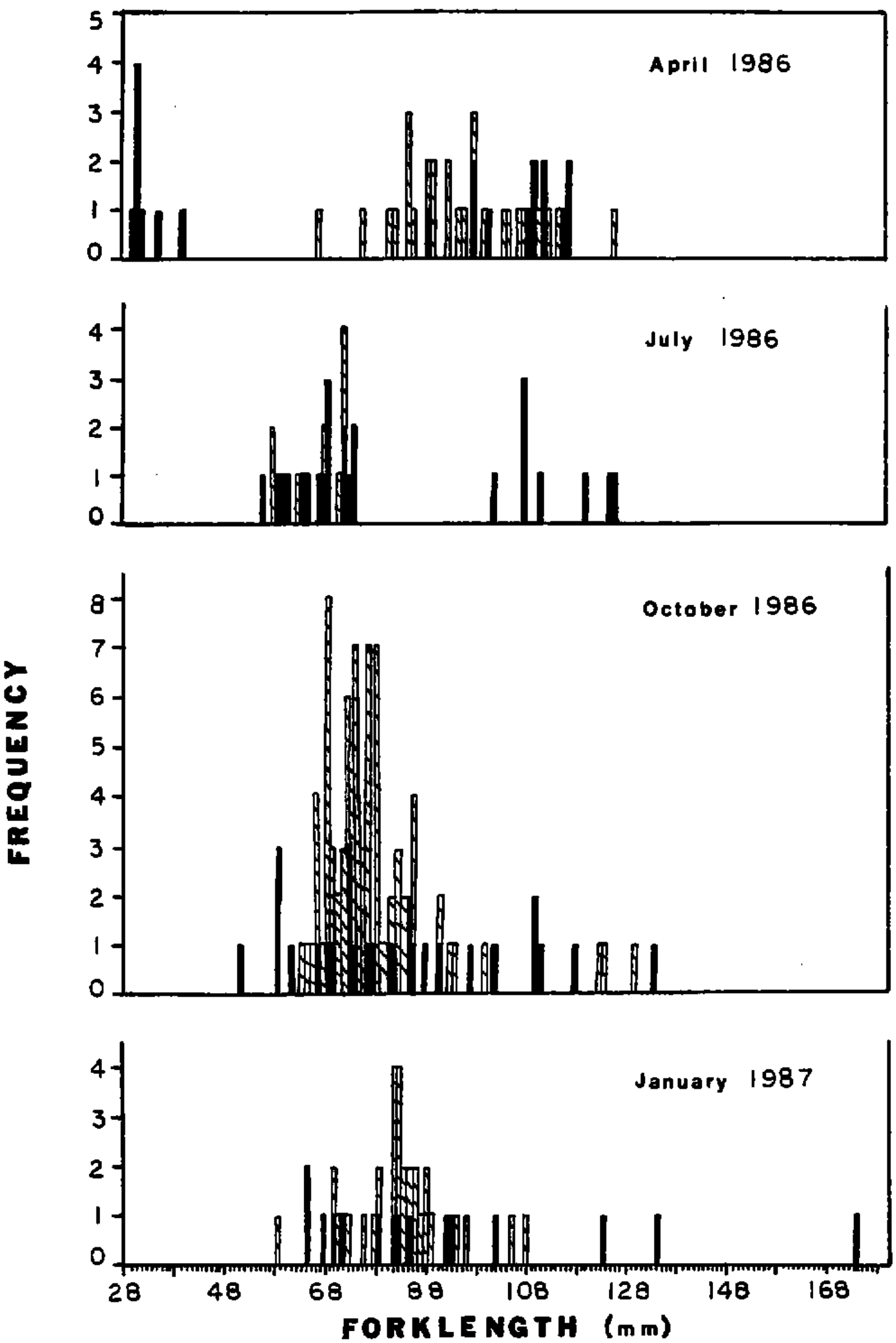


Figure 4. Forklength frequency histograms of brown trout sampled April 1986 - January 1987, at food study sites. Shaded bars are numbers of food study fish, and hatched bars are numbers of growth fish.

Table 1. Least squares regression and ratios used for food item lengths estimated from head capsule widths. Abbreviations used are as follows: r = correlation coefficient, n = number in sample, L = organism length, H.C. = head capsule width.

Food Item	r	n	Significance	Equation
Ophiogomphus sp.	ratio	-	N.S.	L = H.C. (45/10)
Sialis sp.	0.96	7	0.01	L = 5.2 (H.C.) - 1.3
Antocha sp.	0.84	10	0.01	L = 8.7 (H.C.) + 7.9
Chironomidae	0.67	14	0.01	L = 7.0 (H.C.) + 7.9
Chironomidae Pupae	0.91	20	0.01	L = 4.5 (H.C.) - 1.5
Simulium sp.	0.91	14	0.01	L = 7.7 (H.C.) - 4.3
Baetis sp.	0.95	11	0.01	L = 5.5 (H.C.) - 0.7
Ephemerella sp.	0.86	18	0.01	L = 4.0 (H.C.) + 7.8
Rhithrogena sp.	0.88	13	0.01	L = 2.9 (H.C.) + 8.6
Ameletus sp.	ratio	-	N.S.	L = H.C. (33/7)
Drunella sp.	ratio	-	N.S.	L = H.C. (140/45)
Heptageniidae	0.89	7	0.01	L = 2.6 (H.C.) + 13.7
Ephemeroptera Adult	0.63	21	0.01	L = 2.5 (H.C.) + 29.8
Calineuria californica	0.91	6	0.05	L = 4.4 (H.C.) - 2.6
Perlidae	0.92	8	0.01	L = 3.7 (H.C.) + 24.0
Isoperla sp.	0.98	4	0.05	L = 6.9 (H.C.) - 40.1
Perlodidae	0.98	17	0.01	L = 5.1 (H.C.) - 3.36
Amphinemoura sp.	ratio	-	N.S.	L = 5 (H.C.)
Plecoptera	0.96	7	0.01	L = 4.8 (H.C.) + 0.4
Hydropsyche sp.	0.70	20	0.01	L = 2.9 (H.C.) + 42.8
Glossosoma sp.	0.68	20	0.01	L = 7.6 (H.C.) + 4.6
Brachycentrus sp.	0.17	5	N.S.	L = 0.8 (H.C.) + 52.4
Hydroptila sp.	0.50	5	N.S.	L = 6.3 (H.C.) + 8.0
Onocosmoecus sp.	ratio	-	N.S.	L = H.C. (85/10)
Micrasema sp.	0.79	10	0.01	L = 4.8 (H.C.) + 1.9
Lepidostoma sp.	0.80	18	0.01	L = 3.7 (H.C.) + 11.9
Wormaldia sp.	ratio	-	N.S.	L = H.C. (90/8)
Limnephilidae	0.91	8	0.01	L = 4.5 (H.C.) + 10.3
Trichoptera Adult	0.66	12	0.05	L = 3.5 (H.C.) + 21.3

Table 2. Least squares linear regression estimates of food item length versus fish forklength for food study fish, April 1986 through January 1987.

Species	Regression Equation	r^2	n
	a b		
chinook salmon	Y = 0.12 X - 1.89	0.11	89
coho salmon	Y = 0.05 X + 1.42	0.07	243
steelhead trout	Y = 0.04 X + 2.07	0.06	566
brown trout	Y = 0.07 X + 0.11	0.10	340

[a] Y = Food item Length (mm)
[b] X = Fish Forklength (mm)

Table 3. Least squares linear regression estimates of total food weight versus fish weight for food study fish, April 1986 through January 1987.

Species	Regression Equation	r2	n
	a b		
coho salmon	Y = 2.17 X + 0.18	0.34	53
steelhead trout	Y = 1.76 X + 0.60	0.32	145
brown trout	Y = 2.24 X + 0.19	0.25	88

[a] Y = Total Food Weight (mg)
[b] X = Fish Weight (gm)

Seasonal and Daily Patterns in Food Weight

Mean total weight of food in chinook salmon stomachs increased from January to April, as fish grew (Figure 5), but it decreased in July. Mean total food weight in coho salmon peaked in October (Figure 6). Food weight increased as fish grew from April through October, and declined in January.

Mean total food weight of steelhead trout young-of-year peaked in October, and declined slightly in winter (Figure 7). Juvenile steelhead trout mean total food weight was greatest in January, and lowest in July. Brown trout young-of-year mean total food weight gradually increased through the year, with a maximum in January (Figure 8). Mean total food weight of juvenile brown trout was fairly constant throughout the year.

We analyzed mean total food weight for time of day sampled, to examine daily feeding patterns. Chinook salmon food weight increased throughout the day and peaked at 1400 hours (Figure 9). Mean total food weight in coho salmon was lowest at mid-day for April and July 1986 (Figure 10).

Steelhead trout mean total food weight was similar throughout the day in April 1986 (Figure 11). However, in July and October 1986, it decreased in late morning and early afternoon, increasing again during mid afternoon. This trend may not have been apparent in April 1986 because of a lack of samples mid-day. Brown trout mean total food weight showed no definite daily trend during July and October 1986 (Figure 12).

Salmonid Feeding Habits

We summarized food items eaten by each species, pooling all sites and times to determine major food groups. Chinook salmon consumed 21 different food categories (Table 4). Major food items for chinook salmon by decreasing order of percent weight were: adult Ephemeroptera, Chironomidae, *Ephemerella sp.*, *Baetis sp.*, adult Trichoptera, terrestrial insects, Plecoptera, adult Diptera, *Hydropsyche sp.*, and *Glossosoma sp.*.
Coho salmon fed on 37 different food categories (Table 5). Major food items for coho salmon by percent weight were: adult Ephemeroptera, Chironomidae, terrestrial insects, *Hydrochus sp.*, *Simulium sp.*, adult Trichoptera, *Rhithrogena sp.*, Perlidae, *Sialis sp.*, and Lumbriculidae.

Steelhead trout consumed 52 different food types, the highest number among the fish species studied (Table 6). Steelhead food items, in order of decreasing importance by percent weight, were: *Calineuria california*, Perlodidae, fish, *Baetis sp.*, *Rhithrogena sp.*, *Hydropsyche sp.*, *Ophiogomphus sp.*, Lumbriculidae, *Simulium sp.*, and adult Ephemeroptera (Table 6).

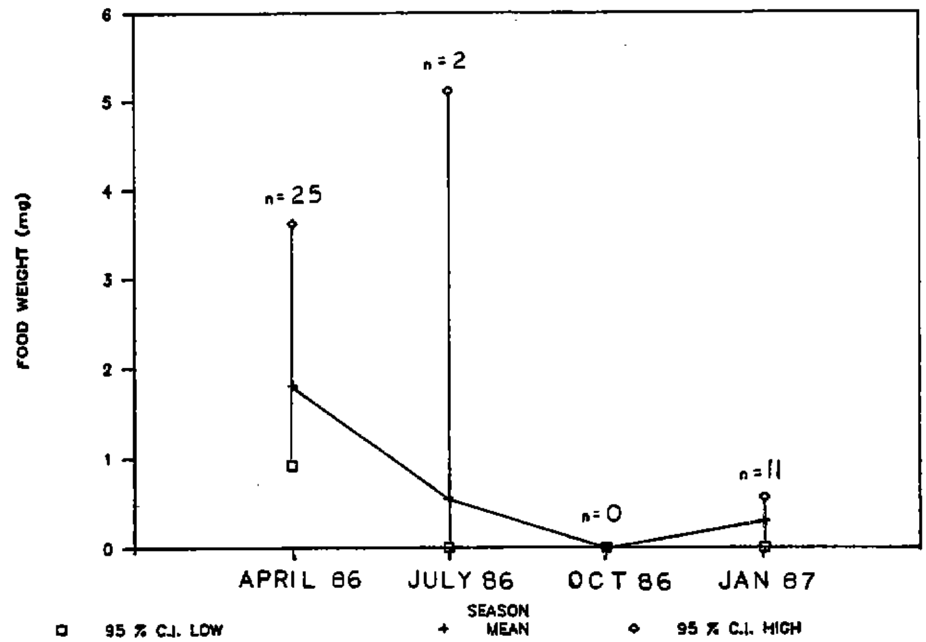


Figure 5. Mean total food weight by season for chinook salmon, April 1986 to January 1987, all sites pooled. Sample size and 95 % confidence intervals about each mean are included.

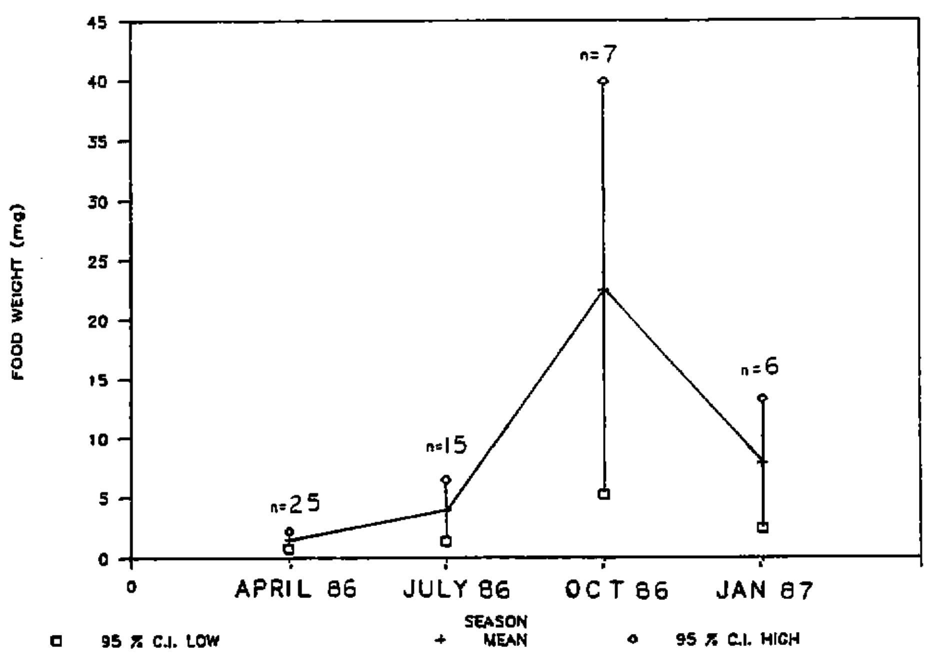


Figure 6. Mean total food weight by season for coho salmon, April 1986 to January 1987, all sites pooled. Sample size and 95 % confidence intervals about each mean are included.

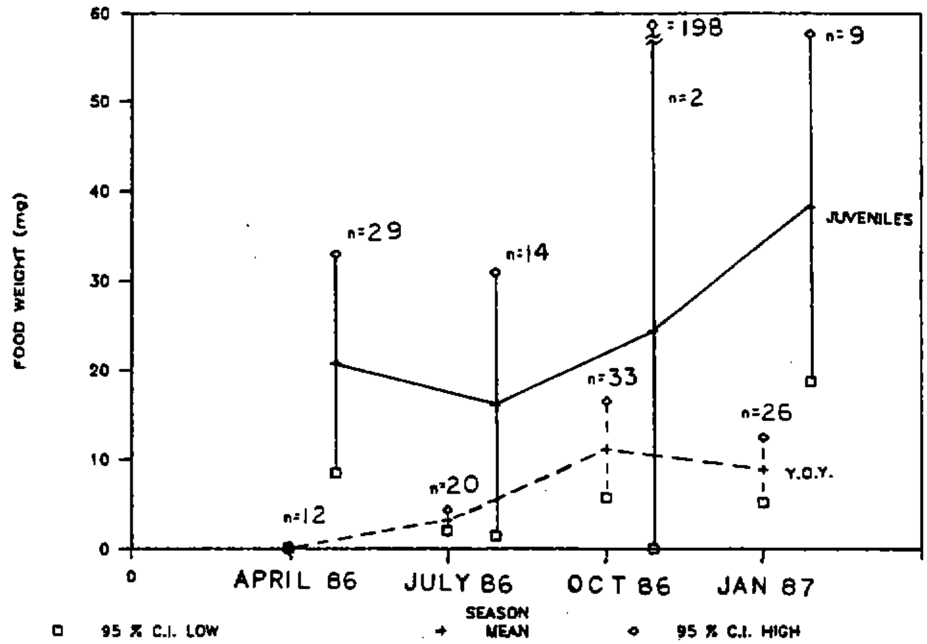


Figure 7. Mean total food weight by season for steelhead trout young of year (y.o.y.) and juveniles, April 1986 to January 1987, all sites pooled. Sample size and 95 % confidence intervals about each mean are included.

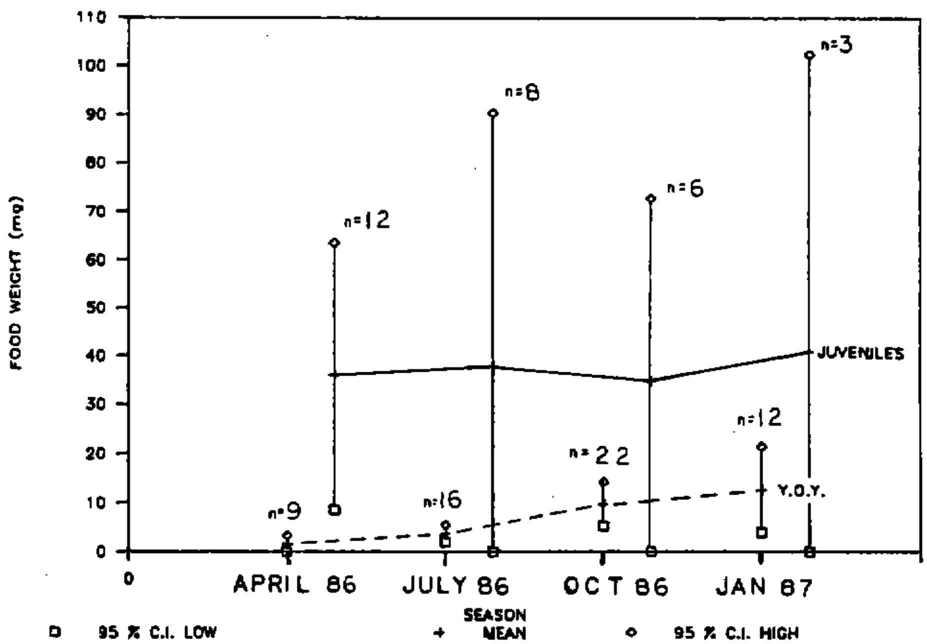


Figure 8. Mean total food weight by season for brown trout young of year (y.o.y.) and juveniles, April 1986 to January 1987, all sites pooled. Sample size and 95 % confidence intervals about each mean are included.

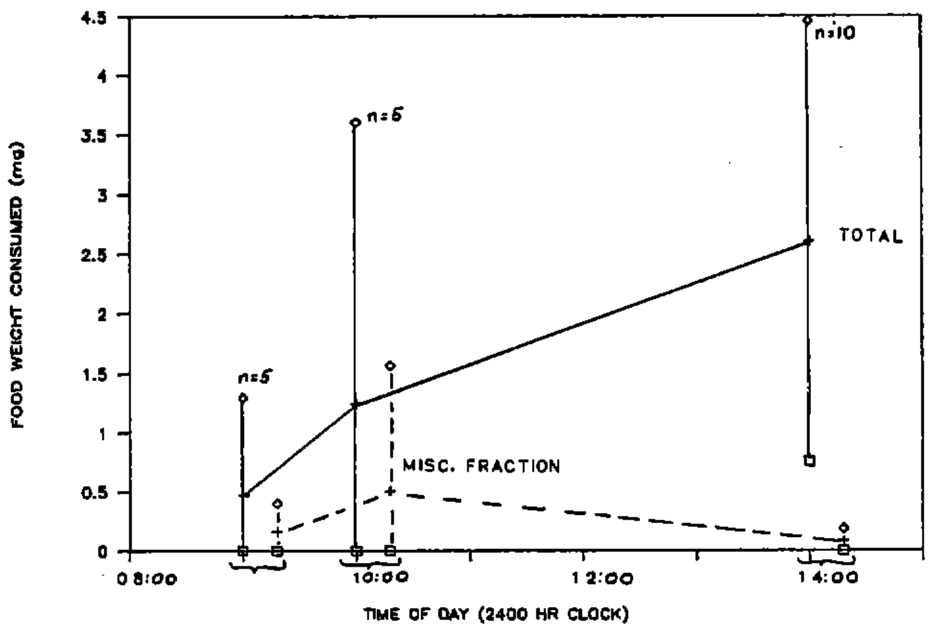


Figure 9. Chinook salmon mean food weight by time of day (on 24 hour clock) for April, 1986. Sample size and 95 % confidence intervals about each mean are included. The amount of partially digested contents are plotted for each time as misc fraction.

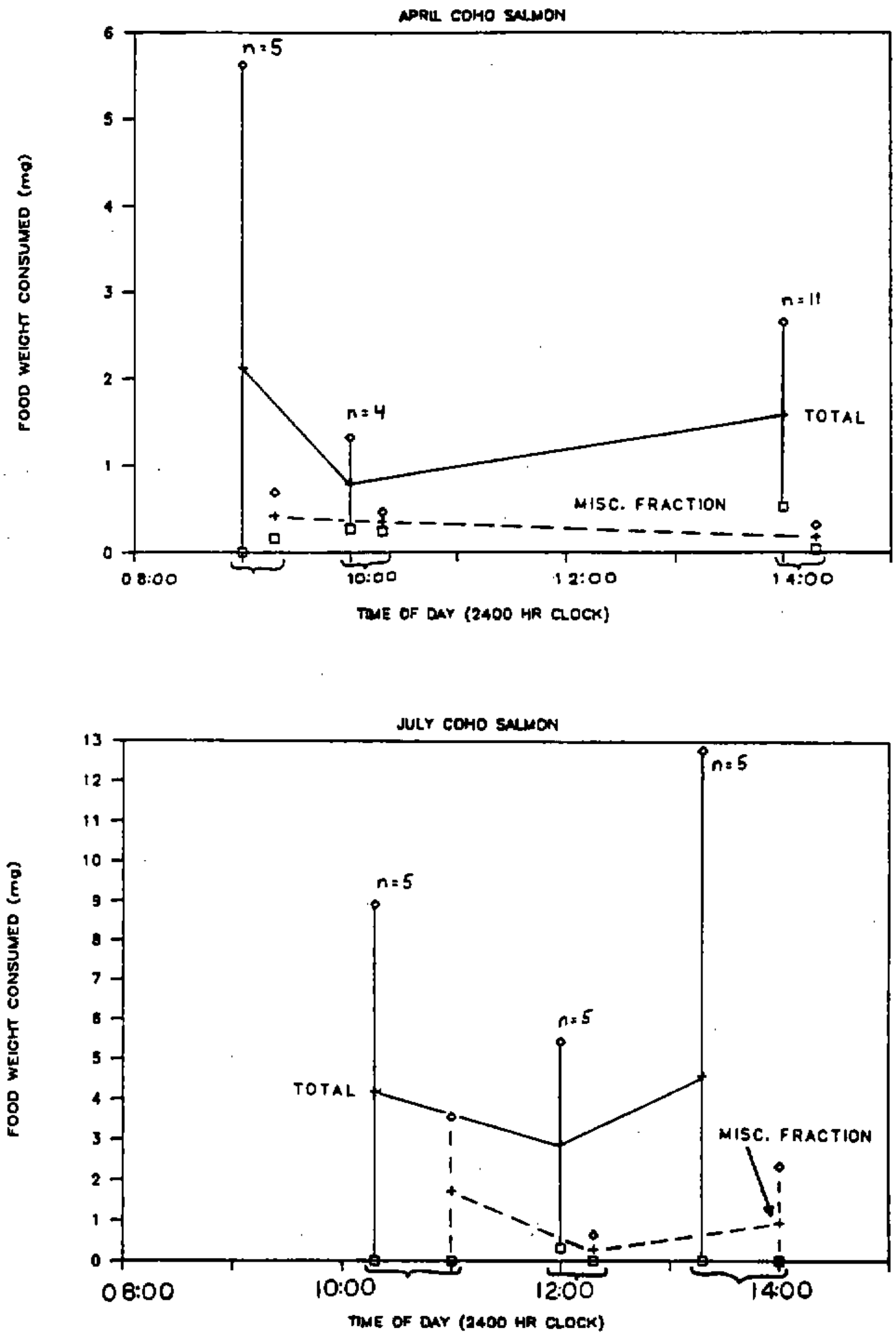


Figure 10. Coho salmon mean food weight by time of day (on 24 hour clock) for April and July, 1986. Sample size and 95 % confidence intervals about each mean are included. The amount of partially digested contents are plotted for each time as misc fraction.

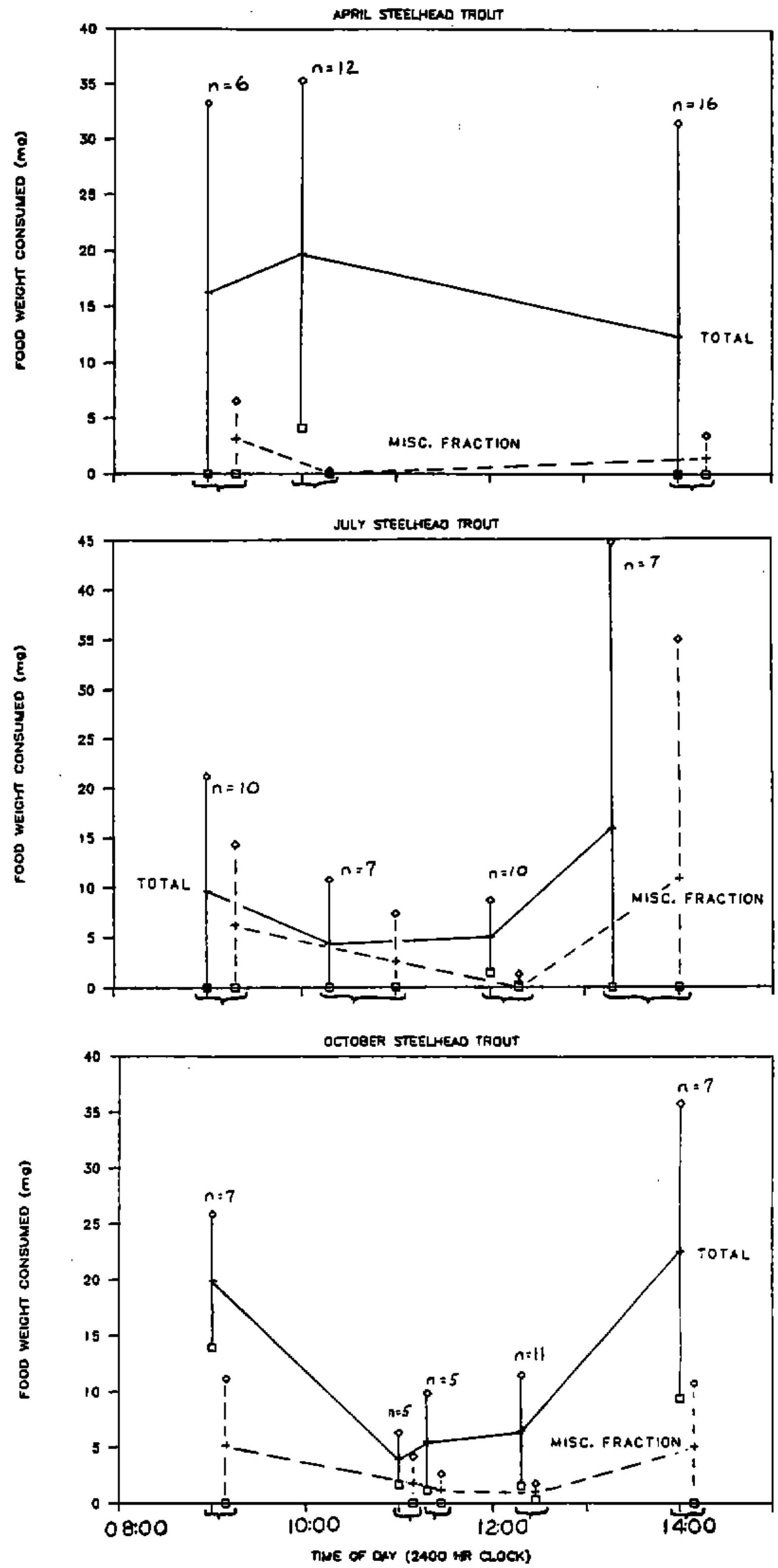
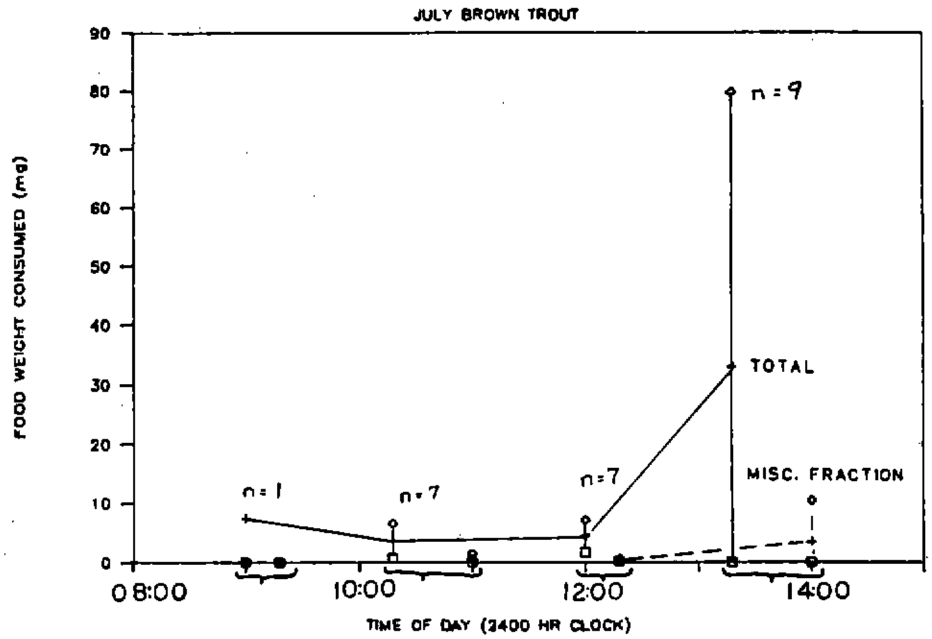


Figure 11. Steelhead trout mean food weight by time of day (on 24 hour clock) for April, July, and October 1986. Sample size and 95 % confidence intervals about each mean are included. The amount of partially digested contents are plotted for each time as misc fraction.



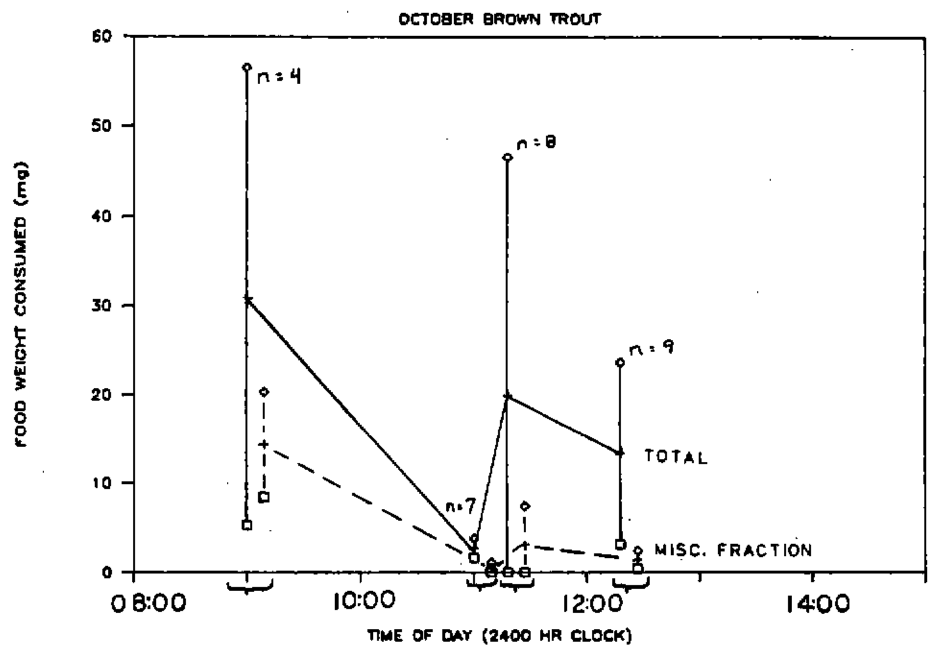


Figure 12. Brown trout mean food weight by time of day (on 24 hour clock) for July and October 1986. Sample size and 95 % confidence intervals about each mean are included. The amount of partially digested contents are plotted for each time as misc fraction.

Table 4. Percent of total number and weight for chinook salmon food items. All sites and times pooled, April 1986 through January 1987.

Food Item	Percent No.	Percent Wt.
Copepoda	0.4	< 0.1
Collembola	0.4	< 0.1
Chironimidae Larvae	37.7	7.9
Chironomidae Pupae	31.5	10.8
Dolichopodidae	0.4	< 0.1
Simulium sp.	2.9	0.8
Tipulidae	0.4	0.5
Diptera Adult	1.5	1.3
Baetis sp.	5.5	8.9
Ephemerella sp.	3.3	14.6
Ephemeroptera Adult	7.3	22.0
Hemiptera	0.4	0.1
Crambus sp.	0.4	< 0.1
Plecoptera	0.7	1.6
Perlodidae	0.4	< 0.1
Glossosoma sp.	1.5	1.0
Hydrosyche sp.	0.7	1.1
Hydroptila sp.	0.4	< 0.1
Lepidostoma sp.	0.4	< 0.1
Trichoptera Adult	1.5	7.0
Total Aquatic Invertebrates	97.4	77.8
Terrestrial Invertebrates	2.2	3.2
Miscellaneous	N/A	19.0
Totals:	Number = 273	Weight = 49.6 mg

Table 5. Percent of total number and weight for coho salmon food items. All sites and times pooled, April 1986 through January 1987.

Food Item	Percent No.	Percent Wt.
Lumbriculidae	1.6	2.1
Hydracarina	0.2	< 0.1
Copepoda	1.4	< 0.1
Zaitzevia sp	< 0.1	< 0.1
Hydrochus sp.	0.6	6.2
Collembola	1.4	0.5
Chironomidae Larvae	31.5	3.6
Chironomidae Pupae	27.7	8.5
Empididae	0.3	0.8
Simulium sp.	9.0	5.4
Antocha sp.	0.3	0.1
Diptera Adult	2.0	1.7
Ephemeroptera (Misc.)	< 0.1	< 0.1
Baetis sp.	1.6	1.7
Ephemerella sp.	0.5	1.6
Rhithrogena sp.	0.5	4.6
Ephemeroptera Adult	5.8	13.0
Crambus sp.	0.2	0.1
Sialis sp.	0.3	2.3
Odonata	< 0.1	< 0.1
Plecoptera	2.4	1.0
Chloroperlidae	0.2	< 0.1
Amphinemoura sp.	< 0.1	< 0.1
Perlidae	0.2	2.3
Perlodidae	0.2	< 0.1
Trichoptera (Misc.)	0.2	< 0.1
Micrasema sp.	< 0.1	< 0.1
Glossosoma sp.	0.5	0.5
Hydropsyche sp.	0.5	0.9
Hydroptila sp.	0.2	< 0.1
Lepidostoma sp.	0.6	0.4
Limnephildae	0.2	0.3
Trichoptera Adult	2.2	4.8
Gastropoda	< 0.1	< 0.1
Nematoda	0.2	< 0.1
Total Aquatic Invertebrates	92.8	62.9
Terrestrial Invertebrates	6.8	7.8
Fish	0.5	0.5
Miscellaneous	N/A	28.9
Totals	Number = 1325	Weight = 299.7 mg

Table 6. Percent of total number and weight for steelhead trout food items. All sites and times pooled, April 1986 through January 1987.

Food Items	Percent No.	Percent Wt.
Lumbriculida	0.2	2.6
Hydracarina	< 0.1	< 0.1
Copepoda	< 0.1	< 0.1
Ostracoda	< 0.1	< 0.1
Elmidae	0.4	< 0.1
Ceratopogonidae	< 0.1	< 0.1
Chironomidae Larvae	32.0	1.3
Chironomidae Pupae	8.3	0.6
Hemerodromia sp.	0.2	0.1
Simulium sp	14.7	2.5
Tabanidae	< 0.1	< 0.1
Tanyderidae	0.1	0.8
Empididae	0.5	< 0.1
Diptera Adult	1.1	0.2
Ephemeroptera (Misc.)	0.1	0.4
Baetis sp.	15.2	5.3
Drunella sp	0.2	0.6
Emphemerella sp	1.2	1.1
Rhithrogena sp	1.0	3.9
Cinygmula sp.	< 0.1	< 0.1
Paraleptophlebia sp.	< 0.1	< 0.1
Ameletus sp.	0.5	0.7
Ephemeroptera Adult	2.5	1.7
Petrophila sp.	1.3	1.5
Crambus sp.	< 0.1	< 0.1
Sialis sp.	0.2	0.6
Ophiogomphus sp.	0.1	2.7
Plecoptera (Misc.)	0.6	1.3
Chloroperlidae	< 0.1	< 0.1
Amphinemoura sp.	0.7	0.3
Calineuria californica	1.2	18.5
Hesperoperla pacifica	<0.1	0.9
Perlodidae	1.7	6.8
Plecoptera Adult	< 0.1	< 0.1
Trichoptera (Misc.)	0.2	< 0.1
Brachycentridae	0.9	0.2
Glossosoma sp.	0.9	0.1
Helicopsyche sp.	0.1	< 0.1
Hydropsyche sp.	3.2	3.3
Cheumatopsyche sp.	< 0.1	< 0.1
Hydroptilidae	2.6	< 0.1
Lepidostoma sp.	3.4	0.7
Limnephilidae	0.1	< 0.1
Philopotamidae	0.2	0.1
Tinodes sp.	< 0.1	< 0.1
Rhyacophila sp.	0.2	0.2
Gumaga sp.	0.2	< 0.1

Table 6. Percent of total number and weight for steelhead trout food items. (Continued)

Food Items	Percent No.	Percent Wt.
Trichoptera Adult	0.6	0.3
Gastropoda	0.2	0.6
Nematoda	0.3	< 0.1
Total Aquatic Invertebrates	97.7	60.1
Terrestrial Invertebrates	2.2	1.0
Fish	0.1	5.7
Miscellaneous	N/A	33.3
Totals	Number = 2183	Weight = 1881.3 mg

Brown trout consumed 42 different food item categories. Major foods eaten by brown trout, in order of decreasing percent weight, were: Calineuria california, fish, Perlodidae, Lumbriculidae, Baetis sp., Hesperoperla pacifica, Limnephilidae, Rhithrogena sp., Simulium sp., and adult Ephemeroptera (Table 7).

We chose sixteen food categories, from the important food taxa consumed by all fish species, for further analysis. These food categories were: Lumbriculidae, Coleoptera, Chironomidae, Simulium sp., Baetis sp., Rhithrogena sp., Ephemerella sp., Calineuria californica, Perlodidae, Hydropsyche sp., Lepidostoma sp., Limnephilidae, Glossosoma sp., aerial adults of aquatic invertebrates (aquatic adults), terrestrial invertebrates, and all fish species and lifestages.

Mean percent weight of food categories consumed by chinook salmon are presented in Table 8. In April 1986, Chironomidae and Ephemerella sp. were important food items for chinook salmon. Other food categories show greater or lesser importance with distance downstream from Lewiston reservoir. Baetis sp., Hydropsyche sp., and Glossosoma sp. are increasingly more important food items with distance downriver (table 8). Aquatic adults and terrestrial invertebrates were more important at upriver sites. In July 1986, only two chinook were sampled, and neither fish had eaten any of the selected food categories. Fish sampled in January were fry, and ate only small food items such as Chironomidae, Baetis sp., and Simulium sp. (Table 8).

Mean percent weight of food categories consumed by coho salmon are presented in Table 9. Chironomidae, Ephemerella sp., and terrestrial invertebrates were important food items in April 1986. Aquatic adults were important food items at the upriver Cemetery and Bucktail sites (sites 2 and 3), while Hydropsyche sp. was important downriver at Del Loma. In July 1986, Chironomidae and Simulium sp. were important food categories at sites 2 and 3, and less important at Steelbridge (site 5). Conversely, Lumbriculidae, terrestrial invertebrates, and fish were of more importance at Steelbridge than at upriver sites. Coho juveniles in October 1986 fed on mostly Chironomidae, aquatic adults, and terrestrial invertebrates. Coho salmon juveniles in January 1987 ate Coleoptera and Rhithrogena sp.

Food categories consumed by steelhead trout young-of-year are presented in Table 10. In April 1986, Chironomidae and Ephemerella sp. were important food categories at upriver sites; while at downriver sites, Calineuria californica, Hydropsyche sp., and Lepidostoma sp. increased in importance. July 1986 steelhead young of year ate Simulium sp. and Baetis sp. commonly at all sites. Lumbriculidae, Chironomidae and aquatic adults were important food items for steelhead young of year at upriver sites in July 1986. October steelhead young of year fed on Chironomidae, Baetis sp.., Hydropsyche

Table 7. Percent of total number and weight for brown trout food items. All sites and times pooled, April 1986 through January 1987.

Food Items	Percent No.	Percent Wt.
Hirudinea	< 0.1	< 0.1
Lumbriculidae	0.2	6.0
Copepoda	< 0.1	< 0.1
Ostracoda	0.2	< 0.1
Dytiscidae	0.2	< 0.1
Narpus sp.	< 0.1	< 0.1
Brychius sp.	< 0.1	< 0.1
Chironomidae Larvae	23.4	1.3
Chironomidae Pupae	2.3	< 0.1
Chelifera sp.	0.1	< 0.1
Muscidae	< 0.1	< 0.1
Simulium sp.	21.2	2.7
Tipulidae	0.3	1.0
Diptera Adult	0.4	0.1
Baetis sp.	16.0	5.7
Ephemerella sp.	0.4	0.5
Rhithrogena sp.	0.7	3.0
Iron sp.	0.4	0.1
Cinygmula sp.	< 0.1	< 0.1
Ameletus sp.	0.1	< 0.1
Ephemeroptera Adult	2.0	2.6
Sialis sp.	0.1	0.5
Plecoptera (Misc.)	0.6	1.8
Amphinemura sp.	0.1	< 0.1
Claassenia sabulosa	0.3	2.2
Calineuria californica	0.6	16.6
Hesperoperla pacifica	0.1	4.3
Perlodidae	2.0	13.9
Trichoptera (Misc.)	< 0.1	< 0.1
Brachycentridae	0.5	0.2
Glossosoma sp.	0.8	0.2
Helicopsyche sp.	< 0.1	< 0.1
Hydropsyche sp.	0.5	0.3
Hydroptila sp.	0.5	< 0.1
Lepidostoma sp.	18.1	2.1
Limnephilidae	4.5	3.9
Wormaldia sp.	0.5	0.3
Trichoptera Adult	0.9	1.3
Gastropoda	0.5	0.3
Pisidium sp.	0.1	< 0.1
Total Aquatic Invertebrates	99.0	71.3
Terrestrial Invertebrates	0.8	0.2
Fish	0.2	15.8
Miscellaneous	N/A	12.7
Totals	Number = 1739	Weight = 1502.6 mg

Table 8. Summary of major food items consumed by chinook salmon, April 1986 - January 1987, at Trinity River food study sites. Values are presented as mean percent weight.

	DATE							
	April 1986					January 1987		
	Site					Site		
FOOD ITEM	2	3	5	7	10	2	3	5
Lumbriculidae	0	0	0	0	0	0	0	0
Coleoptera	0	0	0	0	0	0	0	0
Chironomidae	24.6	25.3	6.5	25.7	26.9	30.2	0.2	100.0
Simulium sp.	0.7	1.0	0	0	0.5	0	19.0	0
Baetis sp.	0	1.5	0.2	0	11.9	4.7	46.1	0
Rhithrogena sp.	0	0	0	0	0	0	0	0
Ephemerella sp.	8.6	0	28.9	0	29.9	0	0	0
Calineuria sp.	0	0	0	0	0	0	0	0
Perlodidae	0	0	0	0	0.1	0	0	0
Hydropsyche sp.	0	0	0	3.8	10.2	0	0	0
Lepidostoma sp.	0	0	0.4	0	0	0	0	0
Limnephilidae	0	0	0	0	0	0	0	0
Glossosoma sp.	8.2	0	0	20.0	0	0	0	0
Aerial Aquatic Adults	57.6	22.5	0	0	0	0	0	0
Terrestrial Organisms	0	6.7	6.5	0	0	0	0	0
Fish	0	0	0	0	0	0	0	0
Mean Total Food Weight (mg)	4.0	1.2	2.1	0.5	1.3	0.1	0.5	0.1
Number of Fish	5	5	5	5	5	5	5	1

Table 9. Summary of major food items consumed by coho salmon, April 1986 - January 1987, at Trinity River food study sites. Values are presented as mean percent weight.

	DATE											
	April 1986					July 1986			October 1986		January 1987	
	Site					Site			Site		Site	
FOOD ITEM	2	3	5	7	10	2	3	5	2	3	2	7
Lumbriculidae	0	0	0	0	0	0	0	12.8	0	0	0	0
Coleoptera	0	0	0	0	0	0	0	0	0	0.1	42.2	0
Chironomidae	22.1	54.4	55.9	7.0	6.8	13.7	26.5	2.2	12.7	13.8	1.5	0
<u>Simulium sp.</u>	0.4	0.6	0	0	0	26.7	37.4	2.2	0.5	3.1	0	0
<u>Baetis sp.</u>	0.5	0	1.0	0	0	2.3	0.3	0.2	0.1	2.2	0.1	0
<u>Rhithrogena sp.</u>	0	0	0	0	0	0	0	0	0	0	27.9	0
<u>Ephemerella sp.</u>	10.4	7.7	20.3	0	18.7	0	0	0	0	0	0	0
<u>Calineuria sp.</u>	0	0	0	0	0	0	0	0	0	3.2	0	0
Perlodidae	0	0	0	0	0	0	0	0.4	0.7	0	0	0
<u>Hydropsyche sp.</u>	4.7	0	0	0	17.1	0	0.2	0	0.7	0	0	0
<u>Lepidostoma sp.</u>	0	2.9	0	0	0	0	0	0	0.3	2.0	0.2	0
Limnephilidae	3.5	0	0	0	0	0	0	0	0	0.3	0	0
<u>Glossosoma sp.</u>	0	6.9	0	0	0	0	0	0.3	0	0	0	0
Aerial Aquatic Adults	25.0	4.5	0	0	0	0	0	0.5	27.5	34.5	1.6	0
Terrestrial Organisms	18.3	0.6	2.2	24.2	0	0.6	6.9	22.4	6.8	4.0	1.4	0
Fish	0	0	0	0	0	0	0	0	0	0	0	0
Mean Total Food Weight (mg)	2.0	1.1	1.1	2.1	0.8	4.6	2.9	4.2	14.9	25.6	9.4	0.3
Number of Fish	6	5	5	5	4	5	5	5	2	5	5	1

Table 10. Summary of major food items consumed by steelhead trout young of year, April 1986 - January 1987, at Trinity River food study sites. Values are presented as mean percent weight.

	DATE																		
	April 1986					July 1986				October 1986					January 1987				
	Site					Site				Site					Site				
FOOD ITEM	2	3	5	7	10	2	3	5	7	2	3	5	7	10	2	3	5	7	10
Lumbriculidae	0	0	0	0	0	0	16.1	0	0	0	0	0	0	15.7	0	0	0	0	0
Coleoptera	0	0	0	0.9	0.3	0	0	0	0	0	0	0	0	0.2	0	0	0	0	0
Chironomidae	47.5	35.6	0	1.3	2.1	12.6	4.4	2.6	0.3	2.3	3.4	15.9	16.2	1.3	0	0.7	0.2	0.9	21.3
<u>Simulium</u> <u>sp</u>.	0	0	0	0	0	31.2	45.7	22.3	18.3	9.3	1.3	0.1	0.4	0.1	0	0	0	0	1.2
<u>Baetis</u> <u>sp</u>.	0	10.6	0	0	6.2	17.6	10.9	9.1	9.4	6.9	2.2	0.6	8.5	9.1	0.7	14.4	2.9	7.3	26.7
<u>Rhithrogena</u> <u>sp</u>.	0	0	0	0	0	0	0	0	0	0	0	0	0.4	0.4	6.0	4.7	25.1	2.5	8.1
<u>Ephemerella</u> <u>sp</u>.	33.5	0	0	1.0	2.5	1.7	0	0	1.5	0	0	0	1.7	0	0	0	0	15.8	0.1
<u>Calineuria</u> <u>sp</u>.	0	0	0	0	11.1	0	0	0	0	9.9	0	0	13.2	0	10.6	0	0	0	0
Perlodidae	0	0	0	0	1.0	0	0	0	0	12.2	4.6	0	1.5	0	0	2.1	71.8	50.6	0
<u>Hydropsyche</u> <u>sp</u>.	0	13.8	0	20.6	20.8	0	0	1.2	0	0.5	16.2	11.7	0	1.9	1.7	0.6	0	0	0
<u>Lepidostoma</u> <u>sp</u>.	0	0	0	0	15.8	0	0	5.7	0.2	0.9	3.6	24.1	0.2	0	0	8.8	0	0	0.4
Limnephilidae	0	0	0	0	0	0	0	0	0	0.8	0	0	0	0	0	0	0	0	0
<u>Glossosoma</u> <u>sp</u>.	0	0	0	0	0	0	0	0.4	0	2.1	0	0	0	0	0.3	0	0	0	0
Aerial Aquatic Adults	0	0	0	0	0	15.6	13.7	0	0	11.1	25.5	0	0.6	3.1	0	7.0	0	0	0
Terrestrial Organisms	0.6	0	0	0	0	3.5	0	2.3	0	0.2	1.2	0	0.9	0.8	0	14.3	0	0	0
Fish	0	0	0	0	0	0	0	0	0	0	0	0	11.6	0	0	0	0	0	0
Mean Total Food Weight (mg)	0.3	2.1	0.1	5.5	3.7	3.1	2.1	1.9	5.5	6.6	5.5	4.0	19.9	19.1	4.7	13.3	11.9	9.2	6.0
Number of Fish	3	6	4	1	5	5	5	5	5	10	5	5	7	6	5	6	3	3	6

sp., Calineuria californica, and Perlodidae at all sites Lumbriculidae and fish were important steelhead young of year food items at downriver sites. In January 1987, steelhead young of year fed on Baetis sp., Rhithrogena sp., and both stonefly categories at all sites. Lepidostoma sp., aquatic adults, and terrestrial invertebrates were important food items at upriver sites; while Chironomidae, and Ephemerella sp. were important downriver.

Steelhead trout juveniles in April 1986 consumed several different food categories at various sites (Table 11). Steelhead trout juveniles ate Ephemerella sp., Perlodidae, aquatic adults, and fish at upriver sites; while Rhithrogena sp., Calineuria californica, and Hydropsyche sp. were consumed more commonly downriver. July 1986 steelhead juveniles ate Chironomidae, and Simulium sp. at all sites. Lumbriculidae and Baetis sp. were important food items upriver, and Ephemerella sp. and Hydropsyche sp. were important categories at downriver sites. Because only two juvenile steelhead were sampled in October 1986, little can be ascertained about food habits by site, only that Chironomidae, Baetis sp., aquatic adults, and fish were common food categories. In January 1987, steelhead juveniles ate Perlodid stoneflies at up and downriver sites. Chironomidae, Baetis sp., Rhithrogena sp., and Hydropsyche sp. were important downriver foods for juvenile steelhead trout.

Mean percent weight of major brown trout young-of-year food categories are presented in Table 12. In April 1986, brown trout ate primarily Coleoptera, Chironomidae, and terrestrial invertebrates. Baetis sp. was consumed more at upriver sites 2 and 3. July brown trout young of year ate Simulium sp., and Baetis sp. at all sites. Chironomidae, Ephemerella sp., Limnephilidae, and aquatic adults were eaten at upriver sites while Coleoptera (mostly Elmidae) and Lepidostoma sp. at sites downriver at Steelbridge and Steiner Flat (sites 5 and 7). In October, brown trout young of year commonly ate Baetis sp., Rhithrogena sp., and Hydropsyche sp. At upriver sites, Perlodidae and aquatic adults had a higher mean percent weight in brown trout stomachs, while conversely, Chironomids were more important at down river sites. January 1987 young-of-year brown trout commonly ate Baetis sp., Perlodidae, and Lepidostoma sp. At upriver sites 2 and 3, Rhithrogena sp., Calineuria californica, and Limnephilidae were important brown trout food, while down river, Ephemerella sp. increased in diet importance.

Major brown trout juvenile food categories by mean percent weight are presented in Table 13. April juvenile brown trout commonly ate Limnephilidae and fish. Lumbriculidae, Calineuria californica, and Hydropsyche sp. were increasingly important food items in upriver sites, conversely, Ephemerella sp. and Lepidostoma sp. further downstream at site 5. In July, common brown trout food items were Simulium sp. and aquatic adults. At site 2, Baetis sp. and fish were impor-

Table 11. Summary of major food items consumed by steelhead trout juveniles, April 1986 - January 1987, at Trinity River food study sites. Values are presented as mean percent weight.

	DATE													
	April 1986					July 1986				October 1986		January 1987		
	Site					Site				Site		Site		
FOOD ITEM	2	3	5	7	10	2	3	5	7	2	10	3	7	10
Lumbriculidae	0	0	0	0	0	0	18.7	0	0	0	0	0	0	0
Coleoptera	0	0	0	0	0	0	0	0	1.0	0	0	0	0	0
Chironomidae	0.2	0.1	5.8	0.1	0.2	1.9	3.1	0.1	2.5	15.4	0.1	0	0.1	3.0
Simulium sp.	0	0	0	0	0	5.4	48.7	10.6	16.9	1.6	0	0	0.1	3.0
Baetis sp.	0	0	0	0	0	41.2	3.7	0	6.3	4.2	1.3	0	49.9	9.6
Rhithrogena sp.	0.4	0	0	16.2	0	0	0	0	0	0	0	0	0	2.3
Ephemerella sp.	0	26.6	0	7.6	9.5	1.3	0	0	6.1	0	0	0	0	1.8
Calineuria sp.	7.1	0	0	0	51.0	0	0	0	0	0	0	0	0	0
Perlodidae	0	21.5	0	1.0	1.1	0	0	2.0	0	0	0	32.5	49.0	0
Hydropsyche sp.	0.7	0	15.3	10.5	22.1	0	0	0	9.0	0	0	0	0	5.9
Lepidostoma sp.	0	0	0	0.1	3.6	0	0.1	0.1	0.8	0	0	0	1.0	0.2
Limnephilidae	0	0	7.5	0	0	0	0	0	0	0	0	0	0	0
Glossosoma sp.	0	1.0	0	0	0	0	0.4	0	0	0	0	0.3	0	0.2
Aerial Aquatic Adults	15.8	0	0	0	0	0	6.2	0	2.0	64.7	0	0	0	0
Terrestrial Organisms	0	1.2	0	2.4	0	1.0	1.3	0.2	1.2	0	0	0	0	0
Fish	11.4	0	0	0	0	0	0	0	0	0	83.5	0	0	0
Mean Total Food Weight (mg)	39.7	8.6	23.5	18.4	31.2	47.7	7.9	10.6	13.9	5.2	43.6	40.7	10.2	47.1
Number of Fish	4	3	3	5	7	2	5	2	5	1	1	1	2	6

Table 12. Summary of major food items consumed by brown trout young of year, April 1986 - January 1987, at Trinity River food study sites. Values are presented as mean percent weight.

	DATE													
	April 1986			July 1986				October 1986				January 1987		
	Site			Site				Site				Site		
FOOD ITEM	2	3	5	2	3	5	7	2	3	5	7	2	3	5
Lumbriculidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Coleoptera	0	16.5	0	0	0	2.7	0	0	0	0	0	0	0	0
Chironomidae	7.3	46.0	4.0	5.5	9.2	1.0	0.6	0	0.2	23.5	6.3	0	0	0
Simulium sp.	0	0	0	25.7	29.2	19.0	72.4	0.3	0	0	0	0.3	0	0
Baetis sp.	44.0	5.2	0.2	57.1	9.8	20.5	1.2	6.0	16.2	10.3	2.3	1.3	5.4	1.0
Rhithrogena sp.	0	0	0	0	0	0	0	2.4	0	3.3	5.7	17.9	0	3.0
Ephemerella sp.	0	0	0	0	10.2	0	0	0	0	0	0	6.8	0	25.0
Calineuria sp.	0	0	0	0	0	0	0	0	0	0	0	37.3	0	0
Perlodidae	0	0	0	0	0	0	0	19.7	31.6	3.4	3.3	10.3	18.3	57.9
Hydropsyche sp.	0	0	0	0	1.1	0.9	0	1.0	1.2	3.2	1.6	0	0	0
Lepidostoma sp.	0	0	0	0	0.6	29.2	1.9	0	8.0	30.3	1.0	0	62.9	0
Limnephilidae	0	0	0	4.5	0	0	0	0.1	0	0	0	22.1	0	0
Glossosoma sp.	0	0	0	0.2	0	0	0	0.7	0	1.6	0	0	0	0
Aerial Aquatic Adults	0	0	0	0	14.1	1.0	0	20.0	13.9	6.3	1.6	0	0	0
Terrestrial Organisms	0	2.6	0.4	0	0.3	0.2	0	0	0.6	1.0	0.5	0	0	0
Fish	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mean Total Food Weight (mg)	0.9	2.0	0.8	2.9	4.0	3.3	7.4	14.2	8.3	2.7	22.0	11.9	7.1	17.6
Number of Fish	2	5	2	5	5	5	1	5	7	7	3	5	3	4

Table 13. Summary of major food items consumed by brown trout juveniles, April 1986 - January 1987, at Trinity River food study sites. Values are presented as mean percent weight.

	DATE									
	April 1986			July 1986			October 1986			January 1987
	Site			Site			Site			Site
FOOD ITEM	2	3	5	2	3	5	2	3	7	2
Lumbriculidae	20.0	11.4	0	0	0	0	0	0	0	10.5
Coleoptera	0	0	0	0	0	7.6	0	0	0	0
Chironomidae	0.6	0	0	0.8	3.0	0	1.4	0.1	0.1	0
Simulium sp.	0.2	0	0	4.8	87.0	0	0.1	0.1	0	0
Baetis sp.	2.9	0.4	0	31.0	0	0	9.4	0.4	4.2	0.5
Rhithrogena sp.	0	0	0	1.5	0	0	0	0	0	0
Ephemerella sp.	0	0	14.1	0	0	8.8	0	0	0.9	0
Calineuria sp.	33.7	23.2	0	0	0	0	0	0	62.9	0
Perlodidae	0	0.6	0	0	0	0	0	14.0	0	41.5
Hydropsyche sp.	7.9	0	0	0	0	0	0	0	0	0
Lepidostoma sp.	0	0	15.1	0	1.3	68.4	0.7	3.4	0	0.7
Limnephilidae	2.8	39.5	29.8	0	0	0	1.1	8.7	0	42.8
Glossosoma sp.	0.6	0	0	0.1	0.2	0	7.6	0.3	0	0
Aerial Aquatic Adults	0	0	0	4.3	0	10.3	18.0	2.8	0	0
Terrestrial Organisms	1.0	0	0	0.1	0	0	0	0	0	0
Fish	0	14.0	0	22.8	0	0	0	0	0	0
Mean Total Food Weight (mg)	26.2	48.0	30.7	70.7	5.3	4.4	12.4	101.4	57.4	40.8
Number of Fish	5	5	2	4	2	2	4	1	1	3

tant brown trout food items while downstream at site 5, Coleoptera, Ephemerella sp., and Lepidostoma sp. were consumed. Common food items for brown trout juveniles in October 1986 were: Baetis sp., Calineuria californica, Limnephilidae, Glossosoma sp., and aquatic adults. January 1987 juvenile brown trout ate Lumbriculidae, Perlodidae, and Limnephilidae.

Food Overlap

We calculated the Schoener food overlap index to examine dietary overlap between different salmonid species and life-stages for each season. Schoener dietary overlap varies from 0 (no overlap) to 1 (complete overlap), and is considered biologically significant when values exceed 0.60 (Wallace 1981).

In April 1986, substantial overlap occurred between chinook and coho fry, and also coho and steelhead trout fry (Table 14). Substantial dietary overlap was observed for almost all combinations of steelhead and brown trout young of year and juveniles in July 1986 (Table 15). Not enough chinook salmon were collected to compare dietary overlap with other salmonids.

In October 1986, dietary overlap had decreased from the high overlap values observed in July (Table 16). Substantial diet overlap occurred only between brown trout and steelhead young of year in October. January 1987 Schoener overlap indices were generally low; substantial overlap occurred only between steelhead young of year and juveniles (Table 17).

Table 14. Schoener food overlap indices calculated for salmonids, all sites pooled, April 1986. The following abbreviations were used for fish species: SH YOY - steelhead young of the year; SH JUV - steelhead juveniles; BT YOY brown trout young of the year; BT JUV - brown trout juveniles.

	COHO	SH YOY	SH JUV	BT YOY	BT JUV
CHINOOK	0.72	0.54	0.29	0.40	0.11
COHO	--	0.60	0.32	0.50	0.11
SH YOY	--	--	0.45	0.51	0.19
SH JUV	--	--	--	0.03	0.48
BT YOY	--	--	--	--	0.03

Table 15. Schoener food overlap indices calculated for salmonids, all sites pooled, July 1986. The following abbreviations were used for fish species: SH YOY - steelhead young of the year; SH JUV - steelhead juveniles; BT YOY brown trout young of the year; BT JUV - brown trout juveniles.

	SH YOY	SH JUV	BT YOY	BT JUV
COHO	0.58	0.55	0.43	0.42
SH YOY	--	0.85	0.70	0.61
SH JUV	--	--	0.67	0.59
BT YOY	--	--	--	0.73

Table 16. Schoener food overlap indices calculated for salmonids, all sites pooled, October 1986. The following abbreviations were used for fish species: SH YOY - steelhead young of the year; SH JUV - steelhead juveniles; BT YOY brown trout young of the year; BT JUV - brown trout juveniles.

	SH YOY	SH JUV	BT YOY	BT JUV
COHO	0.45	0.51	0.38	0.42
SH YOY	--	0.34	0.63	0.52
SH JUV	--	--	0.30	0.36
BT YOY	--	--	--	0.46

Table 17. Schoener food overlap indices calculated for salmonids, all sites pooled, January 1987. The following abbreviations were used for fish species: SH YOY - steelhead young of the year; SH JUV - steelhead juveniles; BT YOY - brown trout young of the year; BT JUV - brown trout juveniles.

	COHO	SH YOY	SH JUV	BT YOY	BT JUV
CHINOOK	0.02	0.29	0.48	0.03	0.01
COHO	--	0.19	0.06	0.10	0.00
SH YOY	--	--	0.69	0.56	0.36
SH JUV	--	--	--	0.41	0.36
BT YOY	--	--	--	--	0.43

DISCUSSION

Sub-sample Comparison

Kolmogorov-Smirnov distribution tests generally concurred with expectations on possible sampling bias between growth- and food study-sampled fish. Our basic concern was that sub-samples might not represent the multiple age classes of trout in the sampled population, and this appeared to not be the case in most instances. Significant differences found for length frequency distributions of April chinook and coho salmon may not imply biological significance because sampled fish occupied a narrow size range and were from a single year class.

Food Size Selectivity

Although all species had significant correlation coefficients (Pearson-product moment), slope and correlation coefficients were low. This was a result of a wide range of food sizes consumed by larger fish. Relationships may have also been obscured by food items such as Oligochaetes (most food items over 30 mm length), which were much longer than other invertebrates consumed. In general, fish ate larger food items as they increased in size. Although larger fish ate items of greater size than smaller fish, they consumed smaller invertebrates as well. A better relationship might have been developed for chinook salmon if larger juveniles had been sampled.

Seasonal and Daily Feeding Patterns

Seasonal trends in the weight of food in stomachs were apparent for all species. Young-of-year fish for all species contained more food as they matured during the course of the year before emigrating. Juvenile steelhead trout that overwinter in the river had their highest mean food weight in January. This may have resulted from low digestion rates due to winter water temperatures in the range of 38 ^{o}F, rather than higher food consumption. Indeed, Brocksen and Bugge (1974) found that food assimilation in rainbow trout increased with temperature. Trinity River steelhead trout become sluggish and seek refuge in cobble interstices during winter temperatures below 45 ^{o} F. (U.S. Fish and Wildlife Service 1986). Bjornn, et. al. (1977) found that Idaho steelhead entered substrate interstices below 41 ^{o} F during tests in artificial stream channels. It is likely that with reduced activity in winter, steelhead trout may actually eat less but retain food in their stomachs because of low digestion rates, and have subsequently low growth rates. Lowest total mean food weights corresponded with highest growth rates and temperatures in April and July (see pages 81-91). These results may have occurred because of high digestion rates during peak growth.

Overwintering brown trout juveniles similarly use cobble interstices as winter rearing habitat, with reduced activity and growth (U.S. Fish and Wildlife Service 1986). However, virtually no change in total food weight consumed with season was observed for brown trout juveniles in this study, probably because of low numbers of brown trout sampled, with high variance in total food weight.

Chinook and coho salmon showed differing trends for diel feeding in our study. Johnson and Johnson (1981) found that coho fry fed heaviest from 2000 to 2400 hours, and that diet changed nocturnally. They found that coho salmon primarily fed on drift, which changed in composition at night. Feeding by steelhead trout generally was lowest mid-day. Our results are in agreement with Johnson and Johnson (1981) who found highest relative food contents in late afternoon, and lowest at mid-day. Tippets and Moyle (1978) concluded that rainbow trout fed primarily during the day in the turbid McCloud River.

Salmonid Feeding Habits

We found that Trinity River chinook salmon fed on Chironomidae and Baetis sp., and this diet diversified to include other food items as the fish grew. Chinook salmon fed on drifting invertebrates as fry, while juveniles occasionally took food off the stream bottom. Occasional benthic feeding seems probable because the food items Lepidostoma sp. and Glossoma sp. are seldom found in the stream drift. Becker (1972) found Columbia River chinook fed primarily upon drifting prey (Chironomidae), and that they are habitat opportunists.

Trinity River coho salmon primarily fed on drifting organisms as fry and juveniles, but occasionally preyed upon benthic invertebrates. We found that coho salmon fed on drifting immature and adult aquatic invertebrates, and on terrestrial insects falling into the stream. Johnson and Ringler (1980) studied the diets of coho salmon in a tributary of Lake Ontario, and found that their diet was closely associated with the drift.

Steelhead trout young-of-year diet varied by river location and season. Steelhead sampled in April fed more on drift at upriver sites, while downriver fish fed primarily on benthic invertebrates. Drifting invertebrates were the most important food source at all sites in July, while during October and January diet shifted to benthic invertebrates. Juvenile steelhead trout generally fed more on benthic invertebrates from October through April, with more drift feeding in July. Jenkins, et al. (1970) found that rainbow trout introduced into Convict Creek fed on mostly benthic invertebrates in December, because of a lack of aerial invertebrates contributing to the drift.

Trinity River brown trout young-of-year fed primarily on drifting Chironomidae and Simulium sp., consuming a greater proportion of their diet as benthos while they grew into juveniles from July to January. Juvenile brown trout fed primarily on benthic invertebrates, but consumed more drift during July.

Of 145 steelhead and 88 brown trout sampled, only 5 had preyed upon smaller fish. Three coho out of 53 ate other fish. However, because of their weight, fish were an important dietary component.

Food Overlap

High dietary overlap between coho and chinook fry in April resulted from their use of stream margins as rearing areas and their diet of drifting invertebrates. Similar high overlap occurred between steelhead trout fry and coho, because they also rear in shallow water and stream margins.

In July, coho salmon had moved to deeper slow water, while trout occupied riffles. This accounted for low diet overlap between coho and trout, while steelhead and brown trout had high dietary overlap. Chinook salmon emigrated out of the upper Trinity by this time. Johnson and Ringler (1980) also found low dietary overlap between summer populations of sympatric coho and steelhead, attributing this to habitat segregation.

October dietary overlap was still high between steelhead and brown trout young-of-year. Overlap between young-of-year and juvenile steelhead may have been low because few juveniles were captured. January feeding overlap was high between young-of-year and juvenile steelhead because by this time, many young-of-year steelhead had caught up in size to juveniles, and shared similar habits.

FINDINGS

Population and growth results for April 1986 to January 1987 indicate that Trinity River salmonids coexisted at levels below carrying capacity. Seasonally high food overlap indices in July 1986 for steelhead and brown trout suggest that although fish were exploiting similar resources, food was not limiting populations during the period studied.

Future sampling years planned for the food study will help clarify the relationship of food resources to juvenile salmonid abundance and growth in the Trinity River. Upon completion of the invertebrate study, we will be able to quantify fish feeding selectivity. Current literature and and our observations in this study imply that juvenile salmonids basically feed on what is available in the river.

EVALUATION OF RESTORED SPAWNING RIFFLES

INTRODUCTION

Habitat use monitoring was included in the Trinity River Flow Evaluation to evaluate selected restoration or enhancement projects authorized by the the Trinity River Management Program. Effective monitoring studies will become important references to assist Fishery Managers in the selection of future restoration projects.

In the summer of 1986 the California Department of Fish & Game in cooperation with the Trinity County Resource Conservation District proposed to rip six spawning riffles in the upper Trinity River of California. The primary objective of the project was to improve the quality of salmon spawning habitat by breaking up cemented substrates and reducing the amount of fine sand within those substrates. A reduction in the percentage of fine sand present in the substrates may increase invertebrate production by increasing substrate interstitial surface areas. An increase in substrate interstitices is also expected to improve juvenile salmonid over-wintering habitat by providing refuge sites where juvenile salmonids can avoid extreme environmental conditions.

Substrates were disturbed by a crawler tractor equiped with rip bars. Work began on September 3, 1986 and continued for two weeks. The uppermost site was ripped first with work progresing downstream. Extra funds and time allowed for a seventh riffle to be ripped below Junction City.

The purpose of this evaluation is to determine the effectiveness of ripping substrates to reduce the amount of fine sediment, mainly decomposed granitic sand, within substrates and to monitor the spawning use of these ripped areas by adult chinook salmon. Hydraulic parameters such as mean column velocity and total depth will also be monitored in order to establish other possible effects on spawning habitat use by chinook salmon other than substrate.

STUDY SITES

Six sites on the Trinity River were recommended by Ed Miller, California Department of Fish & Game District Fishery Biologist, as prefered locations to be ripped (Figure 1). The Diemer site is the uppemost site and is located on private property adjacent to the Trinity River Lodge south of Rush Creek Road and upstream of the confluence of Rush Creek. The

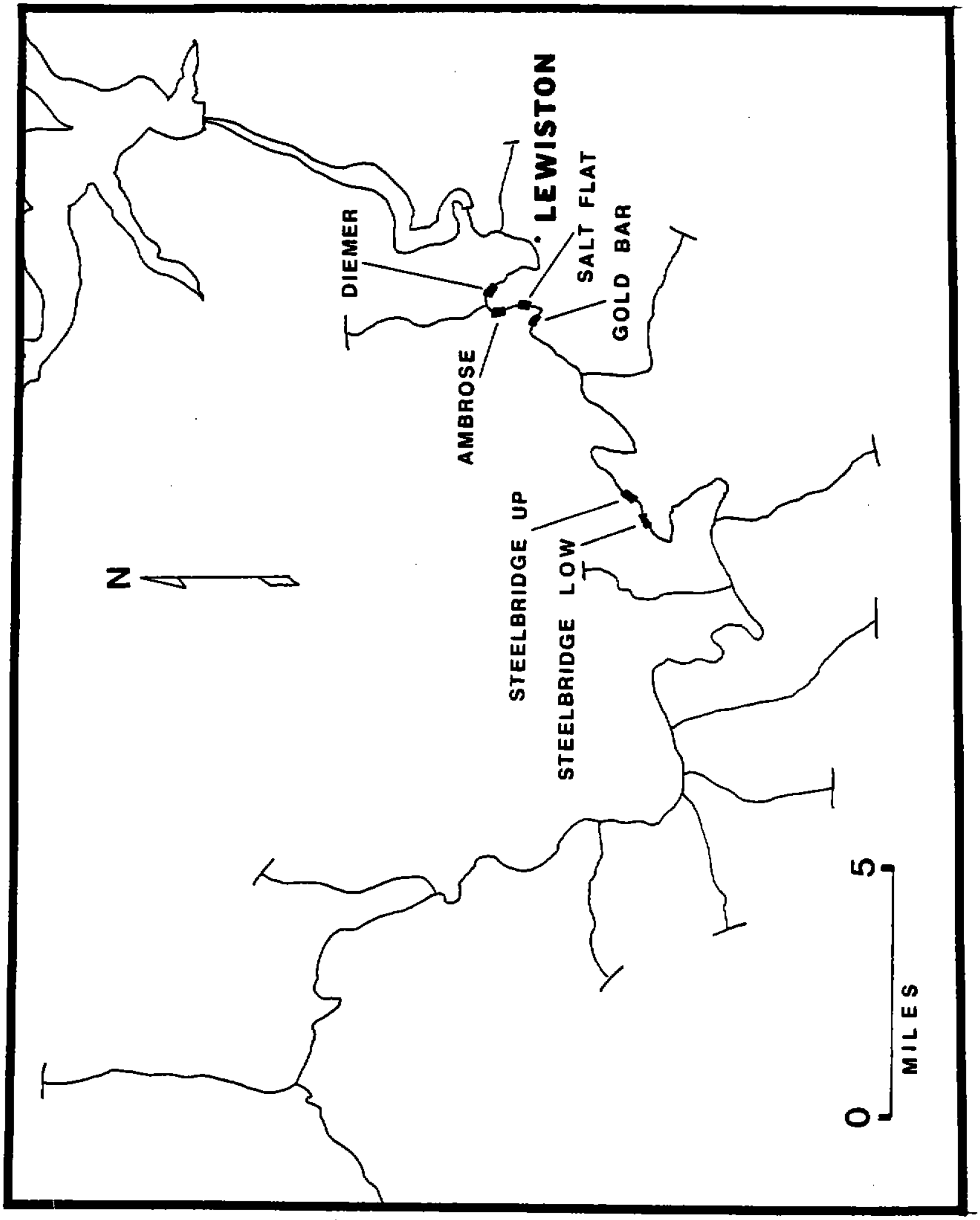


Figure 1. Location of spawning gravel rip sites of the upper Trinity River, Calif., 1986.

Ambrose site is located approximately 1/4 mile below the confluence of Rush Creek on both lands adjacent to private property and lands administered by the Bureau of Land Management . Both the Salt Flat and Gold Bar Sites are located approximately four to five river miles downstream of Lewiston Dam on private property. The Upper Steelbridge Site is accessible by Union Hill Mine Road on the North side of the river and is located on lands administered by the Bureau of Land Management. The Lower Steelbridge Site is adjacent to the BLM campground at the end of Steelbridge Road. The upper four riffles, Diemer, Ambrose, Salt Flat, and Gold Bar, were selected for evaluation.

METHODS

Habitat Mapping

Each riffle was evaluated before and after ripping occurred. Each site evaluation consisted of a series of isopleth habitat maps depicting total depth and mean column velocity before and after ripping. Mean column water velocities and total depth were measured with a Price AA current meter and top setting wading rod. Water velocity measurements were taken at 0.4 times depth for water less than 2.5 feet deep, and at the average of two measurements taken at 0.2 and 0.8 times depth for water 2.5 feet deep or greater. Substrate composition was described utilizing the Modified Brusven Substrate Index (Brusven 1977) using the substrate size categories shown in Table 1. Substrate descriptions were noted at each location where a depth and velocity measurement was

Table 1: Brusven index substrate size classes used to evaluate effects of ripping riffles in the Trinity River, CA.

Description	Particle size	Code
fines	0 - 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	600 + mm	8
bedrock		9

taken. Several photographs of the substrate were taken at each riffle to assist in substrate descriptions and to more effectively evaluate substrate changes before and after project completion. Cover objects, such as boulders, logs, and root wads, were described and mapped before and after project completion. The actual points of data collection used for mapping were obtained using a Lietz/Sokkisha Total Station model SDM3FR/SDM3F.

Spawning Survey

Spawning surveys were conducted at each site towards the end of the chinook salmon spawning season during November. Chinook salmon redd locations were determined with the use of the Lietz/Sokkisha Total Station. The total depth, mean column velocity and fish nose velocity were also collected at the top of each redd. Fish nose velocities were taken at 0.4 feet above the stream bottom. Redd size and area were obtained by taking three width measurements and one length measurement. Redd length was measured from the top of the redd to end of the tailspill. Redd widths were measured at 0.25, 0.50, and at 0.75 of the total redd length. These three measurements generally corresponded with the area at the top of the redd, across the center of the pot, and across the center of the tailspill. Redd area was calculated by multiplying the average of the redd widths by redd length. Category II habitat utilization criteria were developed for total depth and mean column velocities as described by Bovee (1986).

RESULTS

Habitat maps of each riffle displaying total depth, mean column velocity, and cover items before and after each riffle was ripped are presented in Appendix B. The tractor rip bars left a series of parallel ridges and troughs. Approximately one foot separated ridge tops from trough bottoms. These erratic changes in depth complicated our post-project mapping. In order to resolve this problem average depth estimates were made with the realization that there may be errors of up to 0.5 feet in our post-project maps.

Diemer Site

Substrate ripping in the Diemer site caused major changes in total depths and mean column velocities in the upper section of the site. The tractor managed to pull up several large boulders and formed several mounds of cobble, greatly increasing cover and velocity diversity in this upper section. The numerous shear velocity zones and eddies that were created made effective mapping of post-rip velocities nearly impossible. The most important fact to realize about this upper section is that the velocity profile changed from one of fairly consistent, almost laminar, flow patterns to a profile that is very irregular and highly diverse in velocity.

Changes in the substrate composition for the Diemer site are presented in Figure 2. Dominant and subdominant substrate compositions changed very little as a result of substrate ripping. The percentage of fines within substrates declined considerably after substrates were ripped. Before the substrates had been ripped, more than half of our observations described substrates as 50 percent of more embedded in fines, after the substrates were ripped more than half of observations described substrates as less than 30 percent embedded.

Ambrose Site

Substrate ripping at the Ambrose site generally increased total depths over the entire site. In the upper section of the site along the left bank and in the lower section along the right bank large areas of shallow water were deepened to greater than 1.0 feet. The largest change occurred along the upstream boundry of the site where depths were increased along the entire river cross-section.

The depth increases along the upstream boundary of the site caused velocities to slow, eliminating a chute of fast water in which velocities exceeded 4.0 cfs. In place of the chute, velocities from 3.0 to 4.0 cfs are present across the greater part of the river's width forming a fast wide run. Directly below this run velocities have decreased slightly from the pre-rip conditions, increasing the area of water with velocities from 1.0 to 2.0 cfs. Farther downstream towards the lower boundary of the site velocities tend to increase. The amount of area with water velocities between 2.0 and 3.0 cfs increased, while, the area of slow water decreased.

Nine boulders and cobble mounds were placed within the site. The boulders were donated by a local land owner and the cobble mounds were formed by the tractor. These objects provide some velocity shelters and some limited overhead cover.

The predominant substrates present in the site range from large gravel (2" to 3") to large cobble (9" to 12"). Both dominant and subdominant substrates showed slight increases in percent observed for larger substrate size categories (Figure 3). The percentage of fines observed within substrates decreased greatly after being ripped.

Salt Flat Site

Total depths in the Salt Flat site were increased everywhere with two exceptions. The channel along the left, which had been over 4.0 feet deep, was filled and now is less than 4.0 feet deep. Depths in the lower section of the right channel between the cobble bar and right bank have been decreased from over 2.0 feet to less than 1.0 foot deep.

Increased water depths across the upper boundary of the site and across the top of the right side channel entrance eliminated a chute that was present in that channel. Velocities across the upper section of the site increased slightly. In the left channel velocities were reduced from over 3.5 cfs to below 3.0 cfs. An increase in velocities was observed at the end of the left channel where water begins to enter another split channel outside of the ripping boundary.

There were no increases in large cover objects as a result of ripping.

Dominant and subdominant substrate compositions changed very little from pre-rip conditions (Figure 4). The Salt Flat site contained larger amounts of fine sand compared to the other sites that were evaluated. Under pre-rip conditions the majority of substrate observations were embedded by 50% or more in fines. Embeddedness levels dropped to less than 40% for the majority of observations made after substrate ripping.

Gold Bar Site

Of the four sites that were evaluated, Gold Bar best represents riffle habitat. This site has the highest gradient and is the only site that contains considerable amounts of turbulent water. Substrate ripping caused only minor changes in both total depths and mean column velocities. Depths along the thalweg were increased slightly causing a decrease in velocities by approximately 0.5 cfs.

No gains in large cover objects were observed anywhere in the site.

Substrate compositions changed slightly showing a higher percentage of medium (6" to 9") and large (9" to 12") cobbles after substrate ripping (Figure 5). Substrate embeddeness in fines showed a large decreased after ripping. During the postrip evaluation 60% of observations of substrate were clear of fine sediment.

Chinook Salmon Spawning

The locations of chinook salmon redds for each site are located on the habitat maps presented in Appendix B. The total number of chinook salmon redds observed by site and date are presented in Table 2. A total of 216 redds were observed for all sites. The average chinook salmon redd was found to be 43.7 square feet in area (Figure 6). Habitat use criteria describing total depths and mean column velocities selected by spawning chinook salmon are presented in Figure 7.

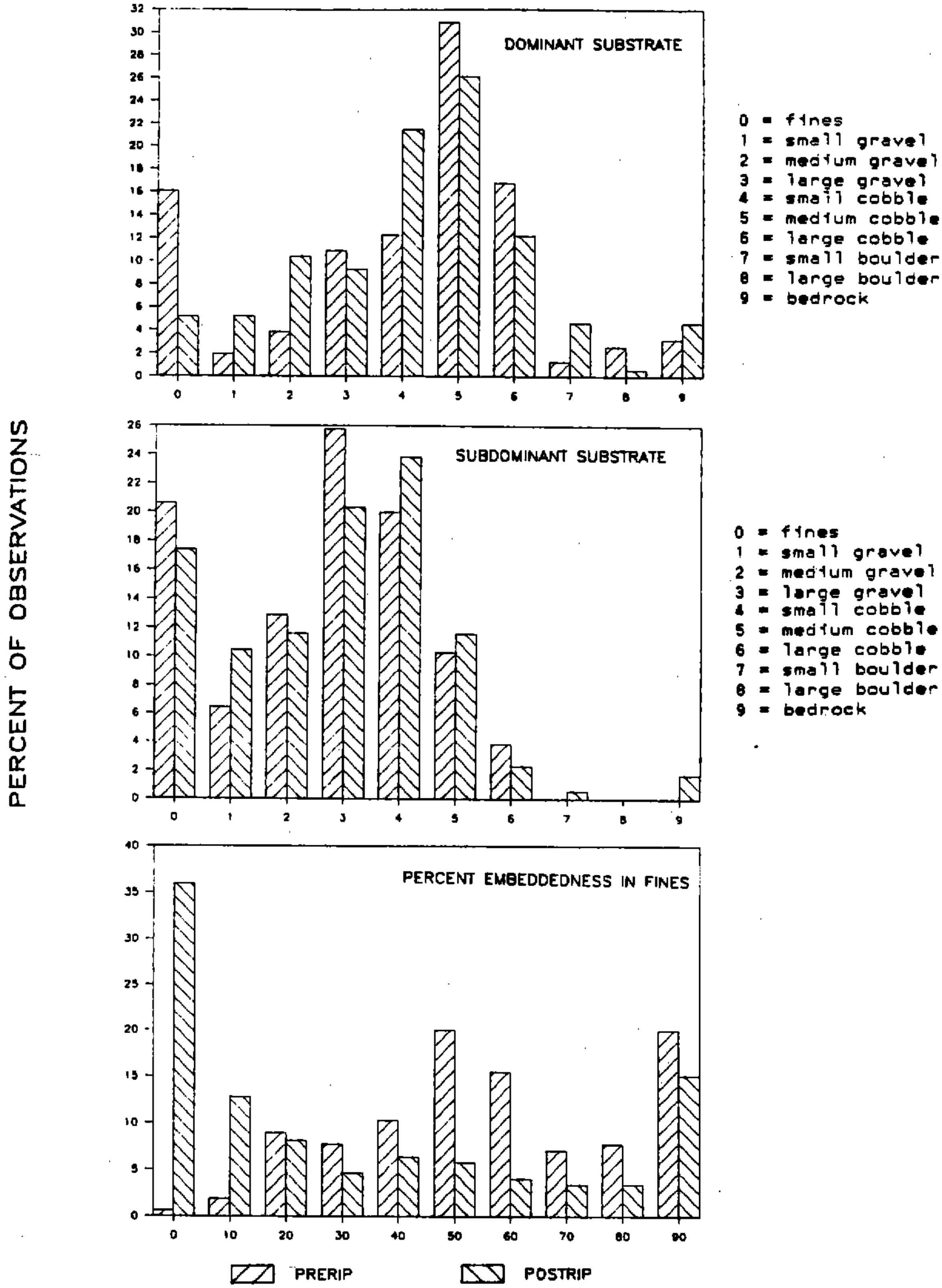


Figure 2. Percentage of substrates, dominant, subdominant, and percent embedded in fines, at the Diemer site before and after ripping.

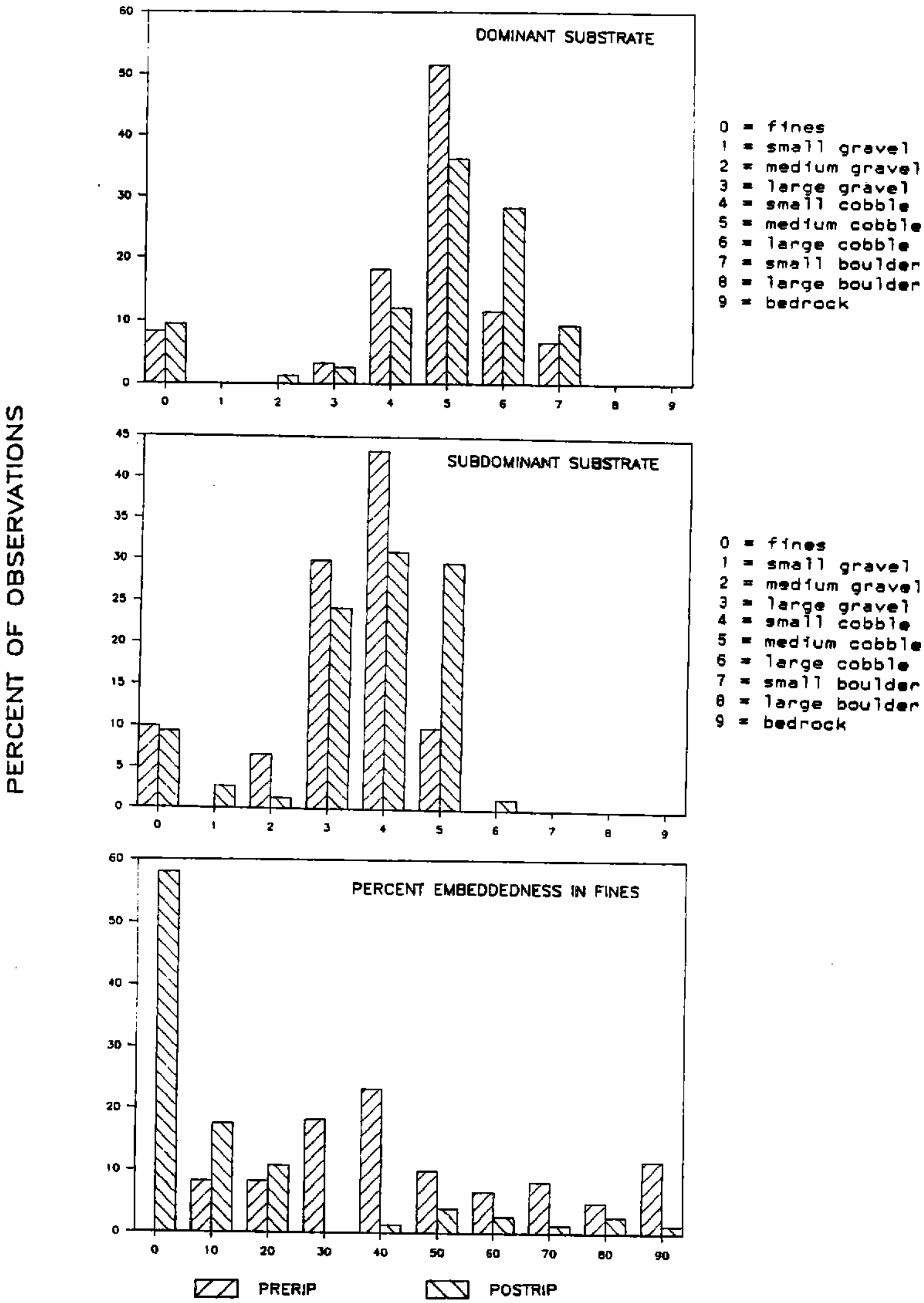


Figure 3. Percentage of substrates, dominant, subdominant, and percent embedded in fines, at the Ambrose site before and after ripping.

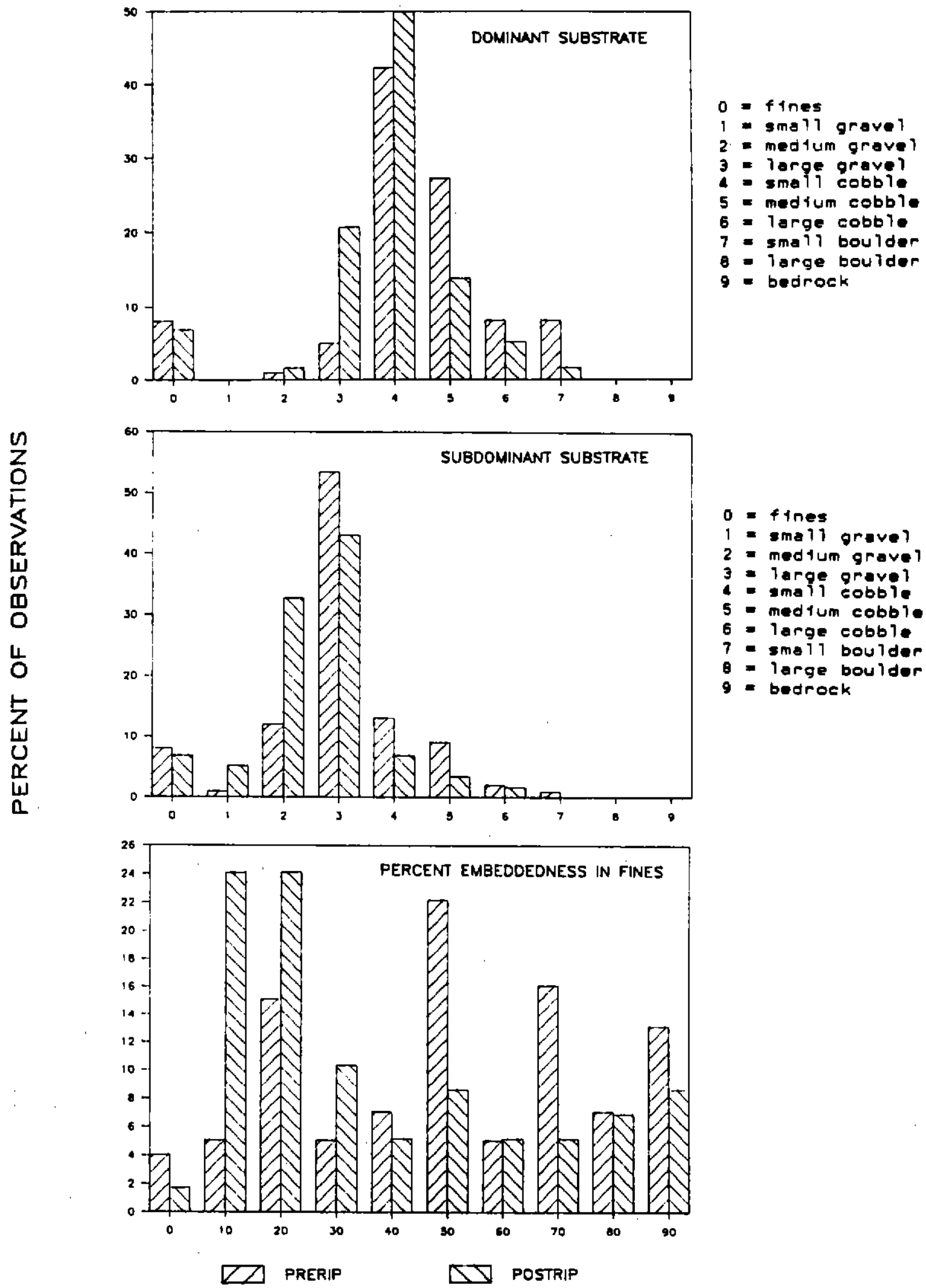


Figure 4. Percentage of substrates, dominant, subdominant, and percent embedded in fines, at the Salt Flat site before and after ripping.

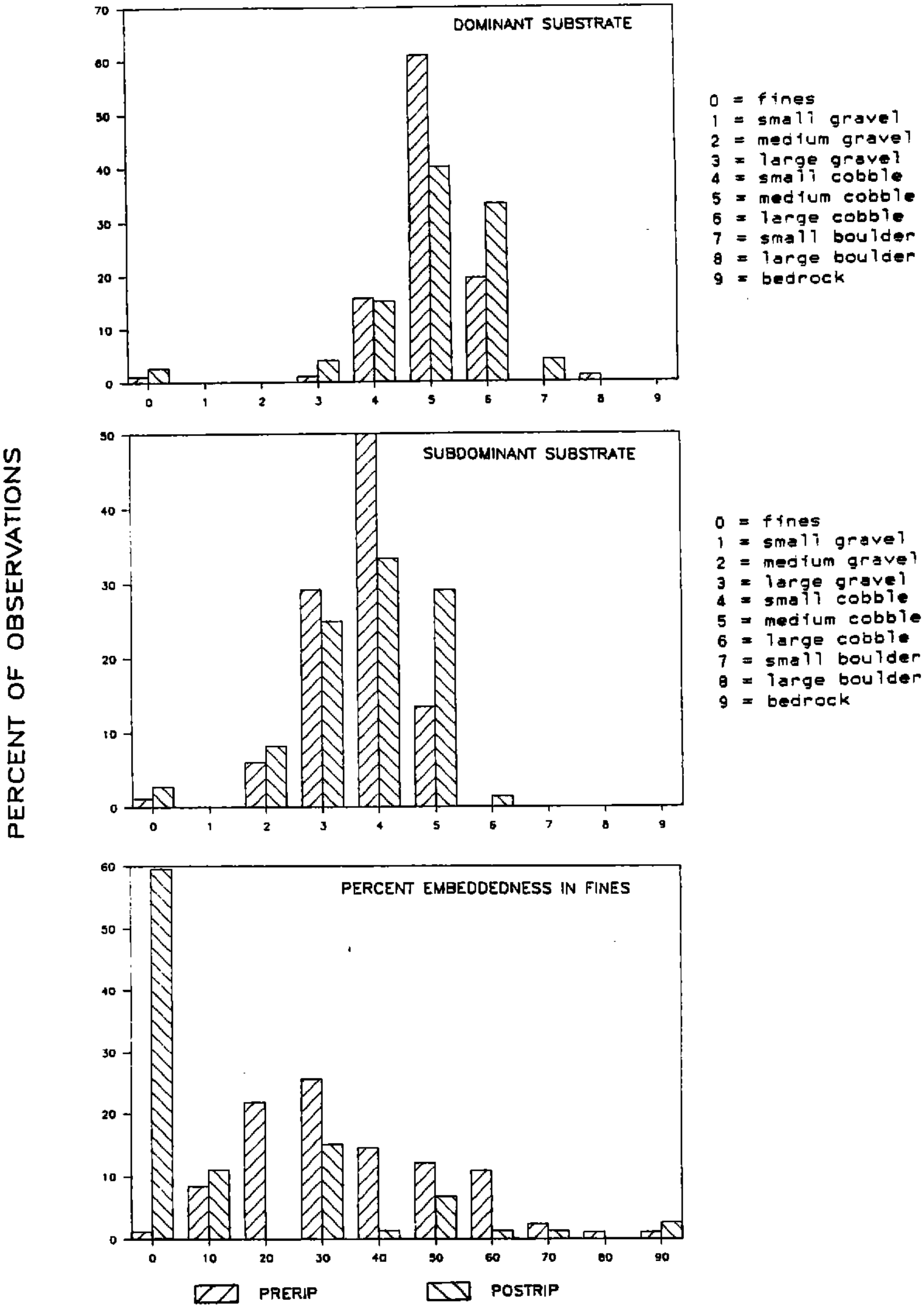


Figure 5. Percentage of substrates, dominant, subdominant, and percent embedded in fines, at the Gold Bar site before and after ripping.

Table 2. Number of chinook salmon redds observed at each gravel restoration site, Trinity River, CA. 1987.

Study Site	Date	Number of Redds
Diemer	11/ 5/86	70
Ambrose	11/ 5/86	37
Salt Flat	11/12/86	37
Gold Bar	11/12/86	72

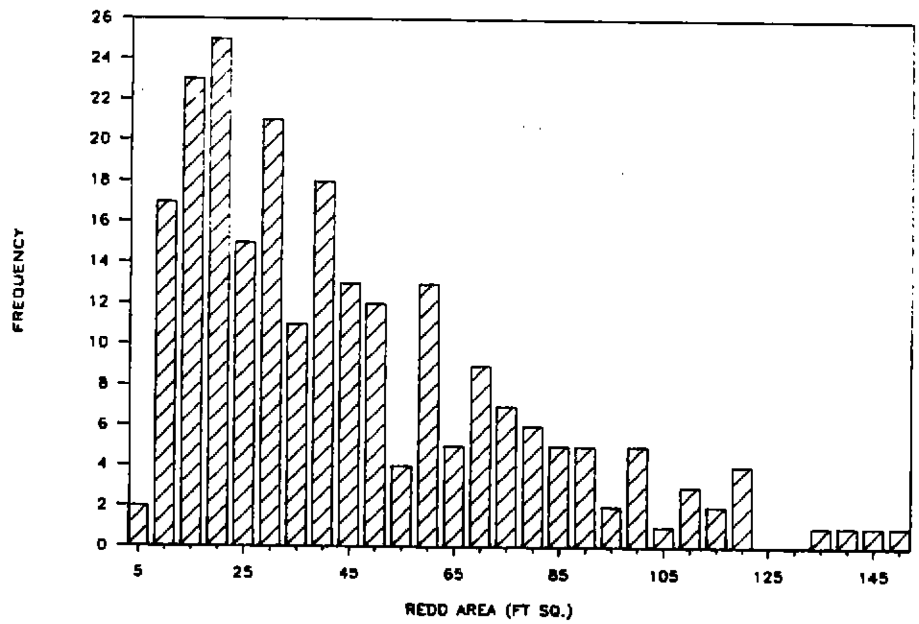


Figure 6. Frequency of chinook salmon redd areas in restored riffles. Average redd area was 43.7 square feet.

DISCUSSION

Substrate ripping appeared to have little affect on changes of dominant and subdominant substrate compositions. In the Ambrose and Gold Bar sites there was a slight increase in percentages of large cobble substrates. The tractor rip bars probably pulled these larger cobbles from underneath bringing them to the surface. There is a possibility that our sampling method, which used visual estimation of substrate size from above, caused the presence of larger sub-

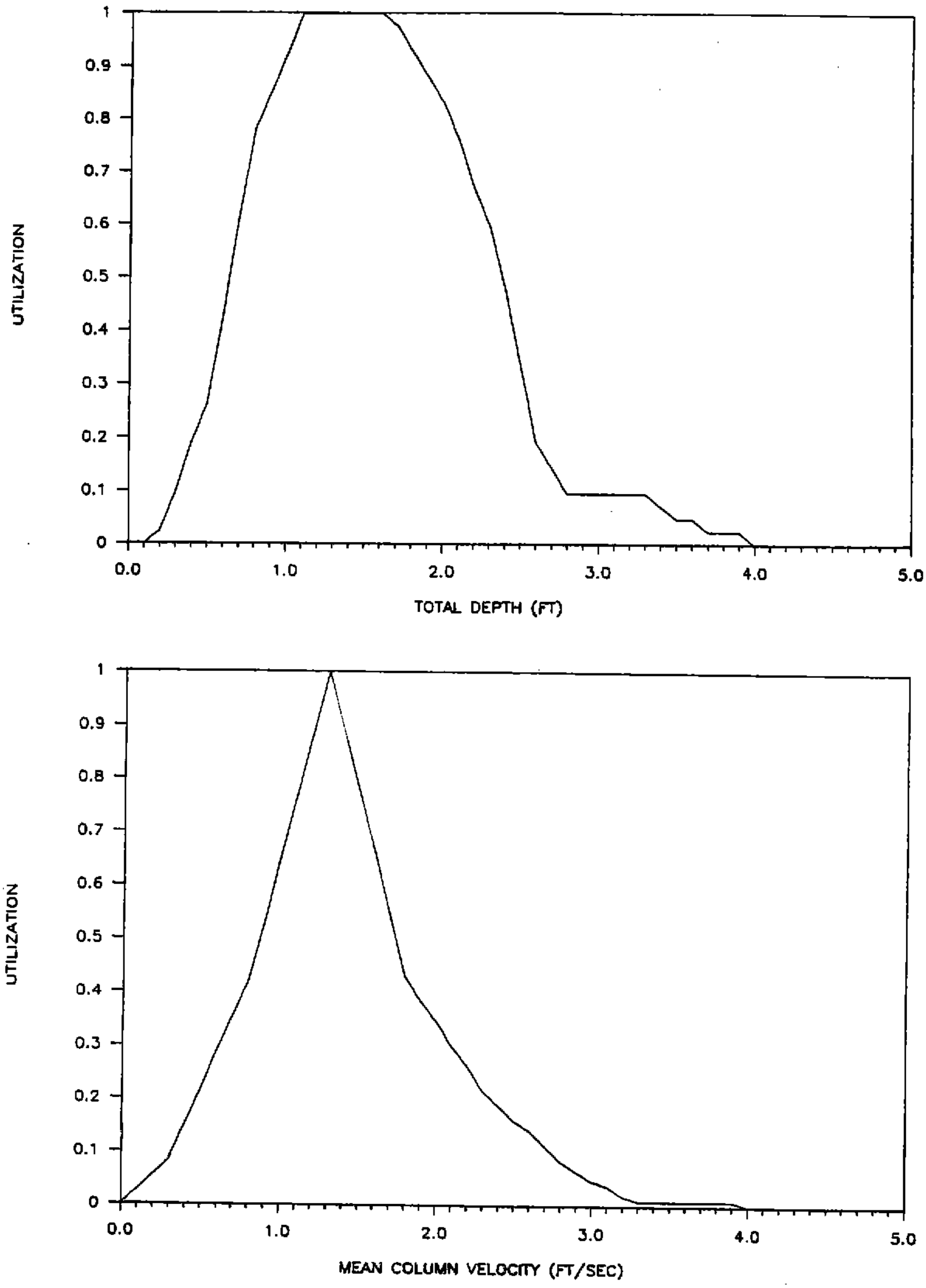


Figure 7. Habitat use criteria describing total depths and mean column velocities selected by spawning chinook salmon within the rip sites, Trinity River, Ca., 1986.

strates to be underestimated during our pre-rip evaluation. This would be particularly true when substrates were cemented or too large for the observers to physically remove for accurate size categorization.

A large decrease in the percentage of fine substrates was observed at all sites. During the ripping operation silt and organic material were effectively flushed downstream below the rip sites. Increased river turbidity levels were noticeable for several miles downstream of the ripping operation. Decomposed granitic sand was not as easily removed from the substrates by the ripping. After the project, deposits of sand were still noticeable along the length of the troughs that were formed by the rip bars. As the tractor churned the substrates sand seemed to settle down underneath the surface to varying depths leaving the surface material clear of fines. Some spawning chinook salmon did manage to reach this sandy layer while digging out their redds.

The quality of spawning gravels was improved by the substrate ripping. In sandy areas of the river, redds that were constructed in the early part of the season were often covered in sand by spawning activities which occurred upstream later in the season. The percent survival of fry salmon in redds covered by sand is probably lower due to entrapment of fry in the redd. With reduced amounts of surface sand, the number of redds that became buried in sand was reduced, probably enhancing chinook fry survival.

Rearing habitat for juvenile salmonids, particularly steelhead trout, was improved at the Diemer and Ambrose sites through the creation of several large roughness elements. Lisle (1981) describes the importance of these elements, boulders and woody debris, as a key resource to fish habitat by providing a diversity of channel form and substrate. The velocity shelters around these large cover objects also provide excellent feeding areas for juvenile salmonids where territories can be established in slow velocity areas close to fast water where drifting invertebrates are more abundant. The large decreases in the embeddedness in fines that resulted from the ripping operation substantially increased interstitial area between cobble substrates. These areas have been found to be valuable overwintering habitats on the Trinity River for juvenile salmonids by providing refuge sites from high flows and predators (U.S. Fish and Wildlife Service 1986).

An evaluation of the effects of ripping on the aquatic invertebrates will not be completed until next year after recolonization of substrates can be evaluated.

Depth and velocity characteristics shifted somewhat in location as a result of ripping, but net changes in the hydraulic characteristics of each site appear to have been limited. Although ripping failed to remove much of the granitic sand in the substrates, a dramatic improvement did occur in the embeddedness of the surface layer. This improved spawning habitat and possibly improved overwintering habitat for juvenile salmonids by increasing interstitial area between cobbles. The creation of large velocity shelters at the Diemer and Ambrose sites enhanced rearing habitat by increasing velocity diversities in these faster water areas.

PROGRAM PLANNING, DIRECTION, AND COORDINATION

Generally, activities associated with the Trinity River Flow Evaluation Study for 1988 will 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 can be affected by streamflow within the Trinity River.

Determination of Habitat Availability and Needs (TASK 3)

During 1988 we plan to continue to develop an analysis of the amount of salmon and steelhead habitat available in the Trinity River under various flow conditions. Existing information from previous Task 2 and Task 3 investigations will be used to produce a time series analysis of habitat availability under a number of alternative flow regimes. In addition, we are planning to continue monitoring mainstem water temperatures and to analyze their relationship to tributary inflow water temperatures and river releases from Lewiston Dam. These data will be used as validation points when conducting an instream water temperature model for the Trinity. Although the area of primary concern is between Lewiston Dam and the North Fork, we plan to establish water temperature monitoring stations in the lower reaches as well.

A more detailed evaluation of mainstem Trinity River side-channels will also be conducted during 1988 emphasizing the existing habitat available and the development potential of these habitat types. This evaluation will be closely coordinated with work aimed at determining the importance of side-channel habitats along the Trinity for juvenile salmonid rearing and holding.

It is hoped that eventually these and other macrohabitat data can be combined with microhabitat and hydrologic data so an overall stream network habitat analysis for the Trinity River basin can be done.

Fish Population Characteristics and Life History Relationships (TASK 4)

During 1986 we initiated a number of elements aimed at providing insight into fish population and life history relationships of salmon and steelhead within the Trinity River. The initial plan of study (FWS 1983) describes this information as necessary due to our limited knowledge about the total distribution of fish within the Trinity River, their spawning success, and the subsequent survival and growth of salmonid juveniles. Initial efforts have been aimed at obtaining information on: 1) the habitat use and distribution of juvenile salmonids; 2) salmonid egg and fry survival within the mainstem of the Trinity; 3) the timing, duration, and magnitude of juvenile emigration; 4) juvenile salmonid growth within the river; and, 5) the overall health and productive capabilities of macroinvertebrate populations of the Trinity. These efforts were continued through 1987 and have been reported on earlier in this report. Generally, this work will be continued through 1988.

Efforts will be initiated to describe the habitats used and the requirements of juvenile salmonids during the winter months, when water temperatures drop below 50 degrees F. Based on our observations to date we believe that overwintering habitat and its availability may play an important role in determining population levels or the carrying capacity of the river as a whole. We will also evaluate selected pool habitats within the mainstem Trinity in an effort to obtain information on pool dynamics and salmonid distribution especially during the critical summer months when pools may be important habitat for holding salmon and steelhead.

Efforts aimed at monitoring the growth of juvenile salmon and steelhead within the mainstem Trinity River, especially of naturally-produced fish will continue through 1988. This work is designed to monitor and to build upon the baseline data obtained in 1986 and 1987. Also, during 1988, we plan to continue monitoring food habits of juvenile salmonids, their selectivity, preferred food items and the degree of overlap between different species and lifestages.

Finally, studies designed to determine and monitor the health and production of benthic aquatic invertebrates within the Trinity will continue through 1988. An initial analysis of macroinvertebrate populations within the mainstem of the Trinity and a comparative analysis of macroinvertebrate availability and the dietary needs of juvenile salmonids is planned for completion in the spring of 1988.

Study Coordination

During 1986 and 1987, the Trinity River Basin Fish and Wildlife Management Program Field Office initiated efforts to rehabilitate fish and wildlife habitat within the basin, including the mainstem Trinity River above Grass Valley Creek. The plan of study for the Trinity River Flow Evaluation Study focuses primarily on evaluating the effects of increased streamflow releases at Lewiston Dam on available anadromous salmoid habitat within the mainstem of the Trinity River. It was recognized, however, that there is a need to monitor changes in available habitat or habitat use brought about through implementation of the Management Program. Such an effort is necessary if habitat changes due to increased downstream releases are to be accurately separated from those brought about by the Management Program. Therefore, we plan to continue our close coordination with the Trinity Management Program Field Office.

Finally, coordination efforts will continue with the Bureau of Reclamation, concerning Trinity River releases, and the California Department of Fish and Game, concerning Trinity River hatchery operations, and other fishery or habitat management efforts planned for 1988.

REFERENCES

Aceituno, M. E. and M. A. Hampton. (in press). Validation of habitat availability determinations by comparing field observations with hydraulic model (IFG-4) output. in K. D. Bovee and J. Zuboy, eds. Proceedings of a workshop on the development and evaluation of habitat criteria for fish. U.S. Fish Wildl. Serv. Rep.

Bagenal, T. B. 1978. Methods for fish production in fresh waters. Blackwell Scientific Publications Ltd., Oxford, 365 pp.

Barnhart, R. A., D. Bremm and R. Deibel. 1983. Fish habitat development project Browns Creek, Trinity County. Calif. Coop. Fish. Res. Unit, Humboldt State University, Arcata, CA. 141 pp.

Becker, C.D. 1973. Food and growth parameters of juvenile chinook salmon, Oncorhynchus tshawytscha, in central Columbia River. Fish. Bull. 71(2): 387 - 400.

Benke, A.C. 1979. A modification of the Hynes method for estimating secondary production with particular significance for multivoltine populations. Limnol. Oceanogr. 24:168-171.

Bjornn, T.C., M.A. Brusven, M.P. Molnau, J.H. Milligan, R.A. 1977. Klamt, E. Chaco, and C. Schaye. Transport of granitic sediment in streams and its effect on insects and fish. OWRT Research Technical Completion Report. Project B - 036 - IDA, Forest, Wildlife and Range Experiment Station, Univ. of Idaho, Moscow. 43 pp.

Bovee, K.D. 1982. Development and evaluation of habitat suitability criteria for use in the instream flow incremental methodology. Instream flow Information Paper No. 21. U.S. Fish Wildl. Serv. Biol. Rep. 86(7). 235 pp.

Bowen, S. H. 1983. Quantitative description of the diet. Pps 325 - 336 in Nielson, L.A., D.L. Johnson (Editors). Fisheries Techniques. American Fisheries Society, Bethesda, Maryland. 468 pp.

Brocksen, R.W. and J.P. Bugge. 1974. Preliminary investigations on the influence of temperature on food assimilation by rainbow trout Salmo gairdneri Richardson. J. Fish. Biol 6: 93-97.

Brusven, M.A. 1977. Effects of sediment on insects. Page 43 in D.L. Kibbee (ed.). Transport of granitic sediments in streams and its effects on insects and fish. USDA Forest Service. Forest, Wildl., and Range Exp. Sta. Bull. 17. Univ. Idaho, Moscow, ID.

Buck, M.K. and R.A. Barnhart. 1986. Evaluation of constructed anadromous salmonid spawning riffles, Trinity River, California. U.S. Fish Wildl. Ser., Calif. Coop. Fish. Res. Unit, Humboldt State University, Arcata, CA. 30 pp.

Burns, J. W. 1971. The carrying capacity of juvenile salmonids in some northern California streams. Calif. Dept. Fish Game 57:44-57.

Bustard, D.R., and D.W. Narver. 1975. Aspects of the winter ecology of juvenile coho salmon (Oncorhynchus kisutch) and steelhead trout (Salmo gairdneri). J. Fish. Res. Board Can. 32:667-680.

Cross, P. D. 1975. Early life history of steelhead trout (Salmo gairdneri) in a small coastal stream. M.S. Thesis, Humboldt State University, Arcata, CA. 44 pp.

Cummins K.W., and J.C. Wuycheck. 1971. Caloric equivalents for investigations in ecological energetics. Inter. Assoc. for Theoretical and Applied Limnology., Special Communication 18:1 - 158.

Doyle, J. E. 1984. Habitat enhancement on off-channels and terraced tributaries in Puget Sound river systems. Pages 81-96 in T.J. Hassler, ed. Pacific northwest stream habitat management workshop. California Cooperative Fishery Research Unit, Humboldt State University, Arcata, California

Electric Power Research Institute. 1986. Instream flow methodologies. EPRI, Palo Alto, California.

Everest, F.H. and J.R. Sedell. 1984. Evaluation of fisheries enhancement projects on Fish Creek and Wash Creek, 1982 and 1983. DOE, Bonneville Power Administration, Division of Fish and Wildlife, Portland, OR. 99 pp.

Everest, F.H., J.R. Sedell, G.H. Reeves, and J. Wolfe. 1985. Fisheries enhancement in the Fish Creek basin--an evaluation of in-channel and off-channel projects. DOE, Bonneville Power Administration, Division of Fish and Wildlife, Portland, OR. 228 pp.

Griffith, J.S. 1974. Trout utilization of invertebrate drift. Trans. Amer. Fish. Soc. 103:440-447.

Hamilton, A.L. 1969. On estimating annual production. Limnol. Oceanogr. 14: 771-782.

Hamilton, R. and J.W. Buell. 1976. Effects of modified hydrology on Campbell River salmonids. Can. Dept. Env., Fish. Mar. Serv., Hab. Prot. Dir., Tech. Rep. Ser. No. PAC/T-76-20. Vancouver, B.C. 156 + 21 pp.

Hampton, M.A. (in press). Development of habitat preference criteria for anadromous salmonids of the Trinity River, California. U.S. Fish and Wildlife Service, Fish and Wildlife Enhancement, Ecological Services, Sacramento, CA.

Hartman, G.F., and T.G. Brown. 1987. Use of small, temporary, floodplain tributaries by juvenile salmonids in a west coast rain-forest drainage basin, Carnation Creek, British Colombia. Can. J. Fish. Aquat. Sci. 44:262-270.

Hassler, T. J., W. L. Somer, and G. R. Stern. 1986. Impacts of suction dredge mining on anadromous fish, invertebrates and habitat in Canyon Creek, California. Calif. Coop. Fish. Res. Unit, U.S. Fish and Wildlife Service, Arcata, CA. 135 pp.

Hynes, H.B., and M.J. Coleman. 1968. A simple method of assessing the annual production of stream benthos. Limnol. Oceanogr. 13:569-573.

Jenkins, T.M.,Jr., C.R. Feldmeth, and G.V. Elliot. 1970. Feeding of rainbow trout (Salmo gairdneri) in relation to abundance of drifting invertebrates in a mountain stream. J. Fish. Res. Bd. Can. 27:2356 - 2361.

Johnson, J.H., and E.Z. Johnson. 1981. Feeding periodicity and diel variation in diet composition of subyearling coho salmon, Oncorhynchus kisutch, and steelhead, Salmo gairdneri, in a small stream during summer. Fish. Bull. 79(2):370-376.

Johnson, J.H. and N.H. Ringler. 1980. Diets of juvenile coho salmon (Oncorhynchus kisutch) relative to prey availability. Can. J. Zool. 58:553-558.

Leopold, L.B., M.G. Wolman, and J.P. Miller. 1964. Fluvial Processes in Geomorphology. W.H. Freeman, San Francisco.

Lisle, T.E. 1981. Roughness elements : a key resource to improve anadromous fish habitat. in T.J. Hassler (ed.). Proceedings: propogation, enhancement, and rehabilitation of anadromous salmonid populations and habitat symposium. October 15-18, 1981, Humboldt State University, Arcata, CA.

Maser, C., B.R. Mate, J.F. Franklin, and C.T. Dyrness. 1981. Natural history of Oregon coast mammals. USDA For. Serv. Gen. Tech. Rep. PNW-133, 496 pp. Pac. Northwest For. and Range Exp. Stn., Portland, Oreg.

Milhous, R.T., D.L. Wegner, and T. Waddle. 1984. User's guide to the Physical Habitat Simulation System (PHABSIM). Instream Flow Information Paper 11. U.S. Fish. Wildl. Serv. FWS/OBS-81/43 (revised). 475 pp.

Moffett, J.W and S.H. Smith. 1950. Biological Investigations of the Fishery Resources of Trinity River, California. USDI Special Scientific Report-Fisheries, No. 12.

Morisawa, M. 1968. Streams--Dynamics and Morphology. McGraw-Hill, New York.

Mundie, J.H. and D.E. Mounce. 1978. Application of stream ecology to raising salmon smolts in high density. Verh. Internat. Verein. Limnol. 20:2013-2018.

Mundie, J.H. and R.E. Traber. 1983. The carrying capacity of an enhanced side-channel for rearing salmonids. Can. J. Fish. Aquat. Sci. 40:1320-1322

Parfitt, D. and K. Buer. 1981. Chinook salmon spawning enhancement potential in the upper Sacramento River. Pages 144-148 <u>in</u> T.J. Hassler, ed. Proceedings: propagation , enhancement, and rehabilitation of anadromous salmonid populations and habitat symposium. California Cooperative Fishery Research Unit, Humboldt State University, Arcata, California.

Pennington, H. M. 1986. Emigration and mortality of juvenile steelhead in a nursery stream. M.S. Thesis, Humboldt State University, Arcata, CA. 55 pp.

Reeves, G. H. and T. C. Bjornn. 1979. Population dynamics of juvenile steelhead trout in relation to density and habitat characteristics. M.S. Thesis, Humboldt State University, Arcata, CA. 67 pp.

Reiser, D.W. and T.C. Bjornn. 1979. Habitat requirements of anadromous salmonids. USDA For. Serv. Gen. Tech. Rep. PNW-96, 54 pp. Pac. Northwest For. and Range Exp. Stn., Portland, Oreg.

Sedell, J.R., P.A. Bisson, J.A. June and R.W. Speaker. 1982. Ecology and habitat requirements of fish populations in South Fork Hoh River, Olympic National Park. Pages 35-42 <u>in</u> E.E. Starkey, J.F. Franklin, and J.W. Matthews, eds. Ecological research in national parks of the Pacific northwest. National Park Service Cooperative Park Studies Unit, Corvallis, Oregon.

Shelton, W. Pete, October 2, 1987. Supervisory Hydrologic Technician, USGS, Redding Field Office. Personnal communication.

Sokal, R.R., and F.J. Rohlf. 1981. Biometry. W.H. Freeman Co., San Francisco, CA. 859 pp.

Theuer, F.D., K.A. Voos, and W.J. Miller. 1984. Instream Water Temperature Model. Instream Flow Information Paper 16. U.S. Fish and Wildlife Service. FWS/OBS-84/15. v.p.

Trihey, E.W. and D.L. Wegner. 1981. Field data collection procedures for use with the physical habitat simulation system of the Instream Flow Group. U.S. Fish. Wildl. Serv., Cooperative Instream Flow Service Group, Ft. Collins, CO. 151 pp.

U.S. Fish and Wildlife Service. 1986. Trinity River Flow Evaluation Study Annual Report - 1986. U.S. Fish and Wildlife Service, Division of Ecological Services, Sacramento, CA. 104 pp.

U.S. Fish and Wildlife Service. 1987. Progress report on Grass Valley Creek studies. U.S. Fish & Wildlife Service, Division of Ecological Services, Sacramento, CA.

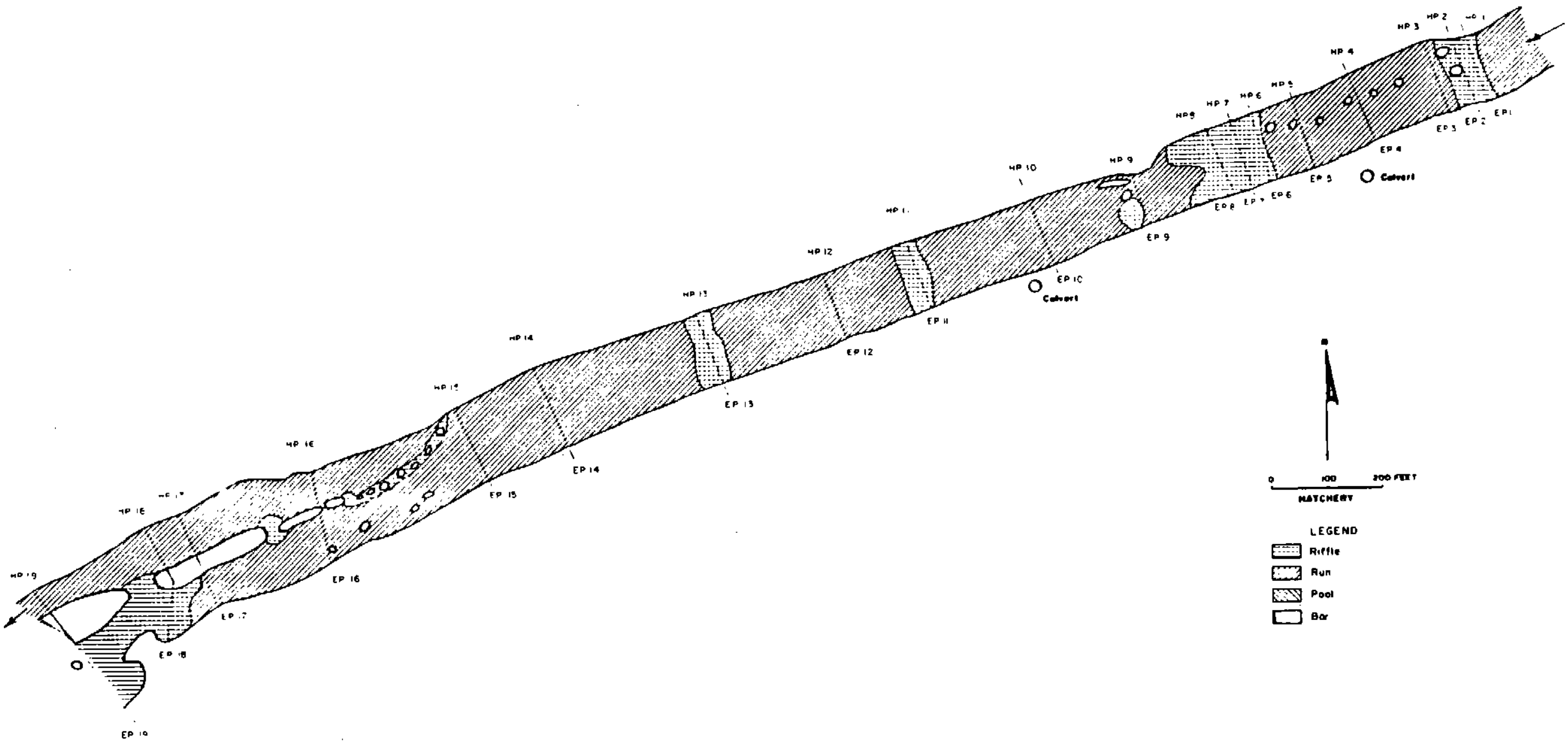
Walburg, C.H., J.F. Novotny, K.E. Jacobs, W.D. Swink, T.M. Campbell, J. Nestler, and G.E. Saul. 1981. Effects of reservoir releases on tailwater ecology: A Literature review. Technical Report E-81-12; U.S.D.I, U.S.F.W.S., Nat. Resv. Res. Prog., East Central Resv. Invest., and Environmental Lab., U.S. Army Eng. Waterways Exp. Stn., C.E., Vicksburg, Miss.

Wallace, R.K., Jr. 1981. An assessment of diet - overlap indexes. Trans. Amer. Fish. Soc. 110:72-76.

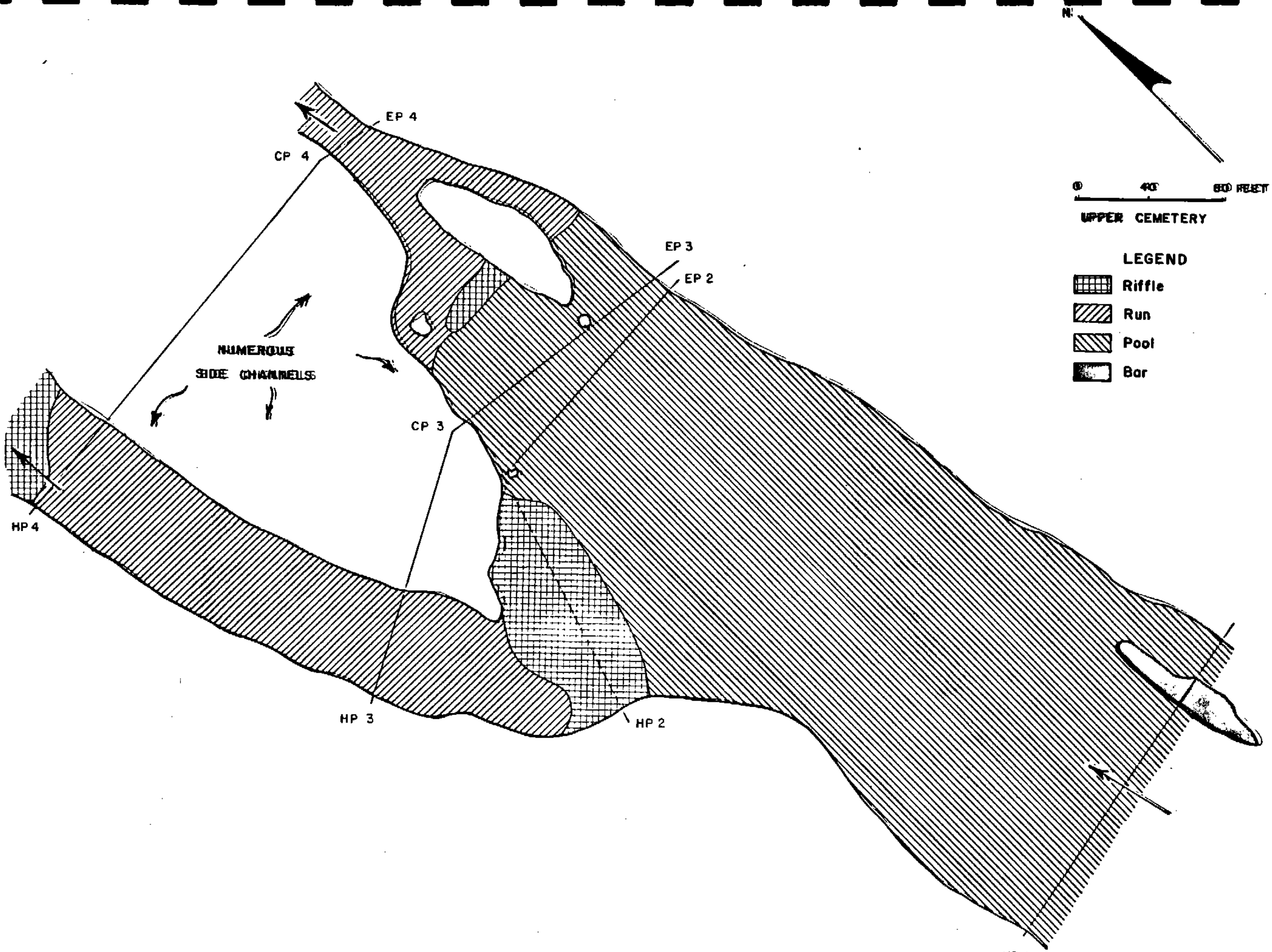
Wilhm, J.L., and T.C. Dorris. 1968. Biological parameters for water quality criteria. Bioscience 18: 447-481.

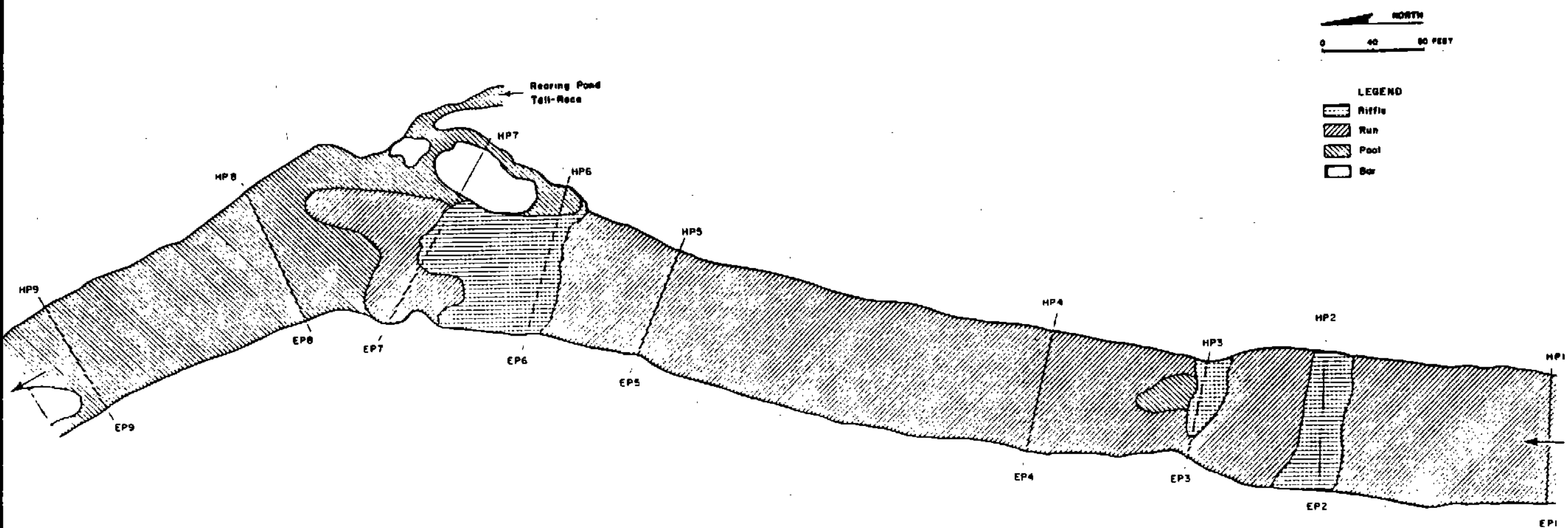
APPENDIX A

IFIM
Study Site Maps

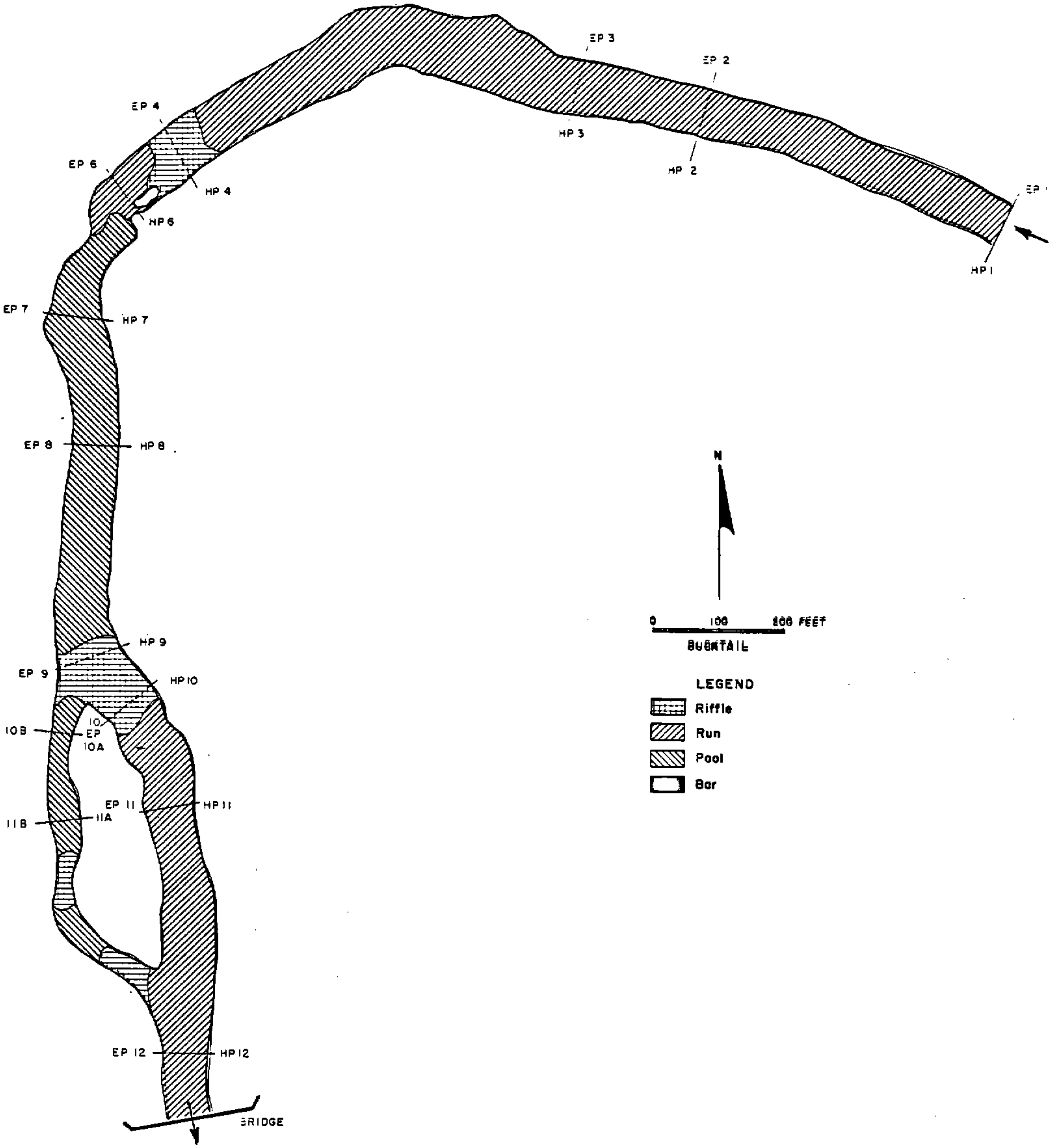


HP 2
HP 3
HP 4
HP 5
HP 6
HP 7
HP 8
HP 9
HP 10
HP 12
HP 13
HP 14
HP 16
HP 18
HP 19
EP 1
EP 2
EP 3
EP 4
EP 5
EP 6
EP 8
EP 9
EP 10
EP 11
EP 12
EP 13
EP 14
EP 15
EP 16
EP 18
Culvert
Culvert
0
100
200 FEET
HATCHERY
LEGEND
Riffle
Run
Pool
Bar

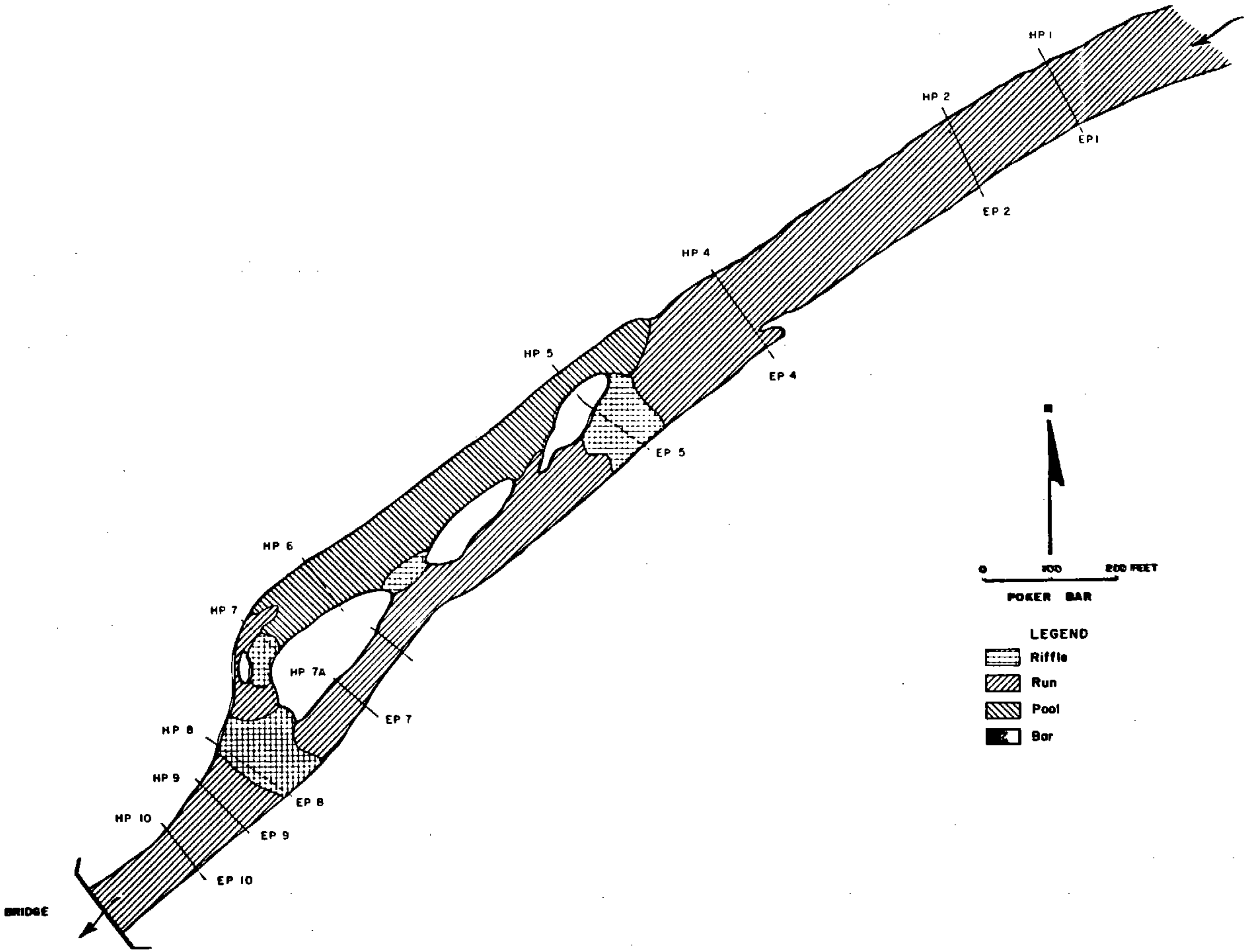

N
0 400 800 FEET
UPPER CEMETERY
LEGEND
Riffle
Run
Pool
Bar
EP 4
CP 4
EP 3
EP 2
CP 3
NUMEROUS
SIDE CHANNELS
HP 4
HP 3
HP 2
HP 1

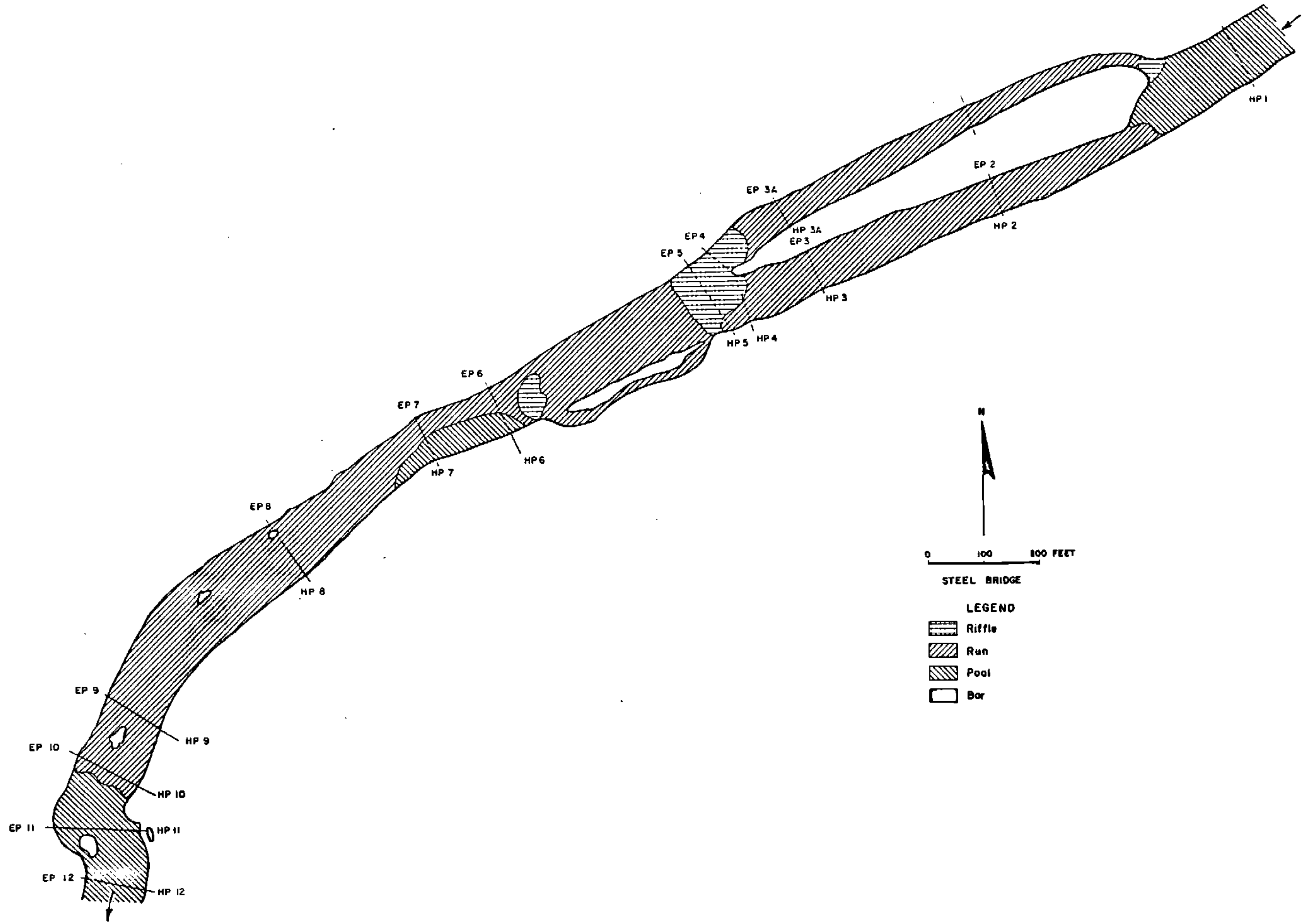


NORTH
0
40
80 FEET
LEGEND
Riffle
Run
Pool
Bar
Rearing Pond
Tail-Race
HP1
HP2
HP3
HP4
HP5
HP6
HP7
HP8
HP9
EP1
EP2
EP3
EP4
EP5
EP6
EP7
EP8
EP9

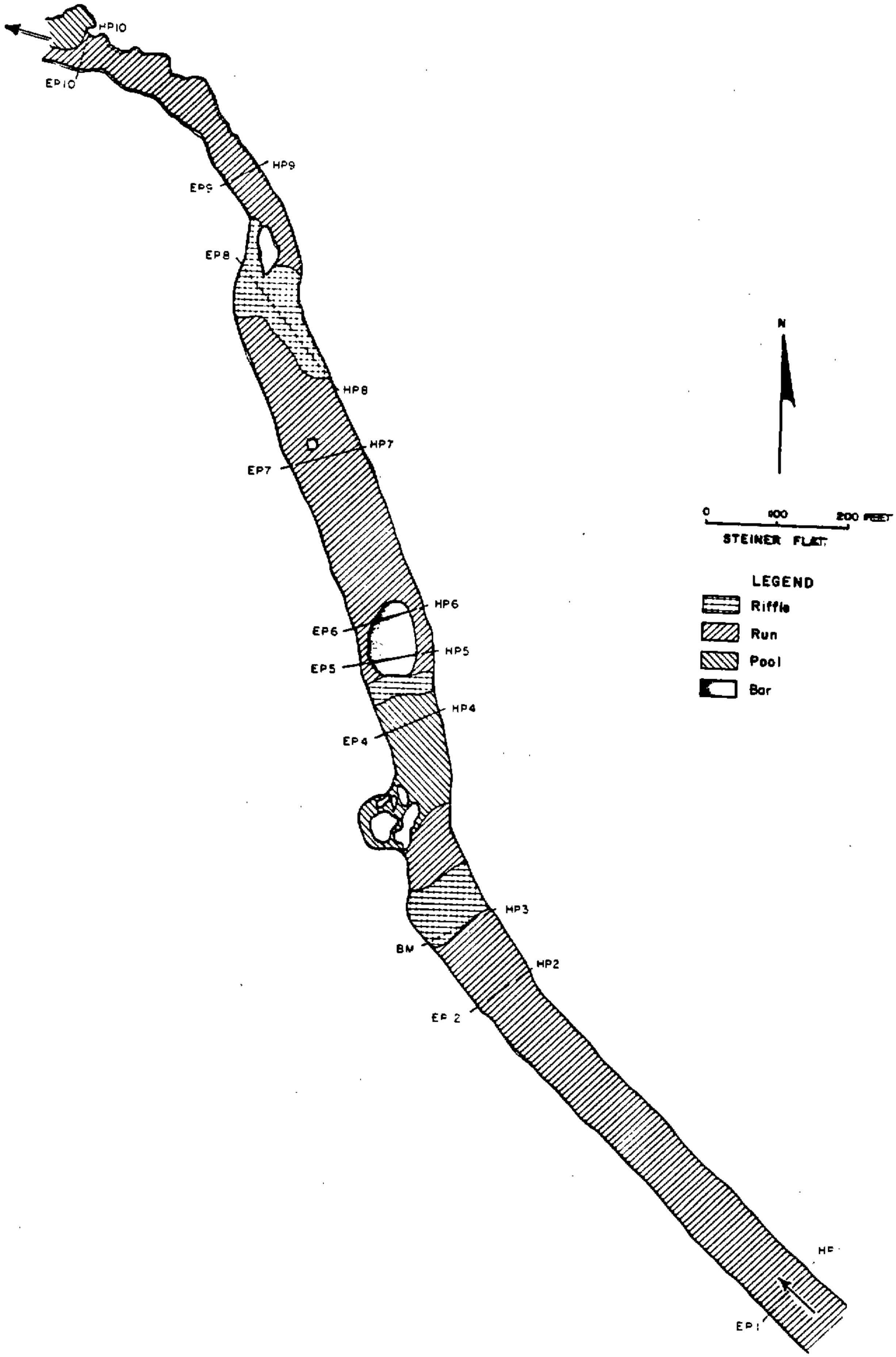


EP 1
HP 1
EP 2
HP 2
EP 3
HP 3
EP 4
HP 4
EP 6
HP 6
EP 7
HP 7
EP 8
HP 8
HP 9
EP 9
HP 10
10
EP
10A
EP 10B
EP 11
HP 11
11A
11B
EP 12
HP 12
BRIDGE
N
0
100
200 FEET
BUCKTAIL
LEGEND
Riffle
Run
Pool
Bar

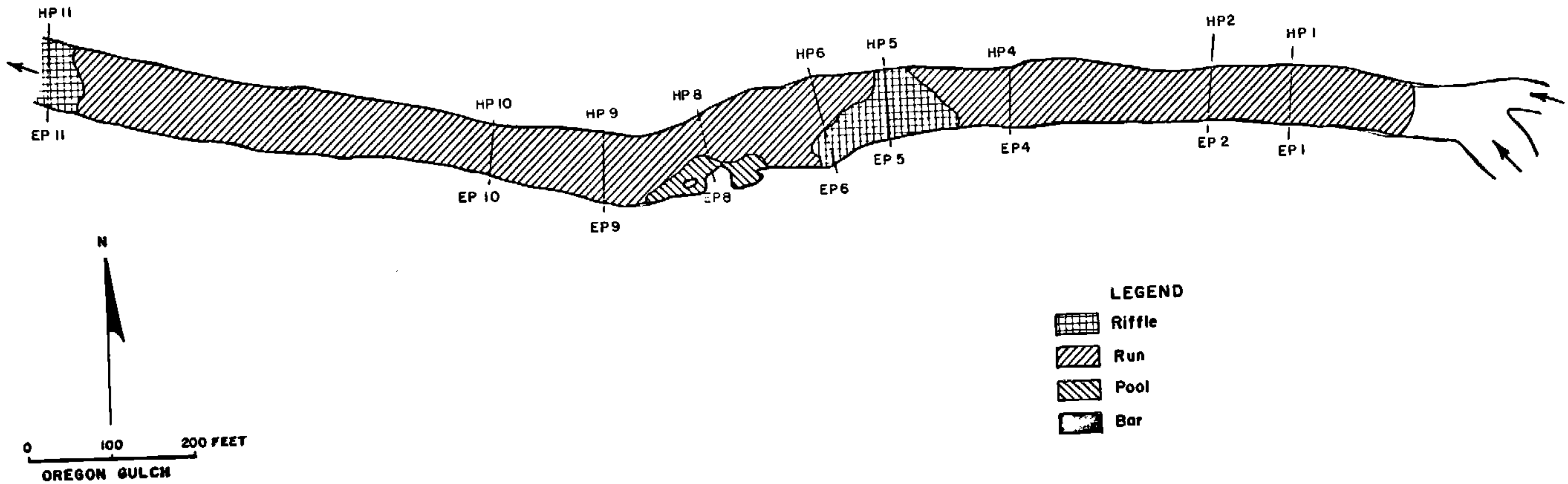

HP 1
EP1
HP 2
EP 2
HP 4
EP 4
HP 5
EP 5
HP 6
HP 7
HP 7A
EP 7
HP 8
EP 8
HP 9
EP 9
HP 10
EP 10
BRIDGE
0
100
200 FEET
POKER BAR
LEGEND
Riffle
Run
Pool
Bar

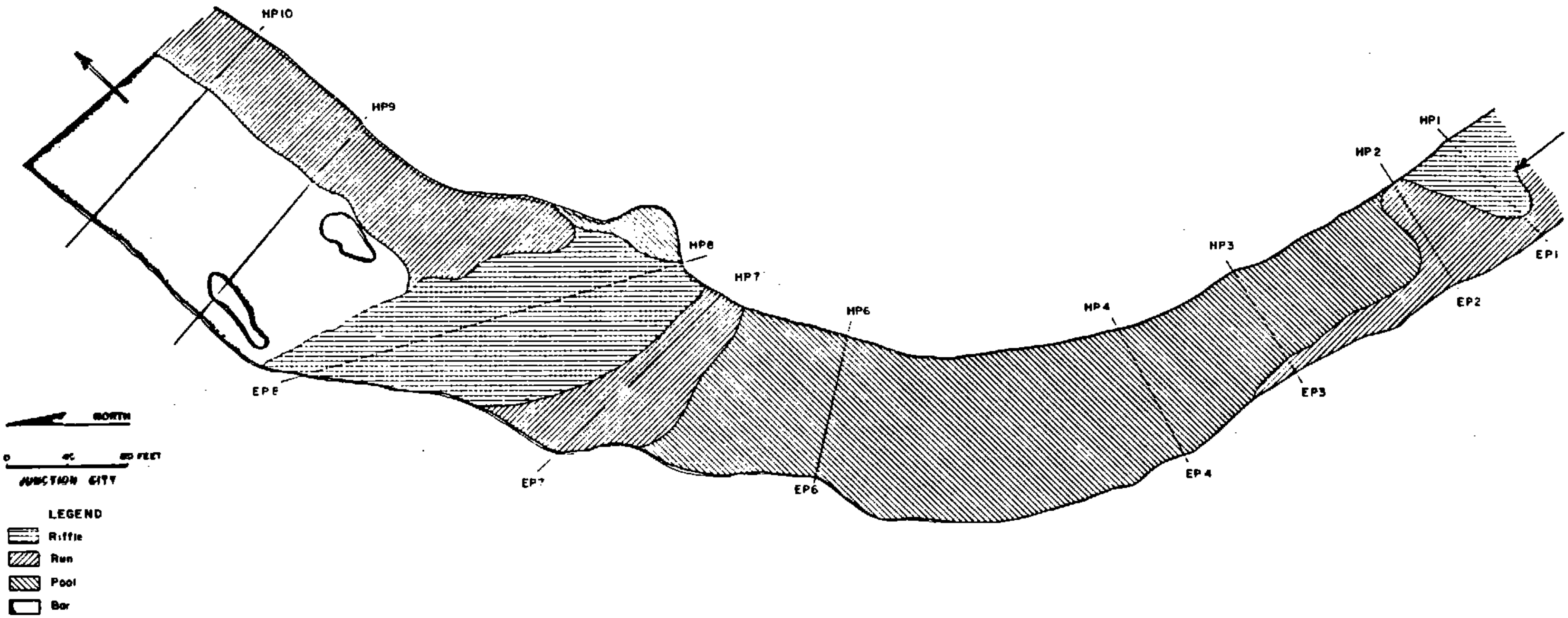


HP 1
EP 2
HP 2
EP 3A
HP 3A
EP 3
HP 3
EP 4
EP 5
HP 5
HP 4
EP 6
HP6
EP 7
HP 7
EP 8
HP 8
EP 9
HP 9
EP 10
HP 10
EP 11
HP 11
EP 12
HP 12
N
0
100
100 FEET
STEEL BRIDGE
LEGEND
Riffle
Run
Pool
Bar

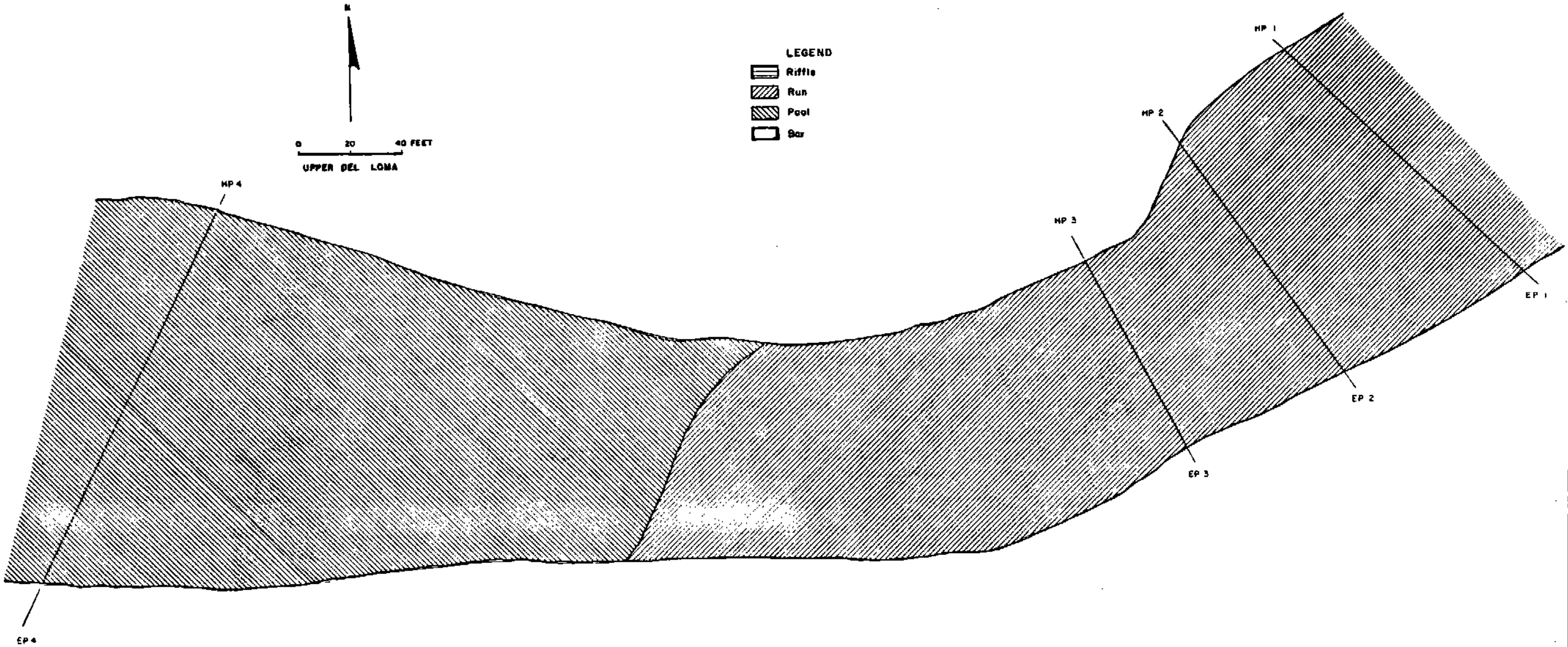


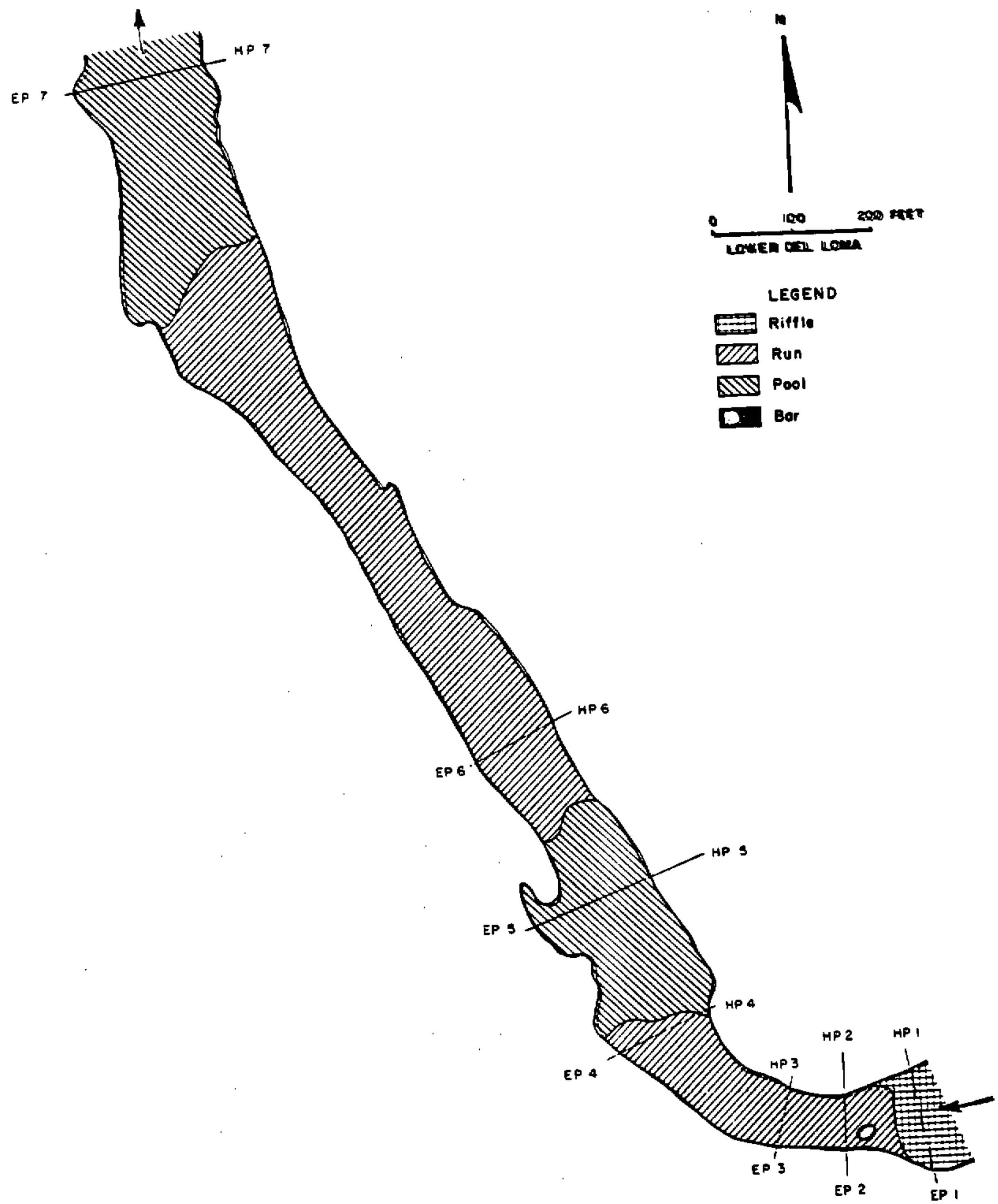
HP10
EP10
HP9
EP9
EP8
N
HP8
HP7
EP7
0
100
200 FEET
STEINER FLAT
LEGEND
Riffle
Run
Pool
Bar
HP6
EP6
HP5
EP5
HP4
EP4
HP3
BM
HP2
EP 2
EP1


HP 11
EP 11
HP 10
EP 10
HP 9
EP9
HP 8
EP8
HP6
EP6
HP 5
EP 5
HP4
EP4
HP2
EP 2
HP 1
EP 1
N
0
100
200 FEET
OREGON GULCH
LEGEND
Riffle
Run
Pool
Bar

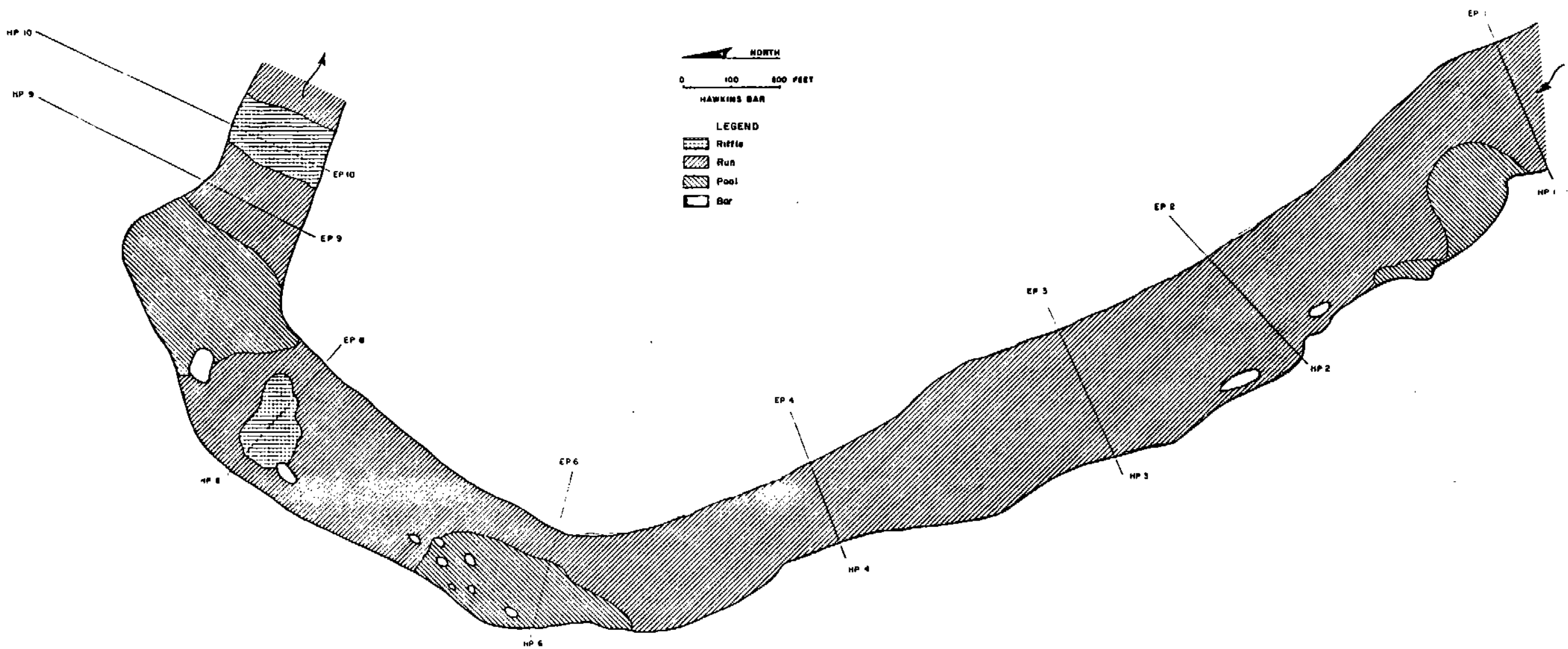


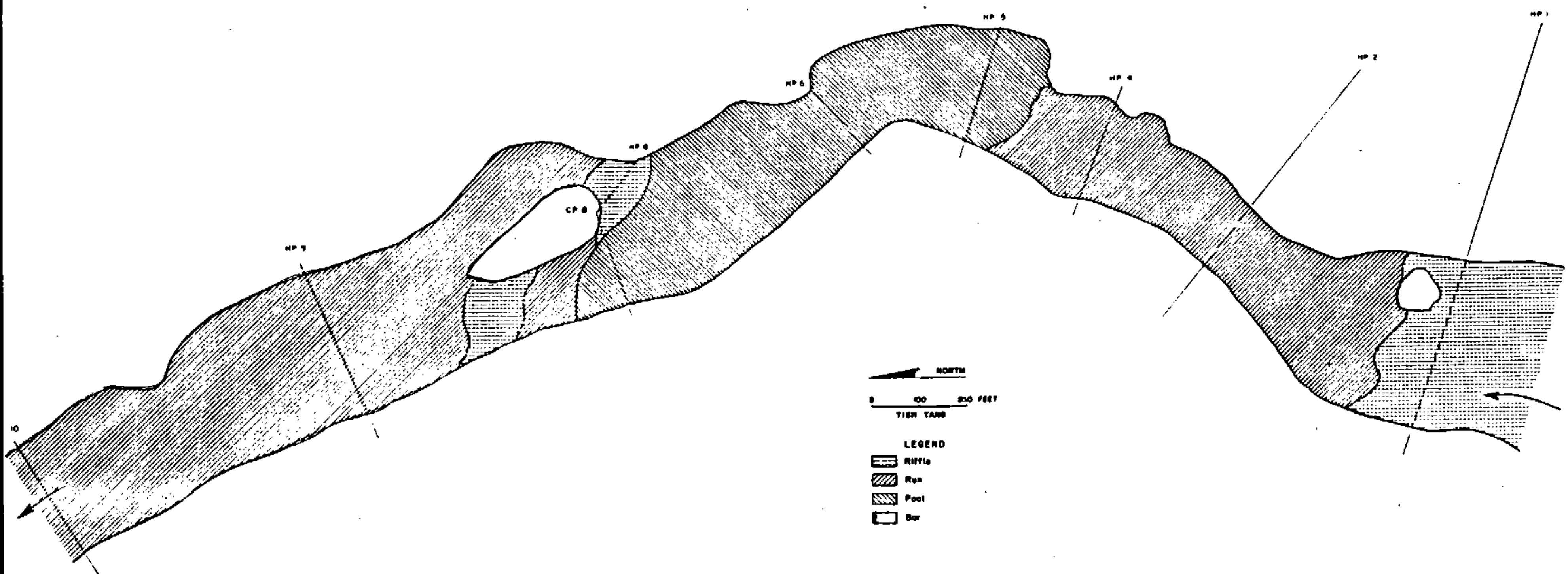
HP10
HP9
HP8
HP7
HP6
HP4
HP3
HP2
HP1
EP1
EP2
EP3
EP4
EP6
EP7
NORTH
0
40
80 FEET
JUNCTION CITY
LEGEND
Riffle
Run
Pool
Bar


N
LEGEND
Riffle
Run
Pool
Bar
0
20
40 FEET
UPPER DEL LOMA
HP 1
HP 2
HP 3
HP 4
EP 1
EP 2
EP 3
EP 4

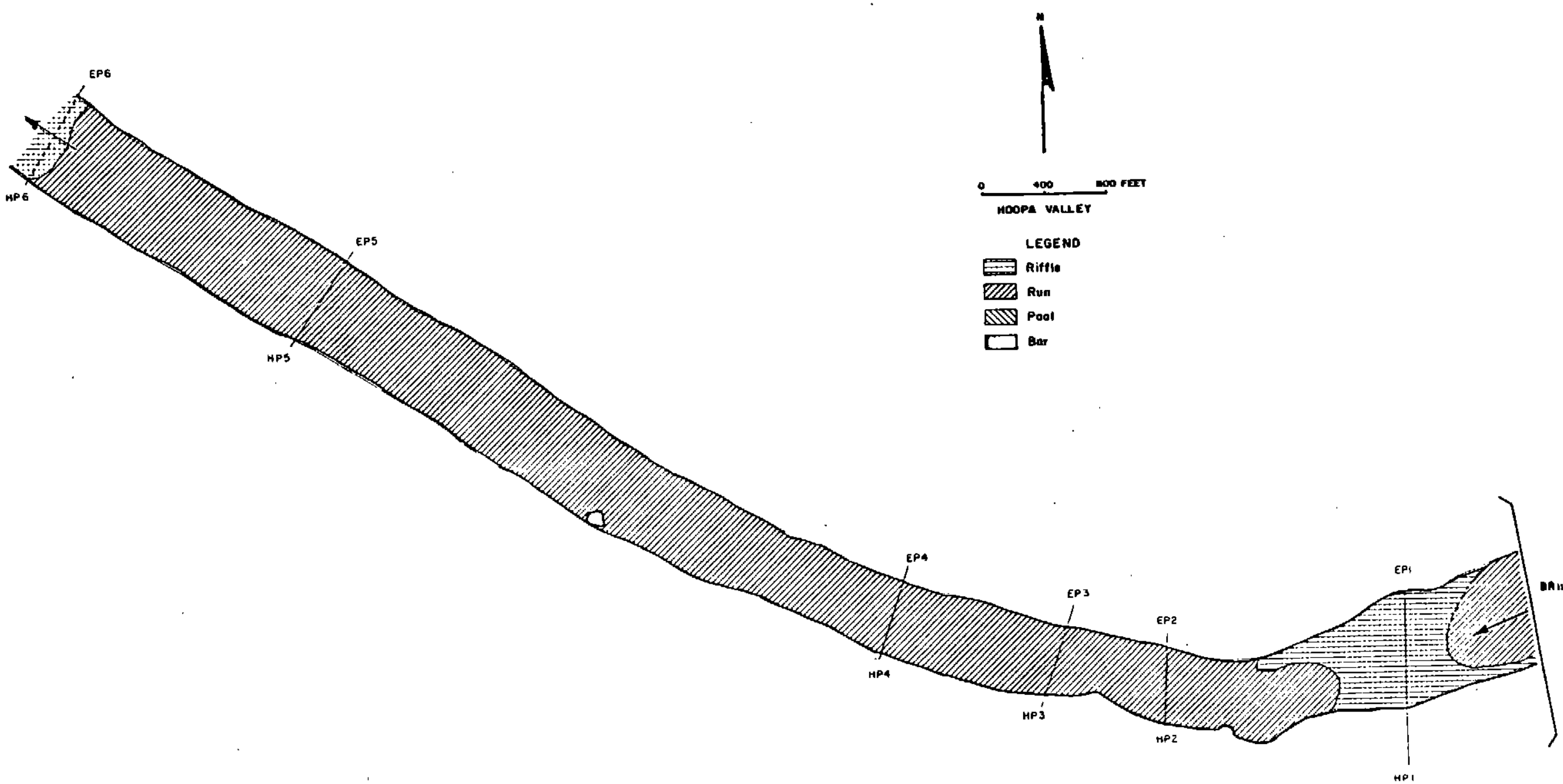


N
0
100
200 FEET
LOWER DEL LOMA
LEGEND
Riffle
Run
Pool
Bar
HP 7
EP 7
HP 6
EP 6
HP 5
EP 5
HP 4
EP 4
HP 3
EP 3
HP 2
EP 2
HP 1
EP 1


NORTH
0
100
800 FEET
HAWKINS BAR
LEGEND
Riffle
Run
Pool
Bar
EP 1
HP 1
EP 2
HP 2
EP 3
HP 3
EP 4
HP 4
EP 6
HP 6
EP 8
HP 8
EP 9
HP 9
EP 10
HP 10



HP 1
HP 2
HP 4
HP 5
HP 6
HP 8
CP 8
HP 9
10
NORTH
0
100
200 FEET
TISH TANG
LEGEND
Riffle
Run
Pool
Bar

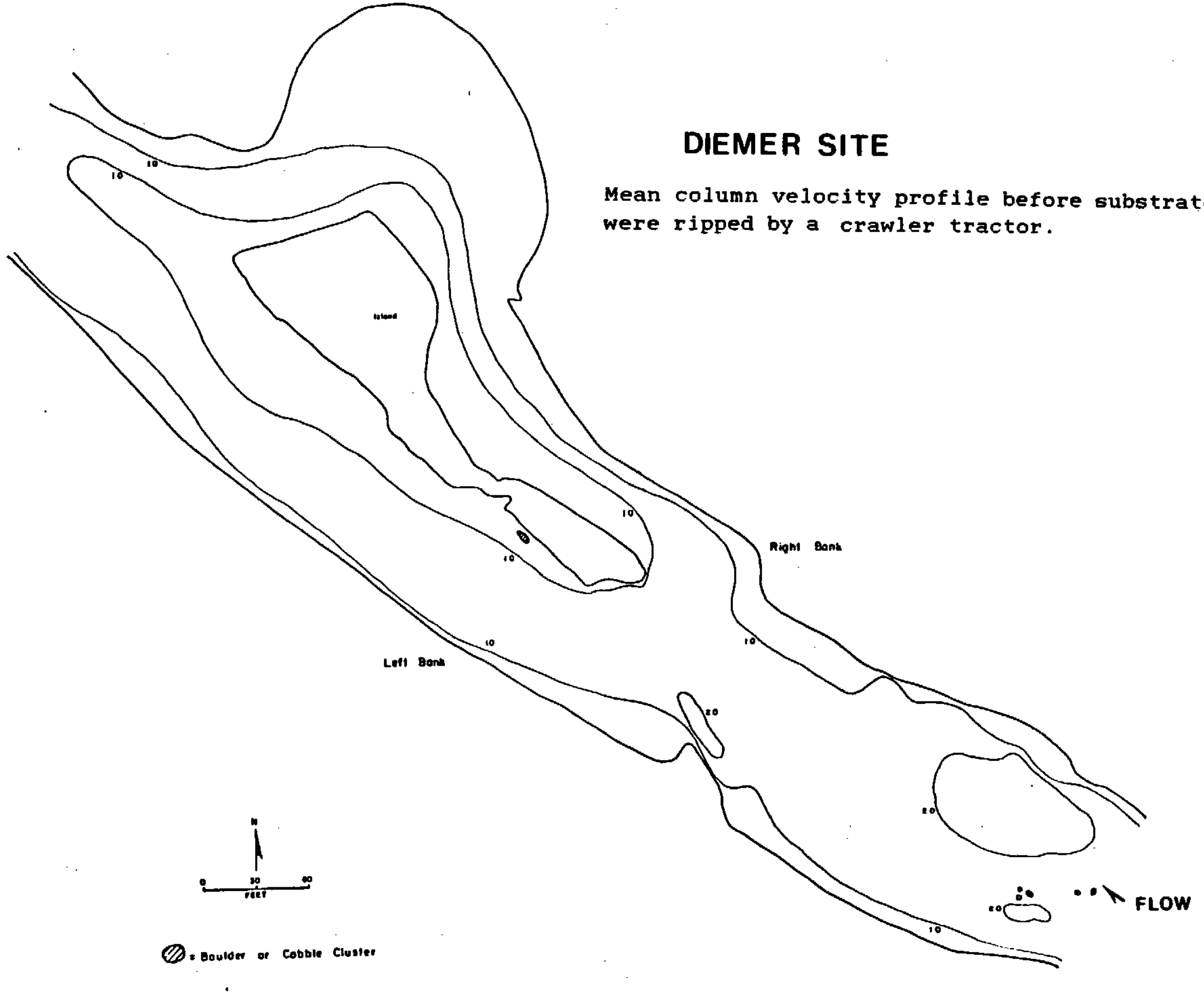

N
0
400
800 FEET
HOOPA VALLEY
LEGEND
Riffle
Run
Pool
Bar
BRIDGE
EP1
HP1
EP2
HP2
EP3
HP3
EP4
HP4
EP5
HP5
EP6
HP6

APPENDIX B

Riffle Restoration Site Maps

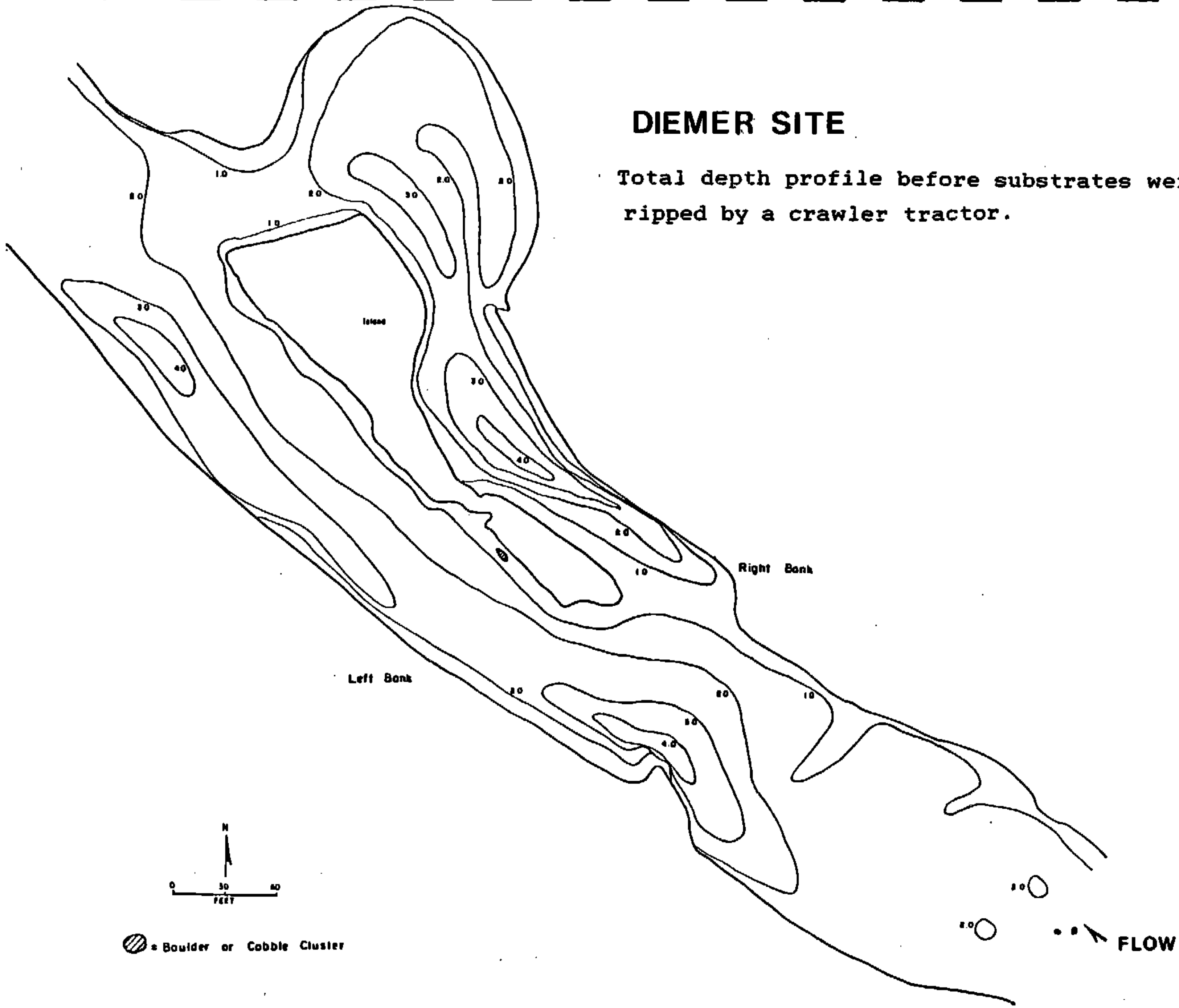
DIEMER SITE

Mean column velocity profile before substrates were ripped by a crawler tractor.



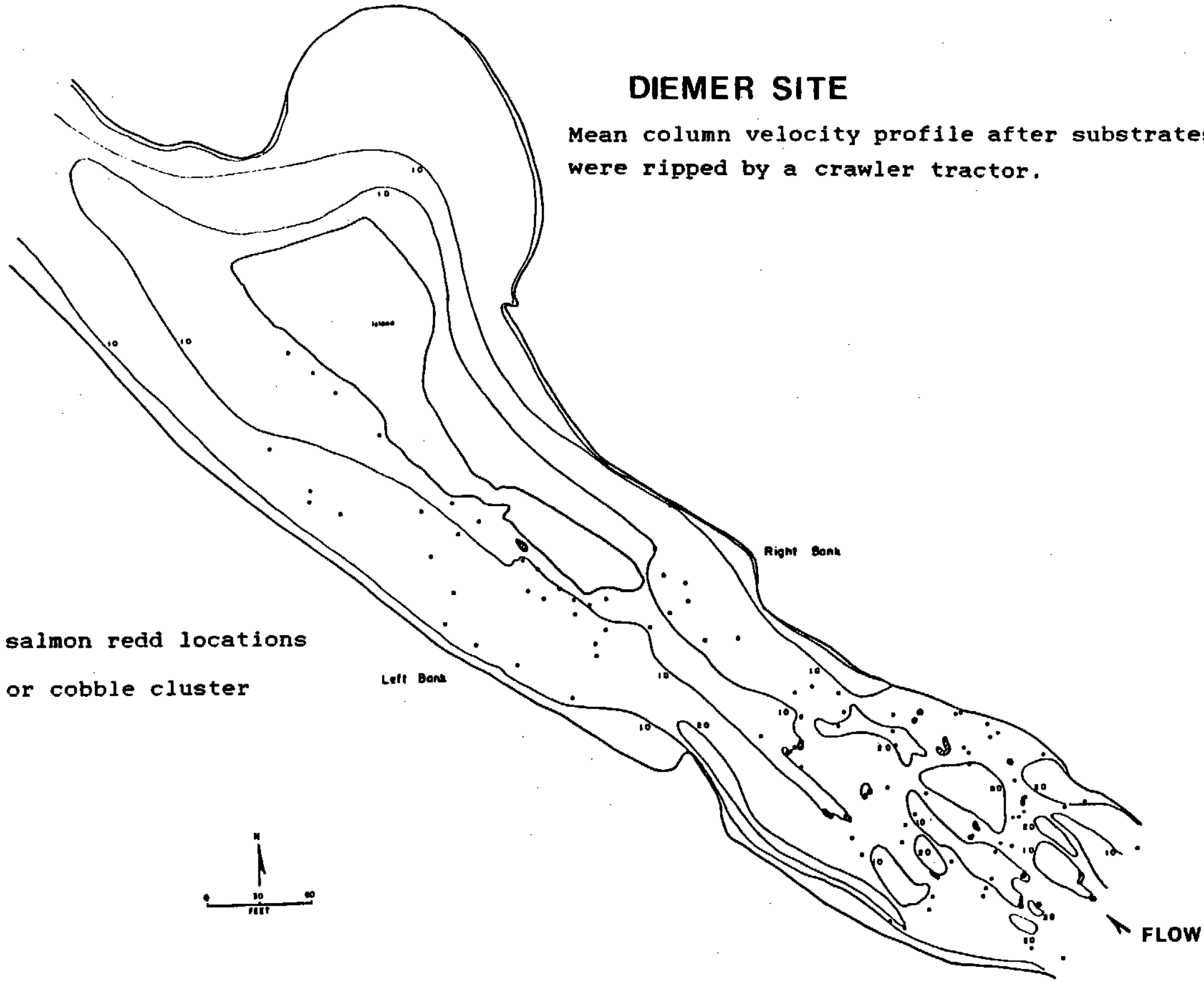
DIEMER SITE

Total depth profile before substrates were ripped by a crawler tractor.



DIEMER SITE

Mean column velocity profile after substrates were ripped by a crawler tractor.

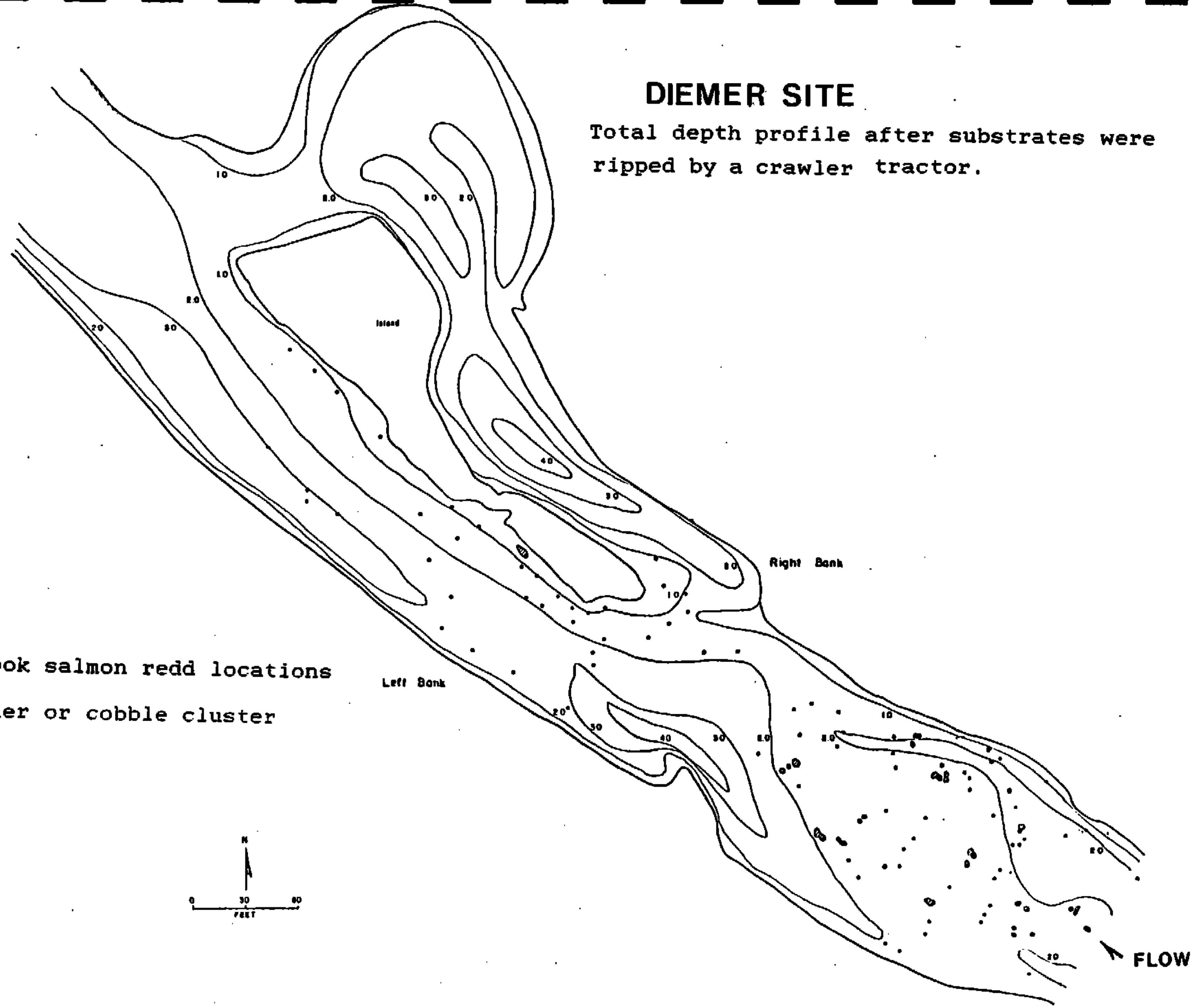


• = Chinook salmon redd locations

= Boulder or cobble cluster

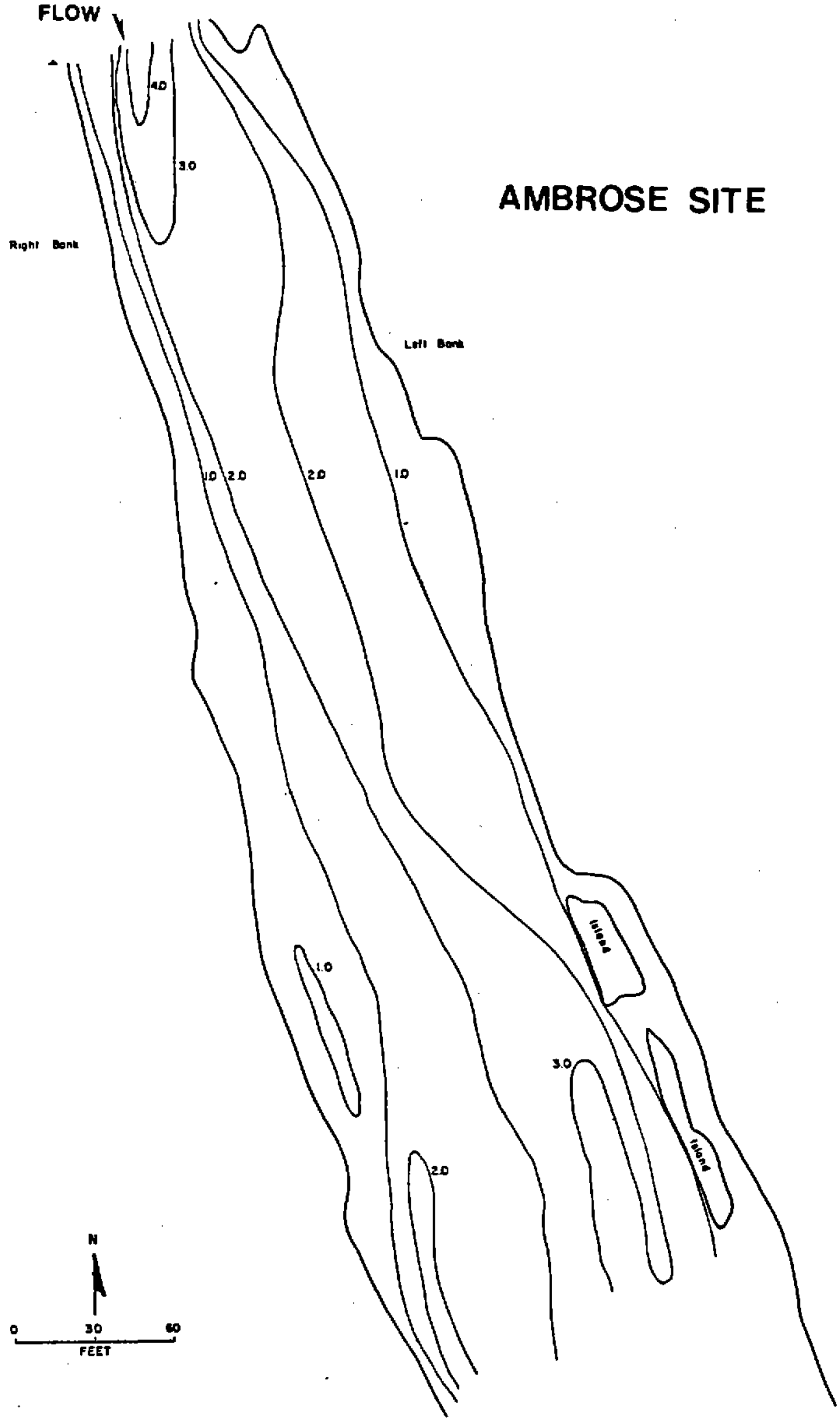
DIEMER SITE

Total depth profile after substrates were ripped by a crawler tractor.

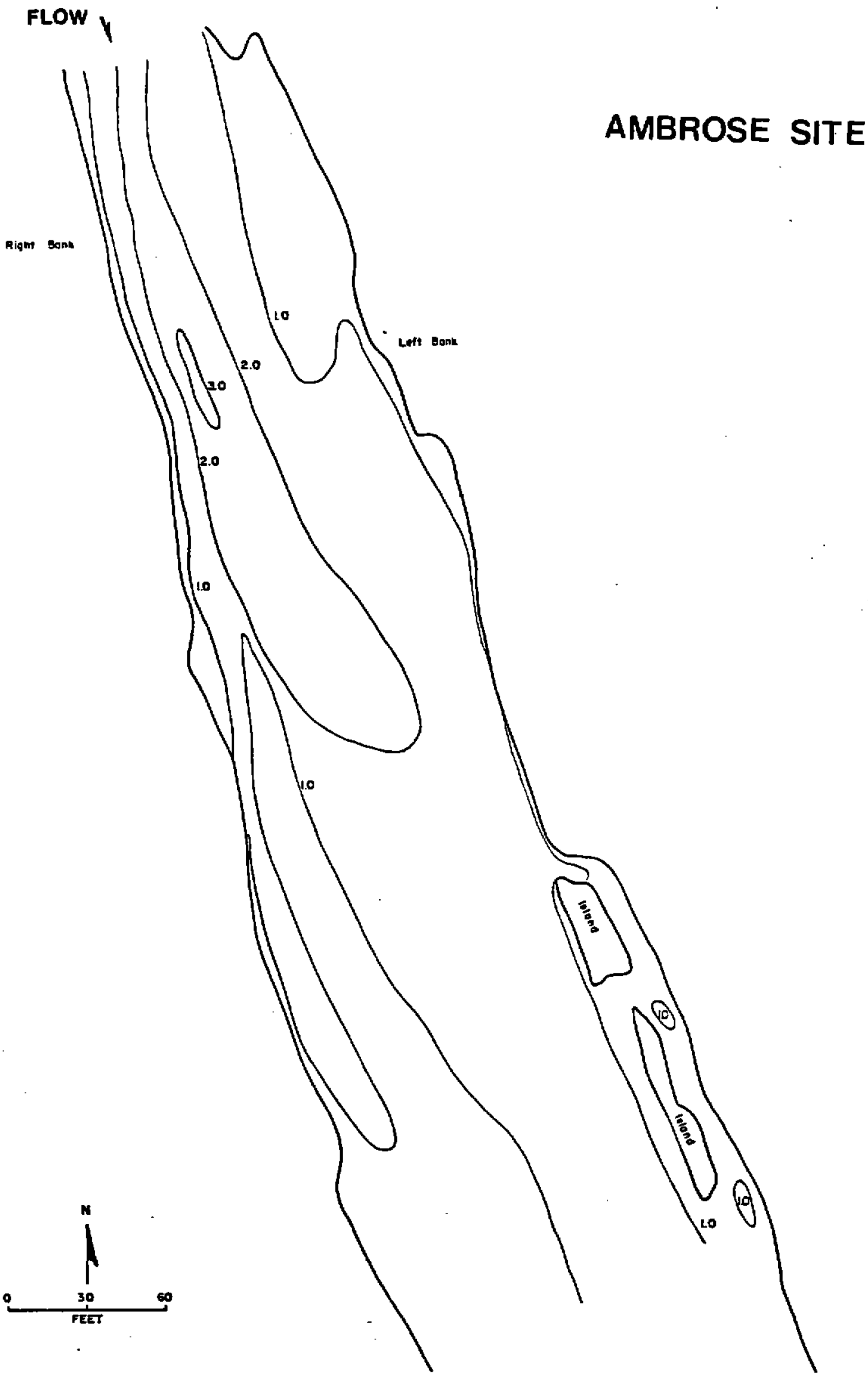


● = Chinook salmon redd locations

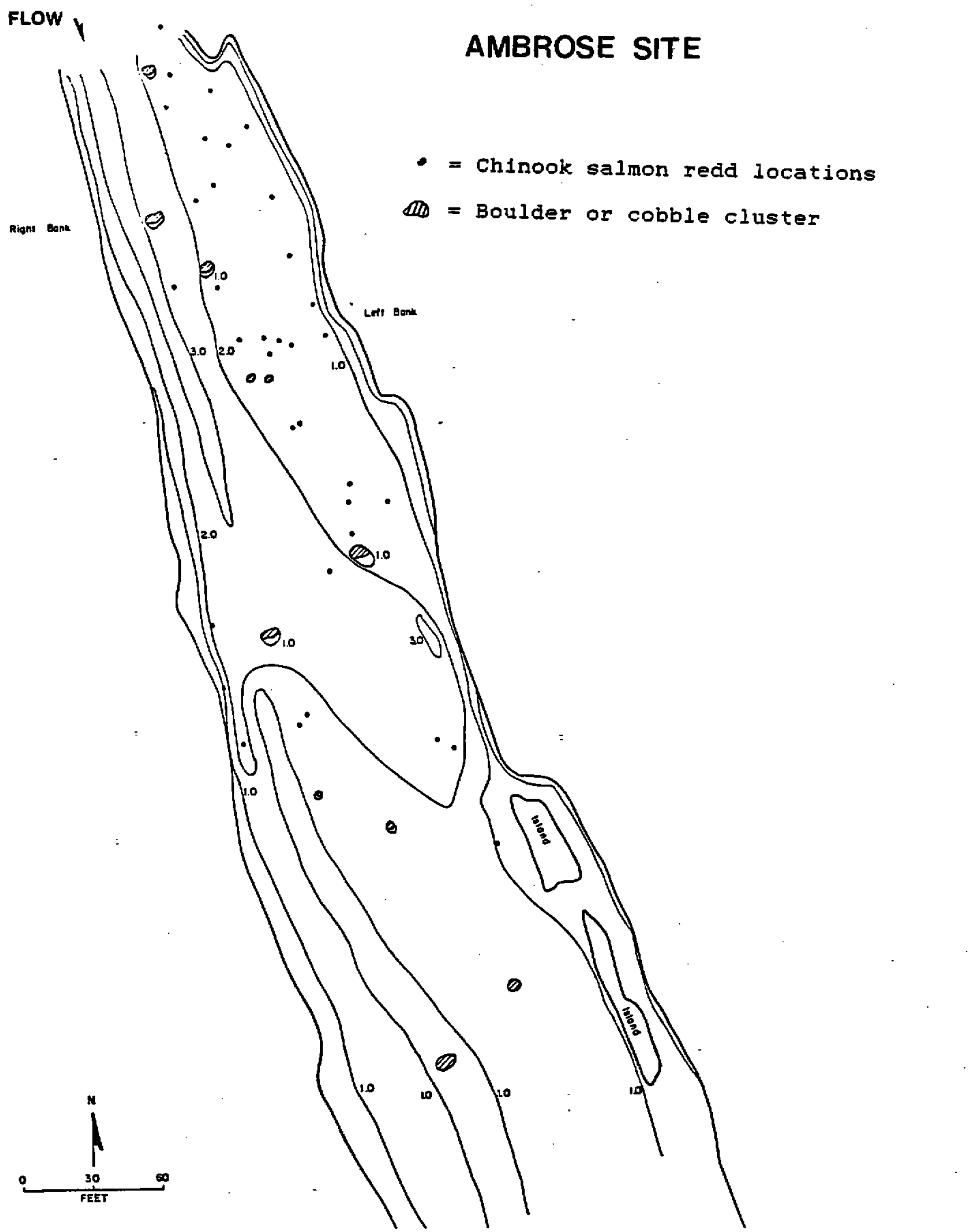
= Boulder or cobble cluster



Mean column velocity profile before substrates were ripped by a crawler tractor.

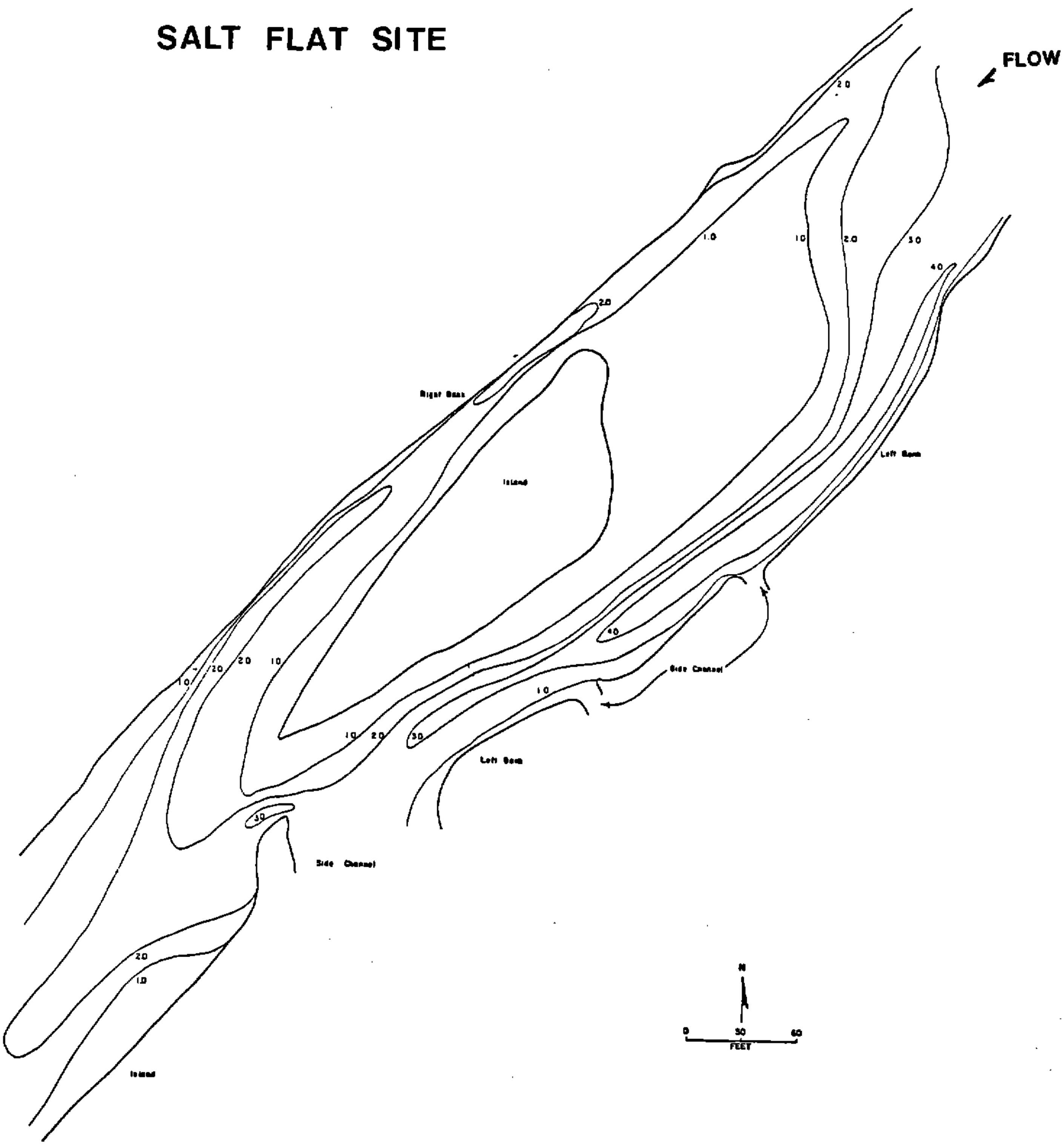


Total depth profile before substrates were ripped by a crawler tractor.



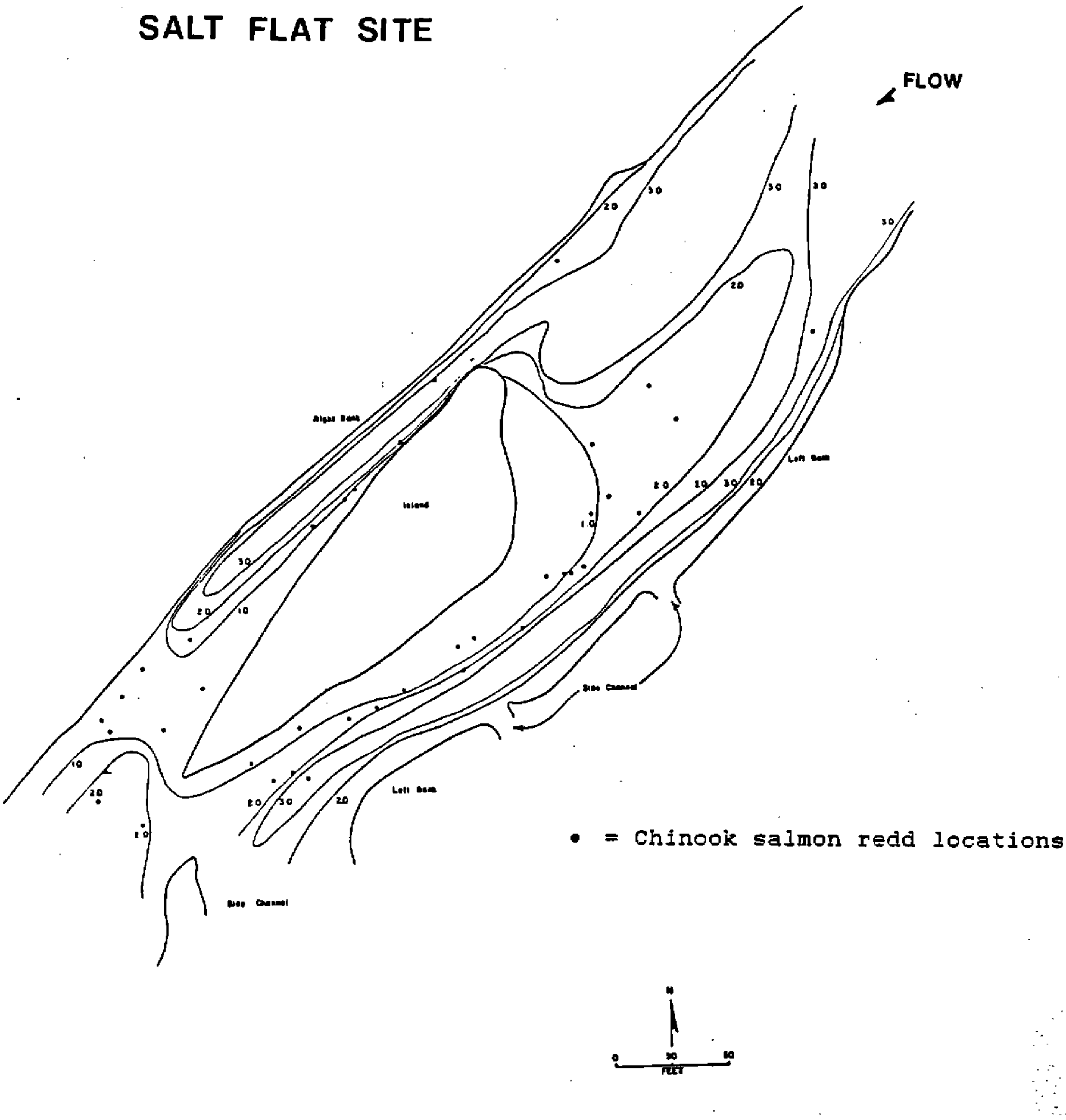
Total depth profile after substrates were ripped by a crawler tractor.

SALT FLAT SITE



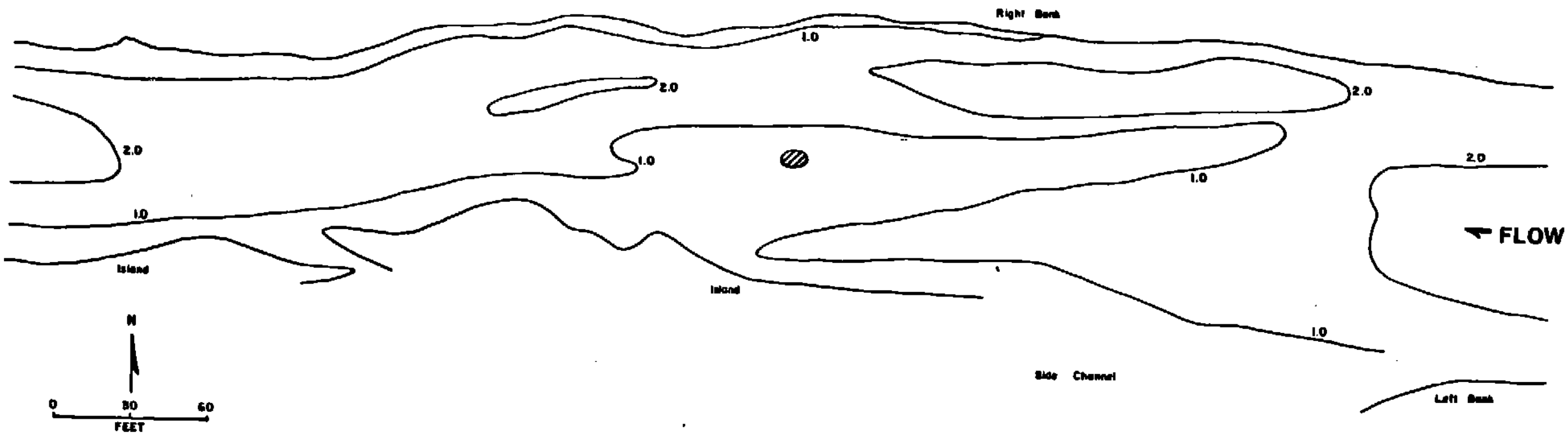
Total depth profile before substrates were ripped by a crawler tractor.

SALT FLAT SITE



Total depth profile after substrates were ripped by a crawler tractor.

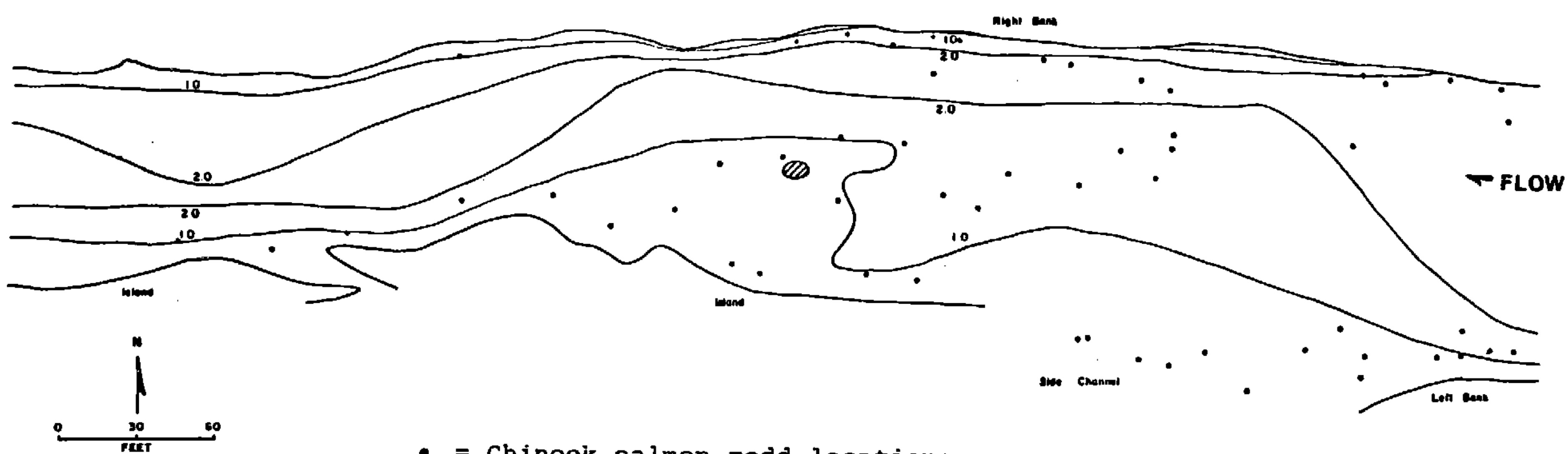
GOLD BAR SITE



= Boulder or cobble cluster

Total depth profile before substrates were ripped by a crawler tractor.

GOLD BAR SITE



• = Chinook salmon redd locations

= Boulder or cobble cluster

Total depth profile after substrates were ripped by a crawler tractor.