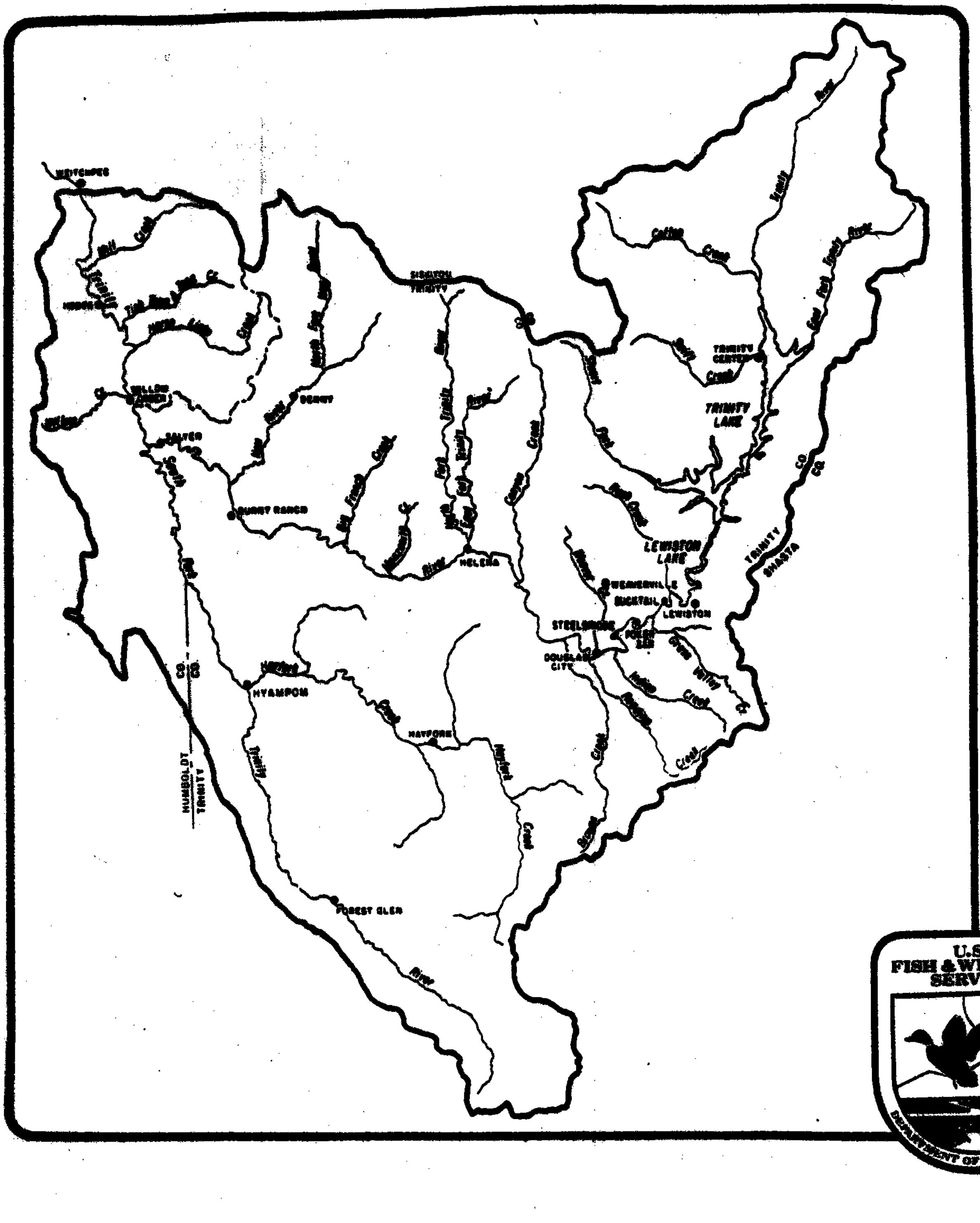
# TRINITY RIVER FLOW EVALUATION STUDY
# ANNUAL REPORT - 1986




U.S. FISH & WILDLIFE SERVICE

Fish and Wildlife Service

U.S. Department of the Interior

# ANNUAL REPORT

# TRINITY RIVER FLOW EVALUATION STUDY

1986

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

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# PREFACE

The following report is the second 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 and/or information can be submitted to:

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## SUMMARY

We are in the 2nd 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 Secretary 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 1986 include:

1. The completion of field data collection to quantify habitat preference for chinook and coho salmon and steelhead trout spawning, incubation, rearing, holding, and migration lifestages in 14 study reaches on the mainstem Trinity River between Lewiston Dam and Hoopa Valley for two rearing seasons and one full spawning season;

2. Hydraulic data collection for the first scheduled instream flow study has been collected for three evaluation flows at 127 river transects in 12 study reaches;

3. The validation of random habitat assessments for use in habitat preference criteria development, with available habitat predictions through the IFIM-IFG4 hydraulic simulation model;

4. An evaluation of chinook and coho salmon use of selected constructed spawning riffles; and,

5. The initiation of efforts to identify and quantify fish population characteristics and life history relationships.

One 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 newly established Trinity River Basin Fish and Wildlife Management Program Field Office.

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## Acknowledgements

We wish to express our appreciation to several individuals whose efforts have been invaluable in the completion of the 1986 field studies and in the preparation of this report.

A special note of appreciation goes to Gwyn Hampton for her able and willing assistance, which included word processing, and editorial assistance as well as general administrative support for the Lewiston Sub-Office.

A note of appreciation is also extended to Randy Brown, Richard Macedo, and Phillip North, all also employed by the U.S. Fish and Wildlife Service, and who assisted significantly in the field work. Mary Buck of Humboldt State University also contributed significantly in the evaluation of constructed spawning riffles.

Further acknowledgement is also extended to Dr. Roger Barnhart, FWS Cooperative Fisheries Unit, Humboldt State University, and Mr. Edouard Crateau, Trinity River Management Program, Weaverville Field Office, for their coordination and cooperation in the flow evaluation program.

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## INTRODUCTION

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

A major tributary of the Klamath River, the Trinity River has historically been recognized as a major producer of chinook and coho salmon and steelhead trout. The Hoopa Valley Indian Reservation borders the lower 12 miles of the Trinity where the Hupa Indians, still dependent on salmon for subsistence and ceremonial uses, maintain a net fishery. In addition, the Trinity River basin supports other important natural resources, many of which sustain significant resource-based social and economic interests. Mineral, timber and water resources are examples of those developed.

The Trinity River Division of California's Central Valley Project, operated by the U.S. Bureau of Reclamation, is the only major water development project in the basin and serves to export water from the Trinity River to the Central Valley of California. The keystones to this project are Lewiston Dam (at river mile 110) and Trinity Dam just upstream. The former represents the upstream limits of anadromous salmonid migration in the basin. As mitigation for upstream losses the Trinity River hatchery was constructed at the base of Lewiston Dam. In addition, downstream flows were to be provided to maintain fish resources.

Coincident with construction and operation of the Trinity River Division, logging accelerated within the Trinity basin. Higher watershed erosion rates and lower streamflows below Lewiston Dam resulted in extensive sedimentation of fish habitat. Maintenance of minimum streamflow releases and construction and operation of the fish hatchery were not sufficient to sustain fisheries populations. 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

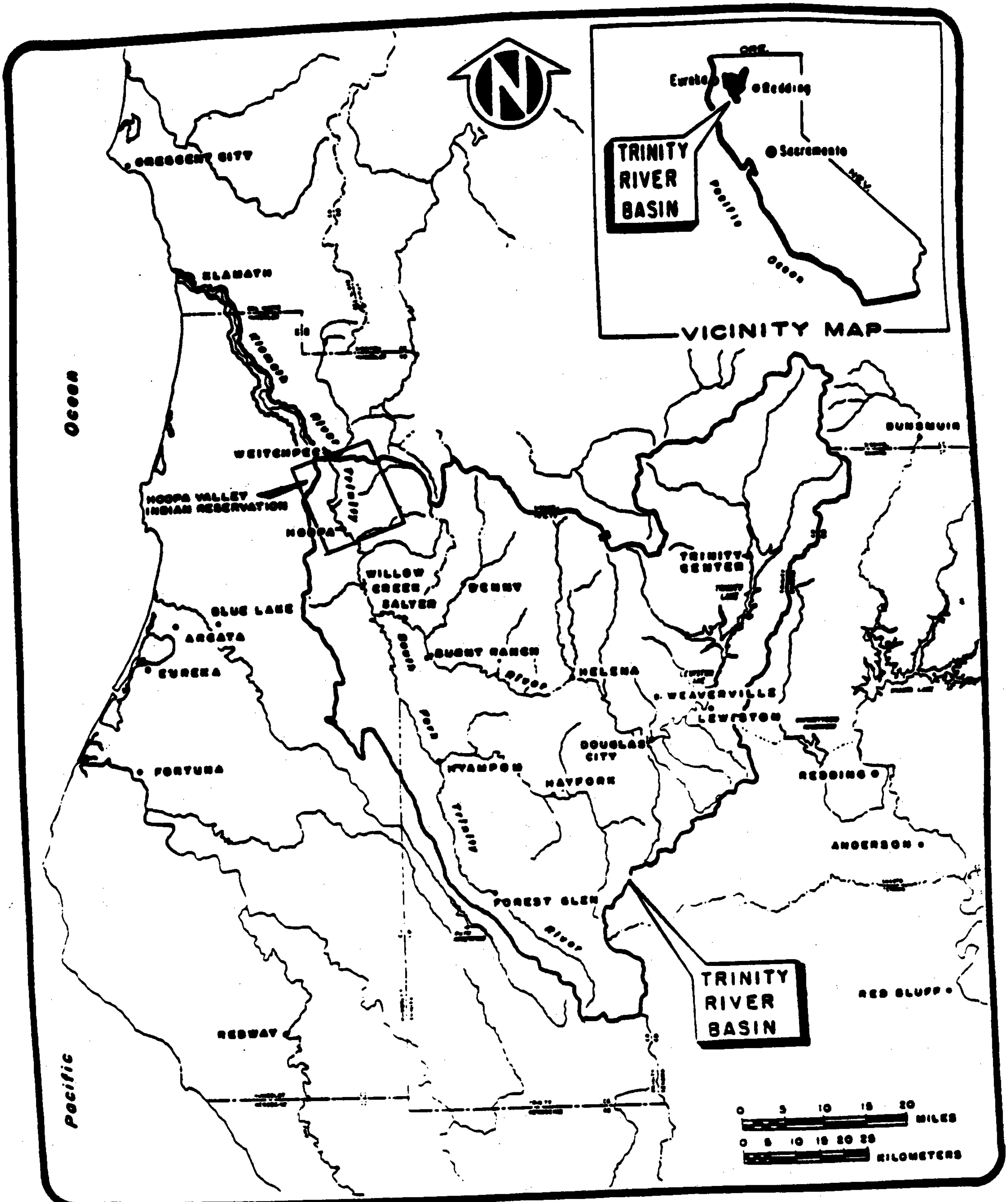



Figure 1. Trinity River Basin Location Map

measures are implemented; 5) in dry-years, releases will be 220,000 acre-feet and in critically dry years 140,000 acre-feet; 6) dry and critically dry years will be based on forecasted Shasta Reservoir inflow; and, 7) at the end of the 12-year study the Service is to report to the Secretary, describing the effectiveness of the improved flows and any other habitat rehabilitation measures (e.g. those contained in the Trinity River Basin Fish and Wildlife Management Program) in restoring fish populations and habitat below Lewiston Dam.

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

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

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

TASK 1. Annual Study Plan Review and Modification.

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

TASK 2. Habitat Preference Criteria 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 amout 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 1986. The final section on program planning, direction, and coordination describes the focus of study efforts planned for 1987.

# HABITAT PREFERENCE CRITERIA DEVELOPMENT (TASK 2)

The objective of task 2 is to develop habitat preference criteria quantifying depths, velocities, substrates, and cover requirements for each lifestage and species of anadromous salmonids in the Trinity River. The resulting habitat preference curves will be used in conjunction with hydraulic streamflow data to determine the amount of habitat available for salmon and trout at various streamflows as well as determine the amount of habitat required to reach target levels of natural fish production. Data collection is planned over a 3-year period, which began in January of 1985. Following is a preliminary report of findings after almost two years of data collection ending on October 31, 1986.

## Preliminary Habitat Utilization Curve Development

### Methods

Habitat use data is being collected for all lifestages of chinook and coho salmon, steelhead/rainbow trout, and brown trout. Data collection has been accomplished through both direct and indirect sampling methods. Direct observations are made either by mask and snorkel, from the bank, or from a raft during float trips. When poor water clarity prevents effective use of direct observation methods, indirect sampling with either a backpack electrofisher or seine is used.

Sampling is conducted within fourteen study sites located on the Trinity River between Lewiston Dam and Weitchpec (Figure 2).

Direct observations with a mask and snorkel requires two persons, one as the snorkel observer and one support person to record data, operate the flow meter, and control the raft. Sampling is conducted in a downstream direction at each study site. Sampling in an upstream direction proved to be impossible due to the size of the river and high water velocities. The observer works in a zig-zag pattern across the river channel from bank to bank. At each bank sampling in an upstream direction for short distances is done when water velocities permit. This sampling technique allows for nearly complete coverage of the study site. When fish are spotted the observer determines the species, lifestage, behavior, and focal point. The support person is then signaled to approach and the observation is completed. When fish are spotted in the thalweg, where water is to deep or swift to stand, the observer floats motionless past the fish until out of sight. The observer then carefully approaches the fish from the rear or side. Once the observer has determined that the fish is not startled by his presence the observation is made. No observations are conducted on fish believed to be startled or

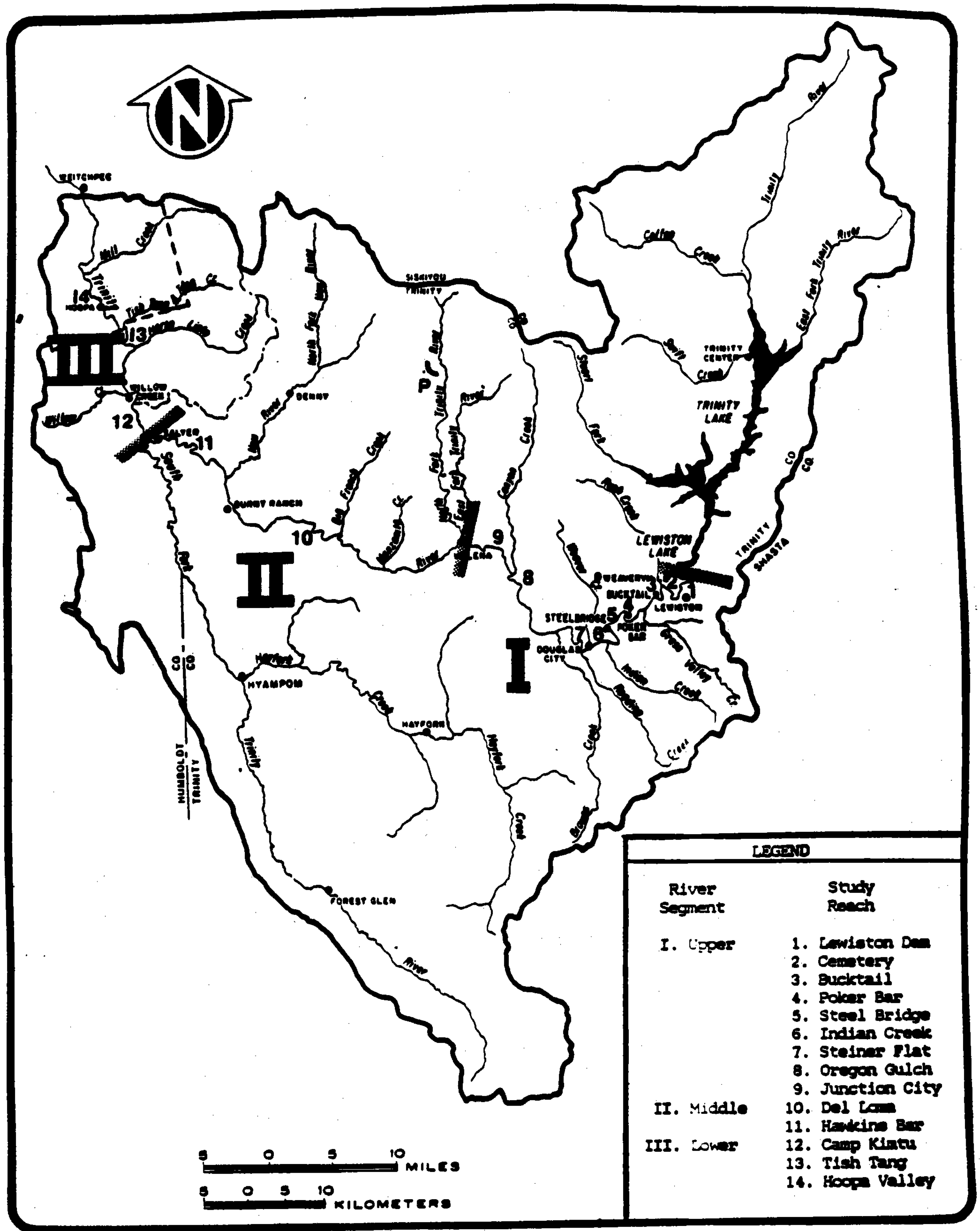



Figure 2. Map of the Trinity River Flow Evaluation Study Area

disturbed by the observer. When schools of juvenile salmon are encountered, the number of fish in the school is counted or estimated and the observation is made at the focal point of the school. When one school of fish is found to occupy more than one microhabitat, additional observations are made in order to accurately represent those microhabitats used. Habitat use measurements of spawning salmon and steelhead trout are taken 0.5 feet upstream of the redd, along the centerline, in an attempt to simulate prespawning hydraulic and substrate conditions. Fish nose velocities are taken at 0.4 feet from the bottom for all spawning observations.

For indirect observations both a backpack electrofisher and bag seine are used. Selected areas within each study site are sampled in an upstream direction with the electrofisher. When fish are sampled the species and lifestage are noted and a marker is placed designating the capture location. Once sampling is completed we go back to the first marker placed and systematically work upstream recording each observation. The area sampled is then measured and habitat availability measurements are taken at 0.25, 0.50, and 0.75 of the length and at 0.25, 0.50, and 0.75 in width, at each of the length intervals for a total of nine observations.

Seining is done in a downstream direction over monotypic habitat types, such as gravel bars or backwaters. All fish captured are recorded for species, length, and lifestage. The area of the seine haul is then measured and representative habitat measurements are made using the same method for obtaining the habitat availability measurements described above.

Data Requirements

Fourteen habitat parameters are recorded for each observation taken when using direct observation field techniques. The species and lifestage are determined. Fish less than 50 mm in forklength are considered fry. Fish greater than or equal to 50 mm and less than or equal to 200 mm are considered juveniles, and fish greater than 200 mm were considered adults. An estimate of forklength is obtained with the help of an underwater slate which has a centimeter scale marked on it. When more than one fish is utilizing the microhabitat focal point, as is often the case with schools of juvenile chinook salmon, the total number of fish is counted or estimated. The behavior of the fish being observed is categorized as either holding, roving, feeding or spawning. The total depth and depth of fish are both measured as the distance up off of the bottom in feet. The depth of fish is measured as the distance from the bottom to the focal point of an individual fish or school of fish. Two water velocities are taken at each observation, a mean column water velocity and a fish nose water velocity. Mean column water velocity is measured at 0.6 depth from the water surface for water less than 2.5 feet deep; and the average of the velocities measured at 0.2 depth and 0.8 depth from the surface for water greater than or equal to 2.5 feet deep. Water velocities are measured with either a Marsh McBirney model

201 flow meter or a Price "AA" current meter.

A three-digit code is used to describe the cover types and quality of the cover being used by the observed fish (Table 1). The first digit in code describes the dominate cover type present while the second digit describes the subdominant cover type, if present. The third code value, which follows a decimal, describes the quality of the cover types present as either poor, moderate, good, or excellent.

Table 1. Cover code descriptions used to develop habitat utilization criteria for the Trinity River Flow Evaluation, Trinity Co., California, 1986.

| Code | Cover Type | Description |
|---|---|---|
| 0 | No cover | gravel less than 2 inches or any larger material which is embedded to the extent that no cover is available. |
| 1 | Cobble | 75 - 300mm and larger, clear of fines. |
| 2 | Boulders | 300mm and larger, clear of fines. |
| 3 | Small woody debris | brush and limbs less than 9 inches in diameter. |
| 4 | Large woody debris | logs and rootwads greater than 9 inches in diameter. |
| 5 | Undercut bank | undercut at least 0.5 feet. |
| 6 | Overhanging vegetation | within 1.5 feet of the water surface |
| 7 | Aquatic vegetation | |

recorded as DS.Q where D = Dominant cover type
S = Subdominant cover type
Q = Quality of cover

The substrate compositions which are utilized or found present under observed fish are described with use of the Brusven sustrate index (Bovee 1982). The Brusven index is composed of a 3 digit descriptor of dominant substrate, subdominant substrate and percent embedded in fines (DS.%E).

We expanded the Brusven index to include bedrock as one of the possible substrate types present (Table 2).

Table 2. Expanded Brusven substrate index used for habitat utilization criteria development, Trinity River Flow Evaluation, Trinity Co., California, 1986.

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

(DS.%) Dominant Subdominant. % Embedded

The stream characteristic present at each observation is categorized into nine different habitat types (Table 3).

Table 3. Stream character descriptions in use for habitat utilization criteria development on the Trinity River, Trinity Co., California, 1986.

| Code | Stream Character |
|---|---|
| 1 | Pool |
| 2 | Run |
| 3 | Riffle |
| 4 | Side Channel |
| 5 | Off Channel ponding (Beaver Ponds) |
| 6 | Backwater |
| 7 | Waters Edge |
| 8 | Pocket |
| 9 | Bar |

Surface turbulance is noted as either present or absent for each observation taken. An estimate of percent canopy is made for each observation taken by visually estimating the percentage of the sky which is blocked by the riparian canopy.

Additional data which is recorded for each sampling day includes an estimate of water visibility in feet, stream discharge, study site, water temperature, weather conditions, observers present, and the data and time of sampling.

## Data Summary

Habitat use data are being summarized by depth, velocity, substrate, and cover. All habitat use curves have been developed from data collected by direct observation, primarily with a mask and snorkel. Habitat use curves are developed from the frequency of the number of observations at each parameter per species lifestage. The habitat use curves for depth and velocity are hand drawn by fitting a smooth curve through a normalized frequency distribution for each species and lifestage. Normalized bar histograms are used to show habitat use for substrate and cover. All of the substrate curves are drawn from the dominant substrate value observed at this time. When the study is complete, cover and substrate curves will be constructed in their entirety.

## Preliminary Results

After two years of data collection 18,555 fish have been seen in 2,418 observations (Table 4).

Table 4. Summary of habitat criteria data collected by direct observation in the Trinity River from January 1985 to June of 1986, Trinity Co., CA.

| SPECIES | LIFESTAGE | NUMBER OF OBSERVATIONS | NUMBER OF FISH |
|---|---|---|---|
| Chinook | Fry | 594 | 7583 |
| | Juvenile | 356 | 6364 |
| | Adult | 12 | 92 |
| | Spawning | 278 | 342 |
| Coho | Fry | 152 | 1314 |
| | Juvenile | 118 | 925 |
| | Adult | 13 | 37 |
| | Spawning | 102 | 198 |
| Steelhead | Fry | 33 | 117 |
| | Juvenile | 420 | 933 |
| | Adult | 117 | 208 |
| | Spawning | 20 | 10 |
| Brown | Fry | 55 | 146 |
| | Juvenile | 104 | 235 |
| | Adult | 41 | 48 |
| | Spawning | 3 | 3 |
| | TOTALS | 2,418 | 18,555 |

Preliminary habitat use curves or histograms for all lifestages of chinook and coho salmon are illustrated in Figures 3 - 8. Curves for all lifestages, except spawning, of steelhead/rainbow trout and brown trout are illustrated in Figures 9 - 14. Use frequency histograms for cover and substrate are based only on the dominant category observed.

## Discussion

After a second year of data collection the quality of nearly every species habitat use curve has improved. It appears that more observations are needed for spawning chinook salmon to improve the quality of the velocity use curves. However, the depth use curves are in very good condition. The habitat use curves for all lifestages of coho salmon should be excellent after the final year of data collection is complete. At the present time their quality may be considered good. Development of adult holding curves for both chinook and coho salmon has been of low priority until this year. There should be no problem in obtaining enough observations to complete holding curves for adult salmon by next year. The only problem encountered with obtaining observations on adult holding salmon thus far has been getting accurate depths and velocities, because of the deep water they seem to prefer.

To date, only 33 observations have been made on fry steelhead trout by mask and snorkel , while 420 observations have been made on juvenile steelhead trout. It is apparent that locating fry steelhead trout by direct observation is difficult. Steelhead trout fry may be using habitat areas of very shallow water, where snorkel and mask observations are difficult or they may blend into the substrate so well that they are easily overlooked by the observer. There is also the possibility that tributary streams, where the majority of steelhead trout spawning occurs, are used by fry steelhead trout until they have grown to juvenile size before entering the Trinity River.

The limited number of observations made on adult steelhead trout during 1986 are most likely due to high flows during February, along with zero visibility for over two months last winter. Greater effort will be placed on getting adult steelhead trout observations this coming year. If good weather conditions and clear water exists long enough we feel that enough data points can be collected to yield good habitat use curves by the end of the study.

More observations are needed for all lifestages of brown trout in order to have enough data points for construction of quality habitat use curves. There were very few brown trout fry observed this year compared to last year. The flood flows during February may have washed many fry downstream, distributing them throughout the system. Last year large numbers of fry brown trout were only observed in the upper river.

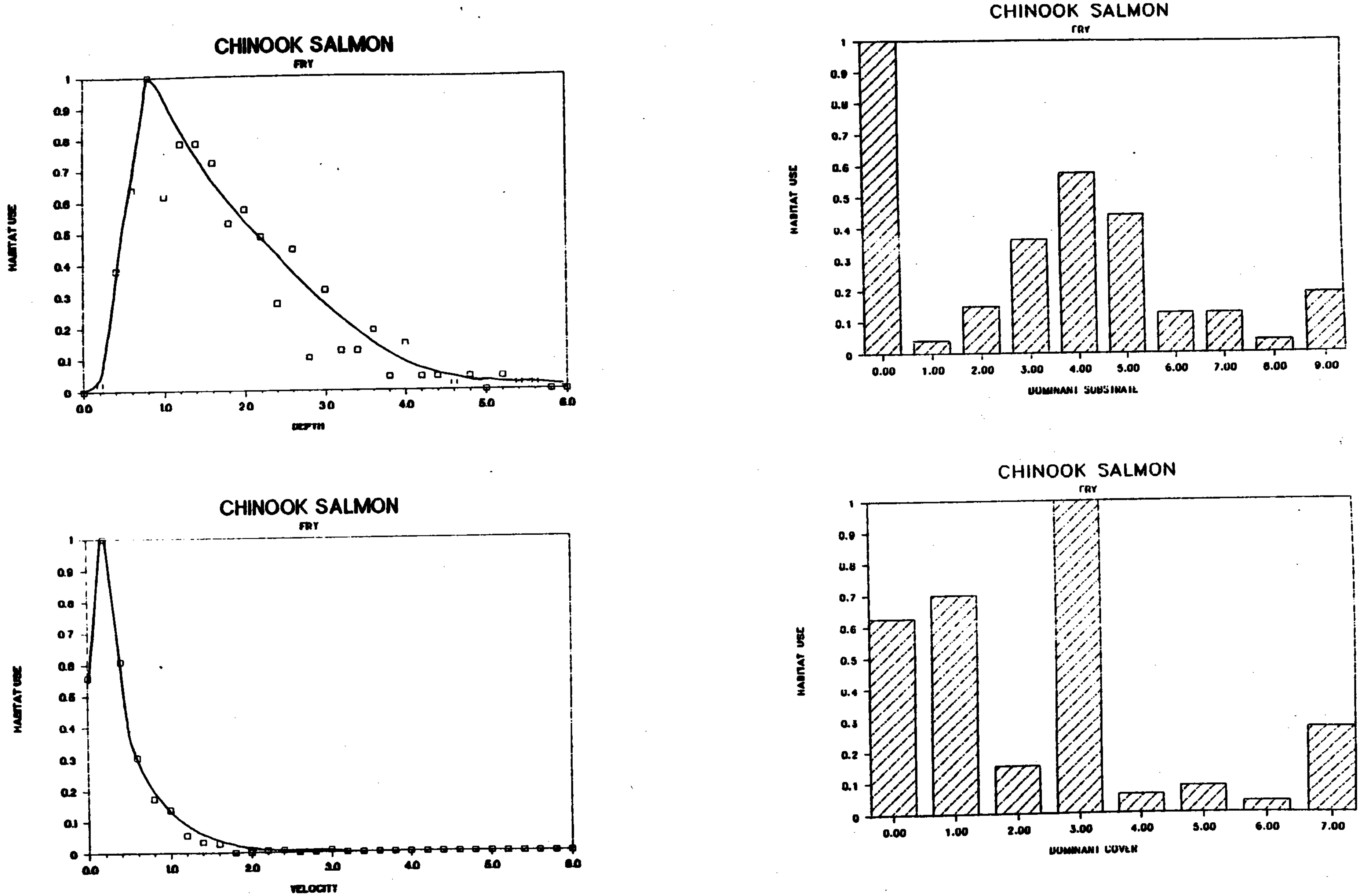



Figure 3. Preliminary Curves, Chinook Salmon fry frequency of habitat use, water depth and velocity, Trinity River, California.

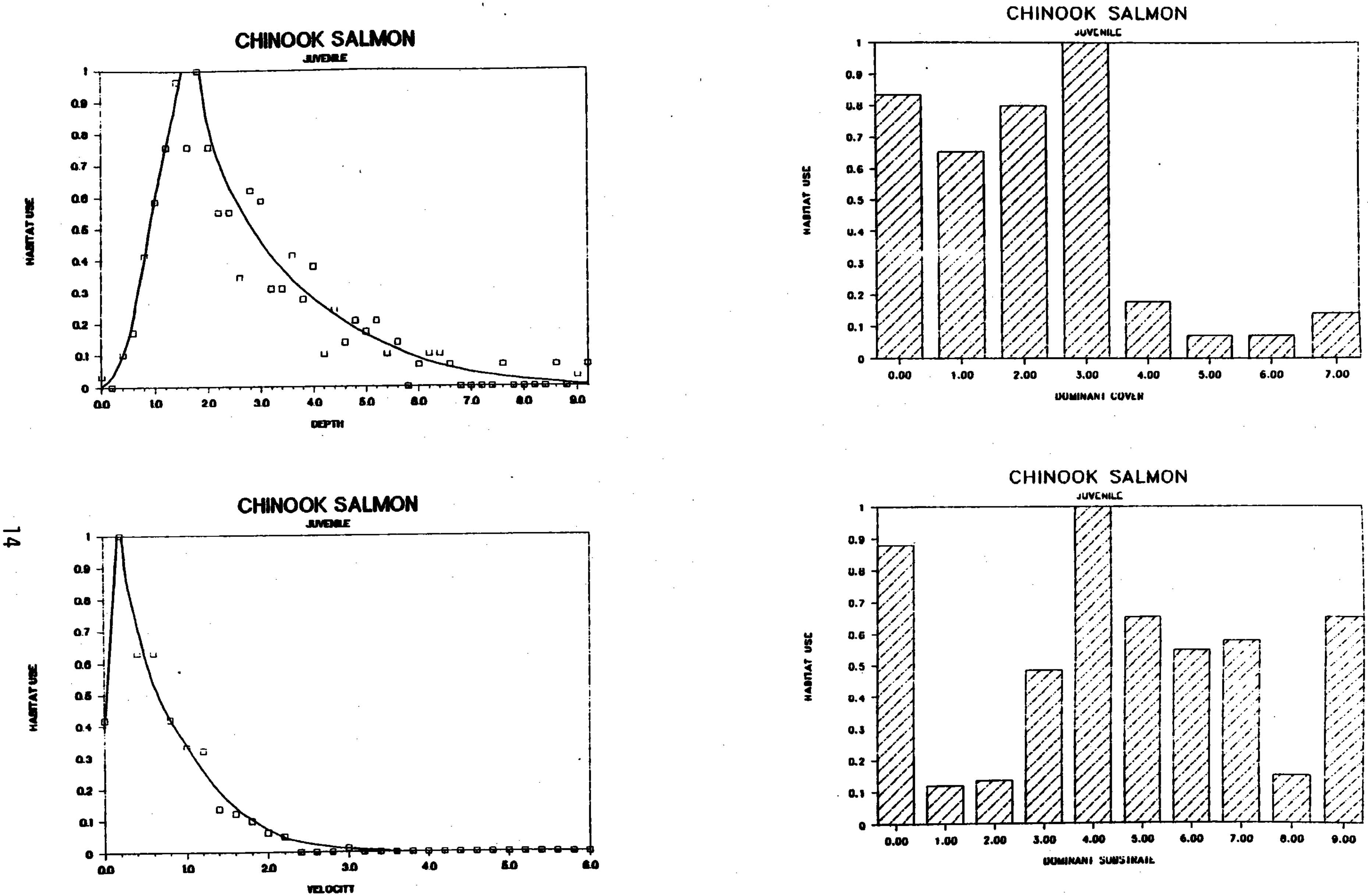



Figure 4. Preliminary Curves, Chinook Salmon juvenile frequency of habitat use, water depth and velocity, Trinity River, California.

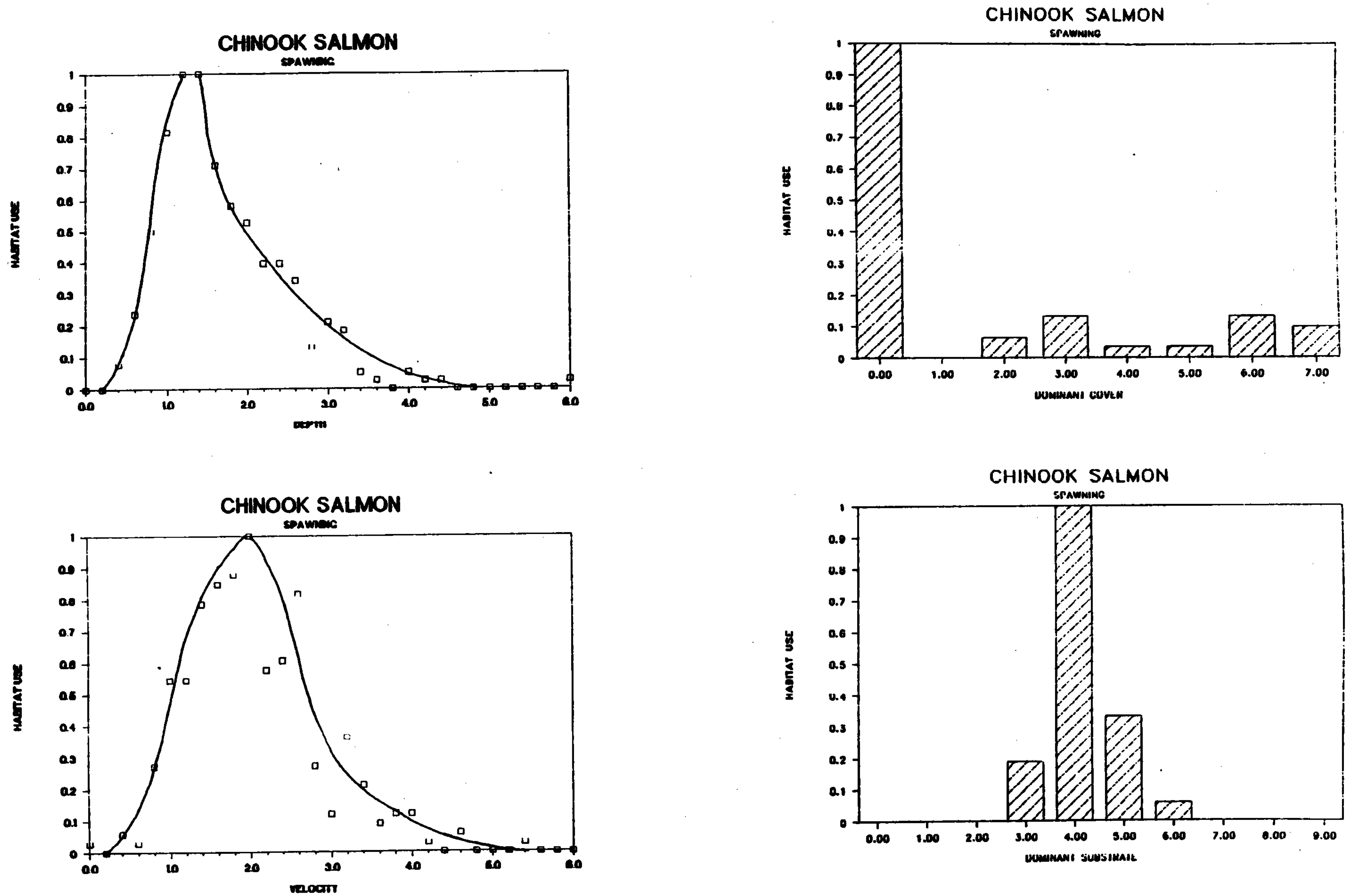



Figure 5. Preliminary Curves, Chinook Salmon spawning frequency of habitat use, water depth and velocity, Trinity River, California.

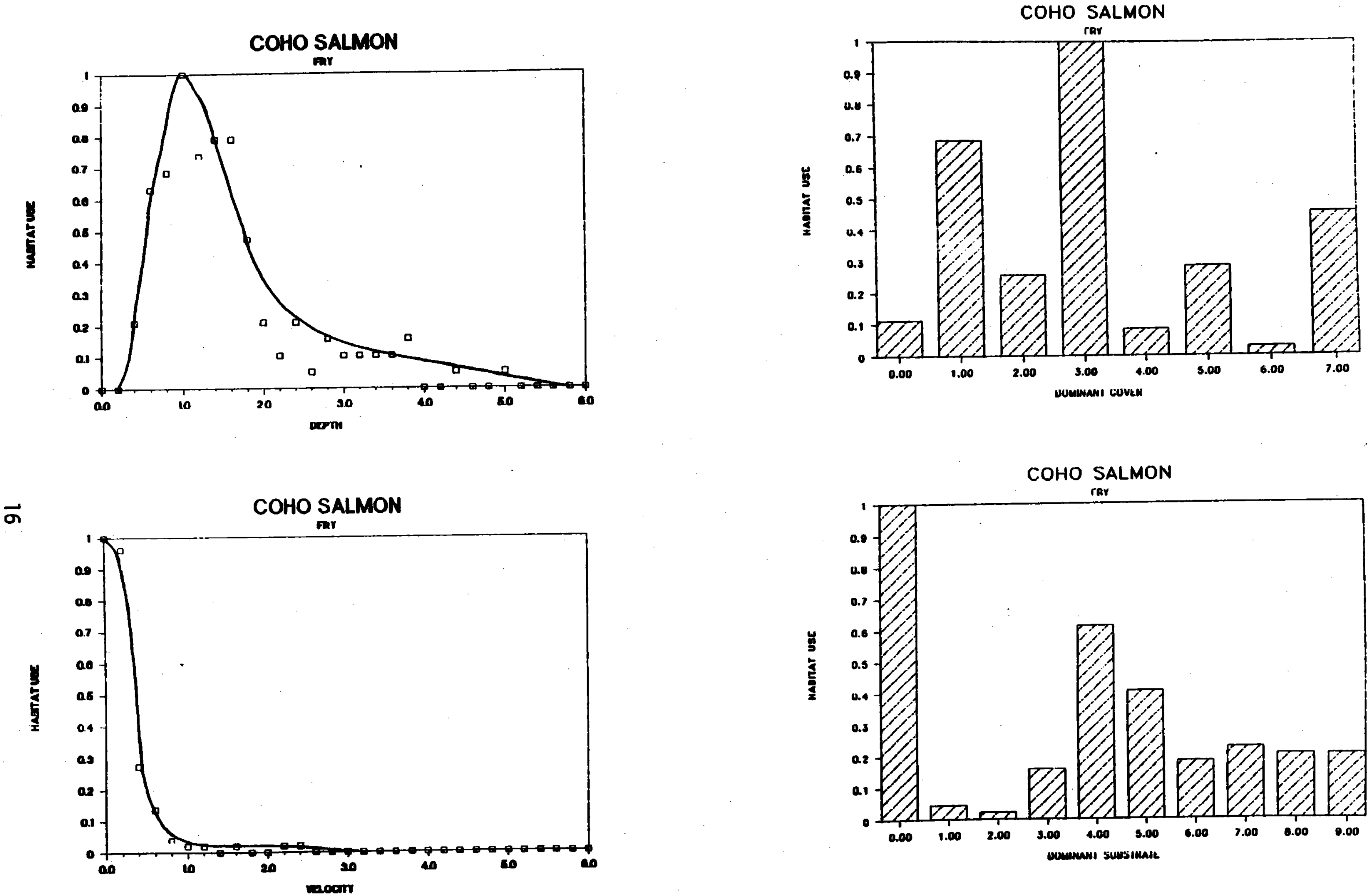



Figure 6. Preliminary Curves, Coho Salmon fry, frequency of habitat use, water depth and velocity, Trinity River, California .

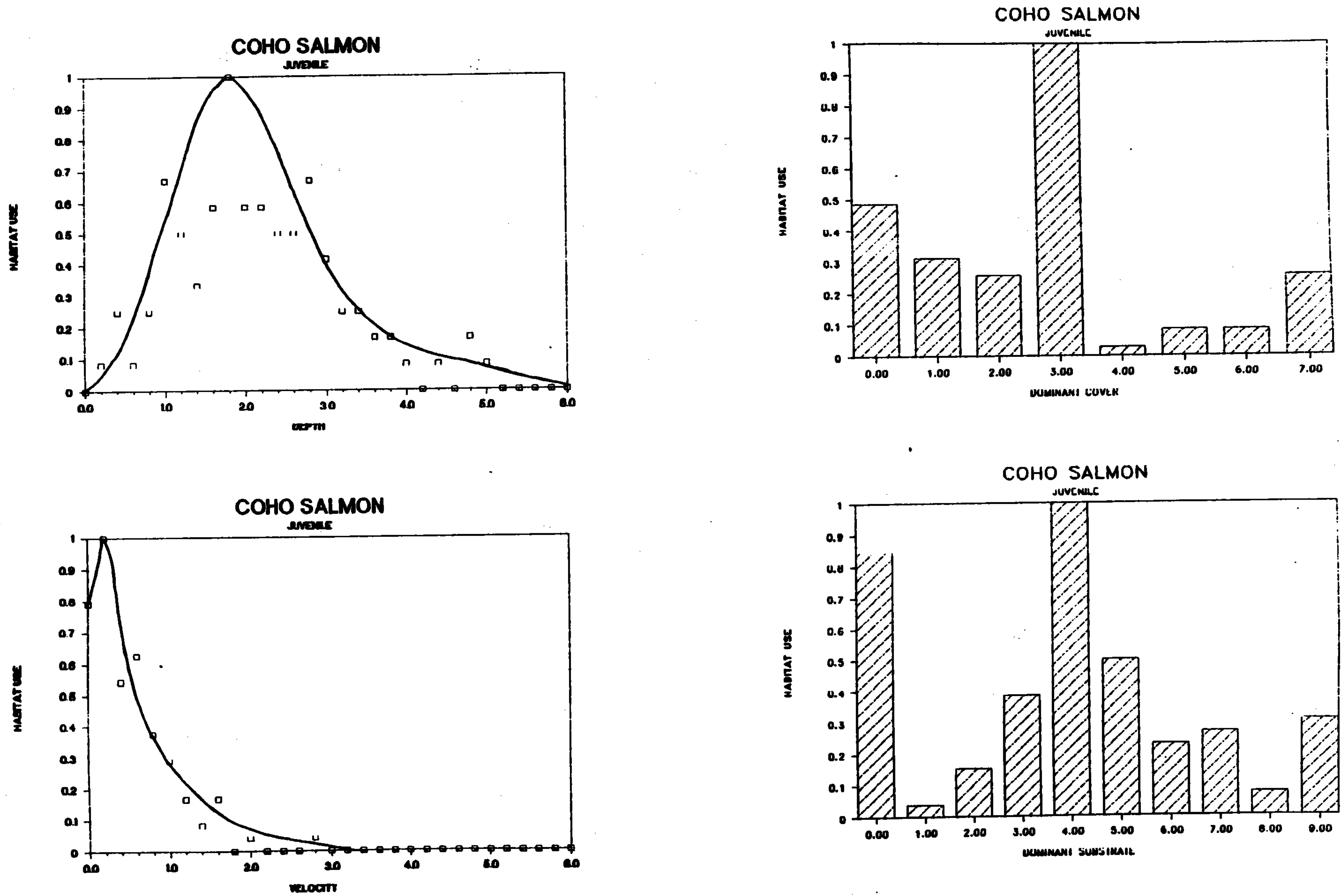



Figure 7. Preliminary Curves, Coho Salmon juvenile, frequency of habitat use, water depth and velocity, Trinity River, California.

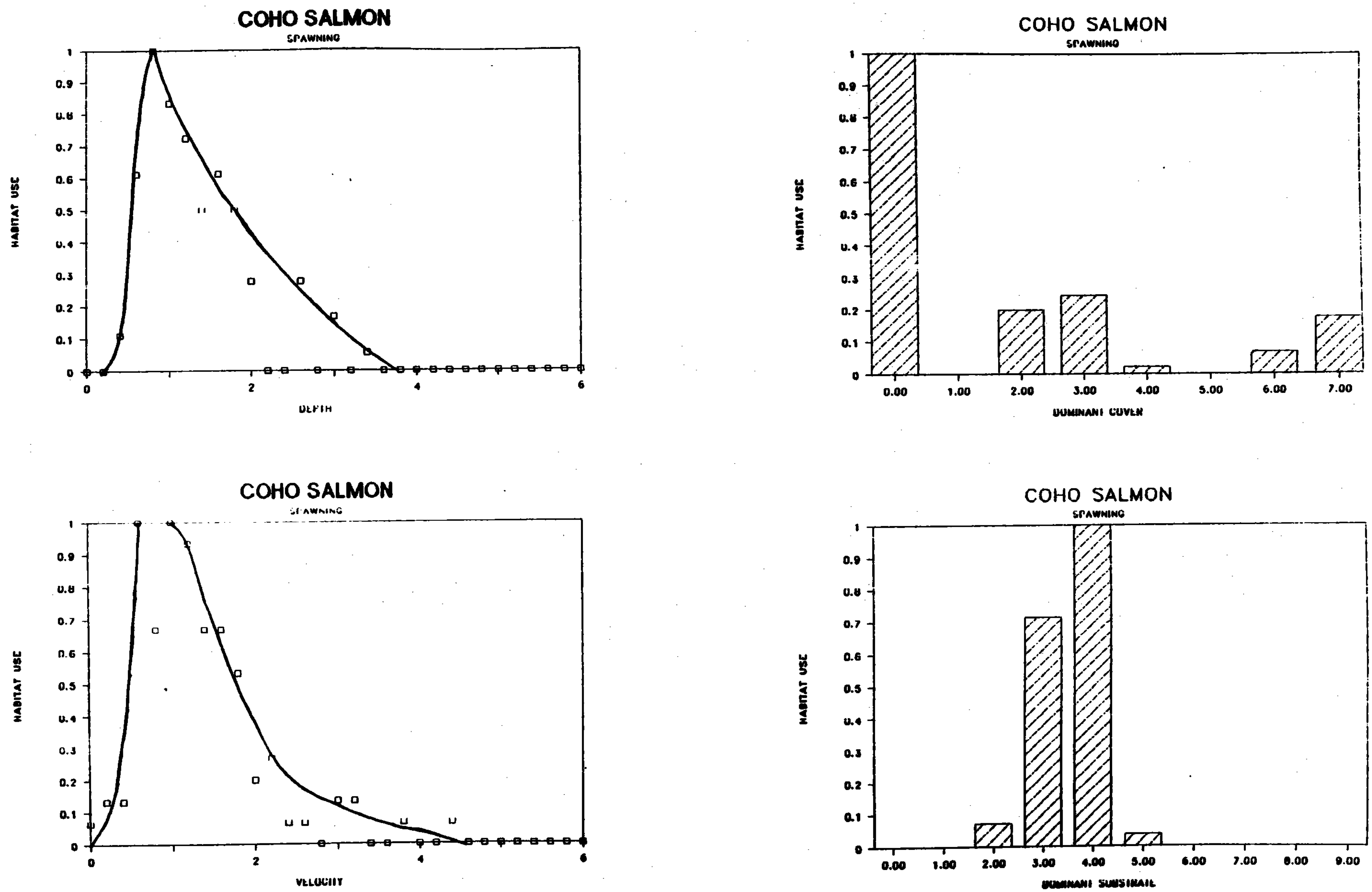



**Figure 8. Preliminary Curves, Coho Salmon spawning frequency of habitat use, water depth and velocity, Trinity River, California.**

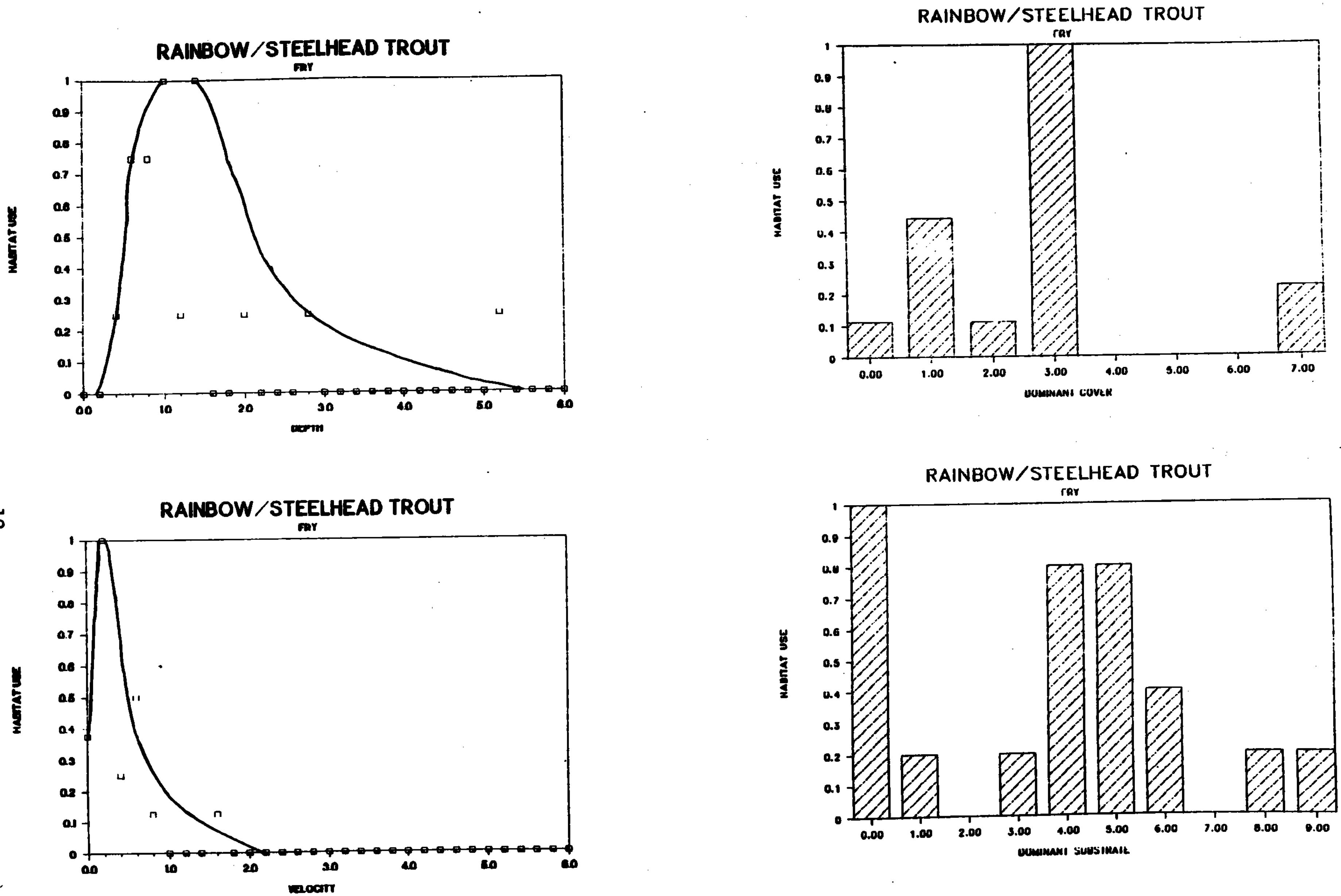



Figure 9. Preliminary Curves, Steelhead Trout fry, frequency of habitat use, water depth and velocity, Trinity River, California.

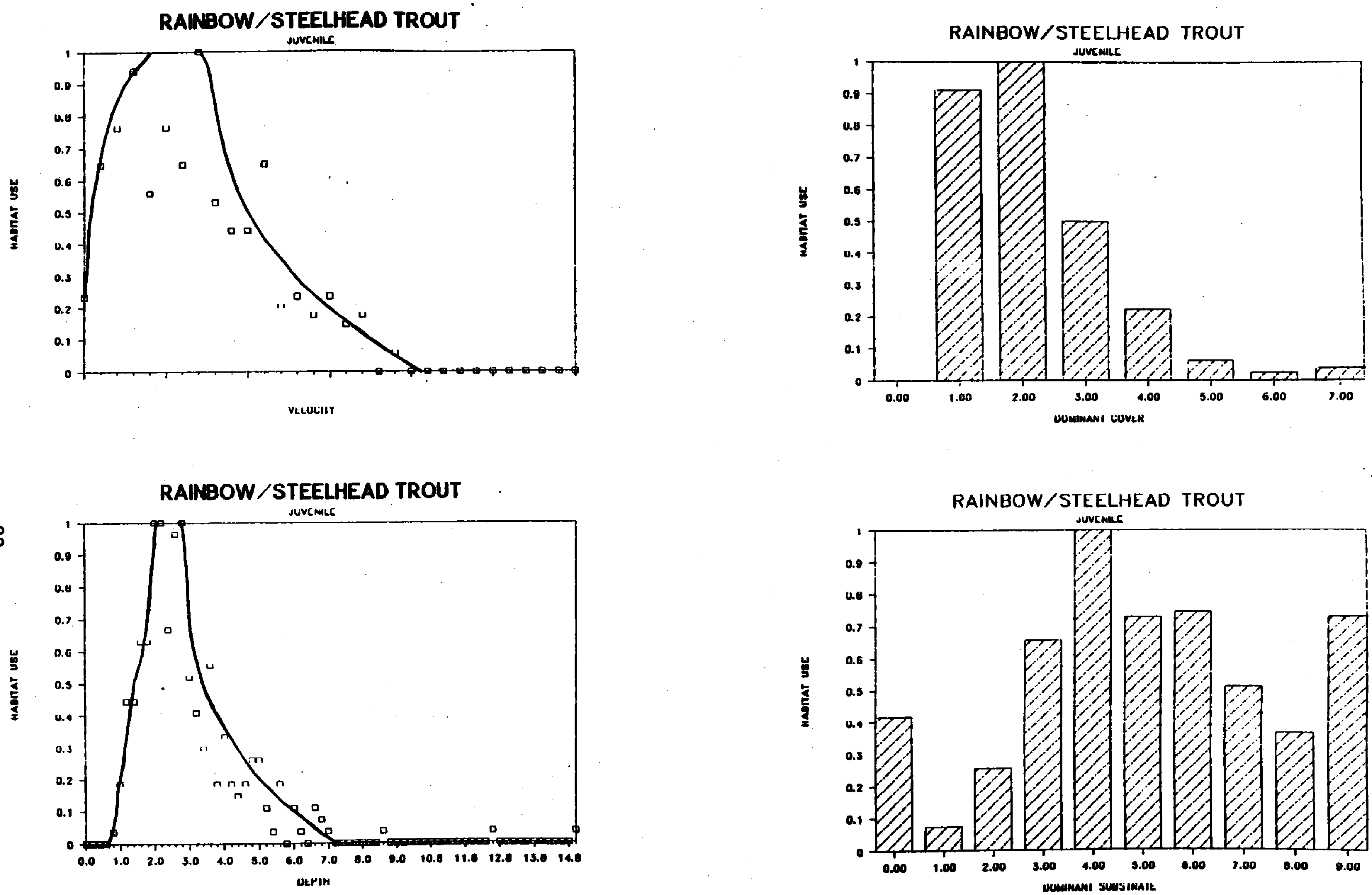



Figure 10. Preliminary Curves, Steelhead Trout juvenile frequency of habitat use, water depth and velocity, Trinity River, California.

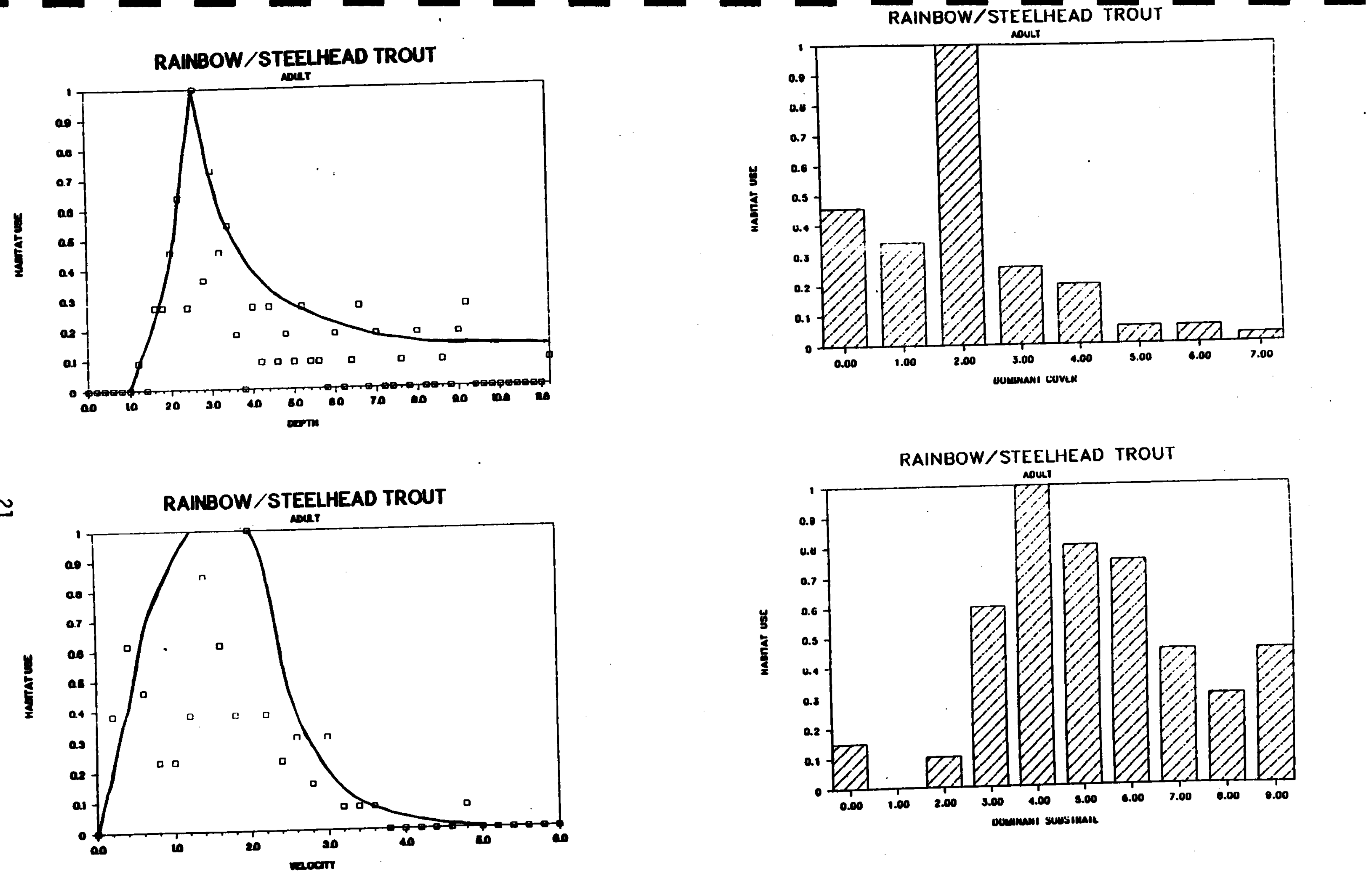



Figure 11. Preliminary Curves, Steelhead Trout, adult, frequency of habitat use, water depth and velocity, Trinity River, California.

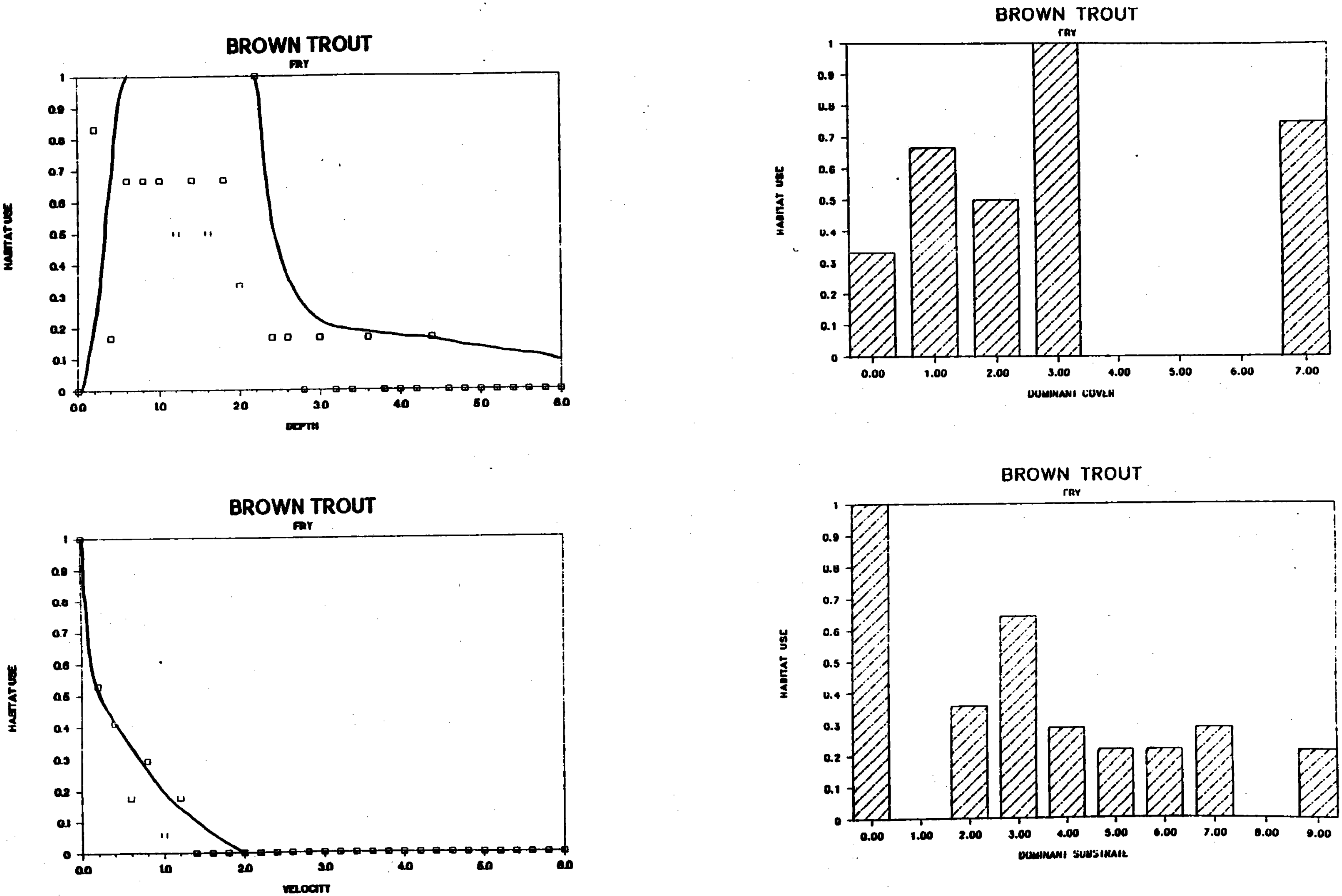



Figure 12. Preliminary Curves, Brown Trout fry, frequency of habitat use, water depth and velocity, Trinity River, California.

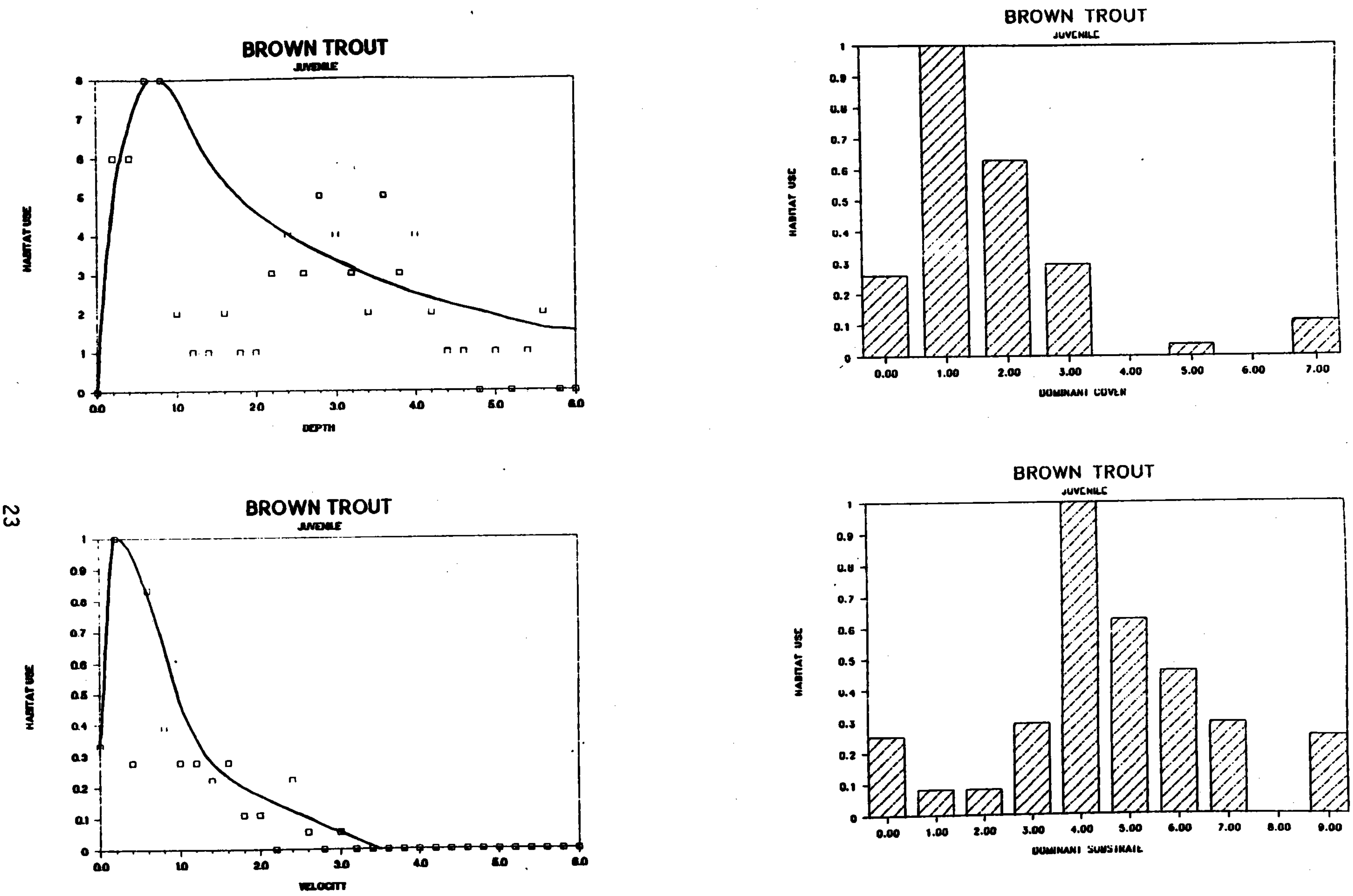



Figure 13. Preliminary Curves, Brown Trout juvenile frequency of habitat use, water depth and velocity, Trinity River, California.

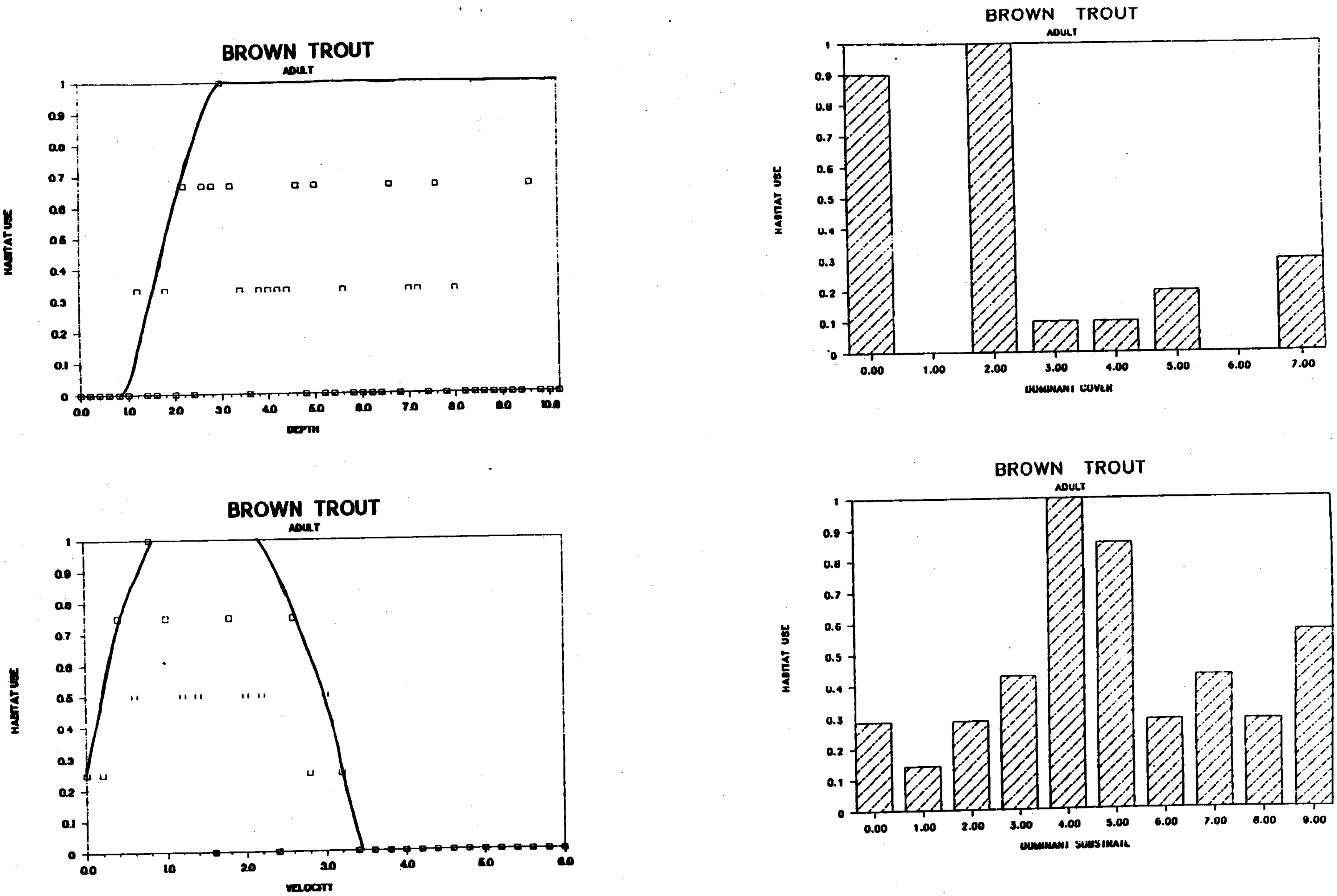



Figure 14. Preliminary Curves, Brown Trout adult frequency of habitat use, water depth and velocity, Trinity River, California.

## Validation of Random Habitat Assessments

Available habitat is estimated by taking a minimum of 150 random microhabitat measurements at each study site for each discharge sampled. The sampling locations are determined with previously prepared tables of paired random values. The first value in the pair represented the distance downstream to the next sampling location, while the second value represented the percent distance across the river channel yielding the exact location where the sample is made. Data collected during available habitat sampling is essentially the same as the data collected during fish observation sampling.

Collection of random habitat availability data proved to be a slow and laborious process. We found that at least one full day of sampling is required to successfully obtain 150 observations. As an alternative method to obtaining habitat availability data, habitat information was taken from the IFIM IFG-4 Hydraulic simulation model output to estimate habitat availability at each study site. The method that is used to select vertical habitat measurements from the IFG-4 model is as follows:

1. The total length of the study site and the distances between each transect is determined.

2. The length of habitat which each transect represented upstream and downstream is determined by multiplying the distance to the upstream transect by the weighting factor upstream and by multiplying the distance to the downstream transect by the weighting factor downstream given by the model. The resulting distance up and down are then added together to obtain the total distance of habitat which is representative of the transect.

3. The amount of habitat which each transect represents within the total study site is determined by dividing the transect length by the total study site length.

4. The value determined in the previous step is than multiplied by the number of verticals within the wetted area located along the transect and an additional multiplier to determine the number of verticals to be selected from that transect for the habitat availability assessment. The additional multiplier can be any number selected to yeild a total sample size at the desired level (in this case between 100 and 150).

5. The actual verticals (cells) be be used from each transect are than randomly selected. The method described above is illustrated in Table 5.

All of the verticals selected from each transect in this process are then pooled together to produce an available habitat curves for the study site.

Table 5. Method of selecting random available habitat measurements from an IFG-4 model output to obtain an estimate of habitat availability, Trinity River Flow Evaluation, Trinity Co., CA

LEWISTON DAM SITE

Simulated Flow = 300cfs                Study Site Length = 2762 ft

| Xsec No. | Wt. Factor Up | Wt. Factor Dn | Cell Distance Up | Cell Distance Dn | Cell Distance Total | Total 2762' | No. Verts. | X5 | No. Verts. selected |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.0 | 0.5 | 0.0 | 14.0 | 14.0 | .0051 | 25 | | 0.64 |
| 2 | 0.5 | 0.5 | 14.0 | 19.5 | 33.5 | .0121 | 25 | | 1.52 |
| 3 | 0.5 | 0.3 | 19.5 | 45.0 | 64.5 | .0234 | 28 | | 3.27 |
| 4 | 0.7 | 0.5 | 105.0 | 53.0 | 158.0 | .0572 | 26 | | 7.44 |
| 5 | 0.5 | 0.5 | 53.0 | 40.5 | 93.5 | .0339 | 23 | | 3.89 |
| 6 | 0.5 | 0.8 | 40.5 | 31.2 | 71.7 | .0260 | 26 | | 3.37 |
| 7 | 0.2 | 0.5 | 7.8 | 25.0 | 32.8 | .0119 | 17 | | 1.01 |
| 8 | 0.5 | 0.5 | 25.0 | 75.0 | 100.0 | .0362 | 22 | | 3.98 |
| 9 | 0.5 | 0.5 | 75.0 | 105.0 | 180.0 | .0652 | 22 | | 7.17 |
| 10 | 0.5 | 0.9 | 105.0 | 207.0 | 312.0 | .1130 | 24 | | 13.56 |
| 11 | 0.1 | 0.2 | 23.0 | 32.6 | 55.6 | .0201 | 27 | | 2.72 |
| 12 | 0.8 | 0.9 | 130.4 | 216.0 | 346.4 | .1254 | 22 | | 13.80 |
| 13 | 0.1 | 0.2 | 24.0 | 62.2 | 86.2 | .0312 | 27 | | 4.21 |
| 14 | 0.8 | 0.5 | 248.8 | 79.0 | 327.8 | .1350 | 32 | | 18.99 |
| 15 | 0.5 | 0.5 | 79.0 | 155.0 | 234.0 | .0847 | 28 | | 11.86 |
| 16 | 0.5 | 0.5 | 155.0 | 115.0 | 270.0 | .0978 | 21 | | 10.26 |
| 17 | 0.5 | 0.5 | 115.0 | 25.0 | 140.0 | .0507 | 35 | | 8.87 |
| 18 | 0.5 | 0.5 | 25.0 | 108.5 | 213.5 | .0773 | 37 | | 14.30 |
| 19 | 0.5 | 0.0 | 108.5 | 0.0 | 108.5 | .0393 | 32 | | 6.29 |

Total number of verticals selected = 137

## Data Analysis

Habitat availability curves have been constructed for total depth and mean column water velocity at each study site from data obtained by both random sampling and selection of verticals from the IFG-4 model output. The curves have been fit from frequency distributions of depth and velocity. Two running averages are then made on the frequency distributions to reduce deviations between adjacent intervals that are apparent on some curves. The resulting averaged distributions are normalized to a value of one.

## Results

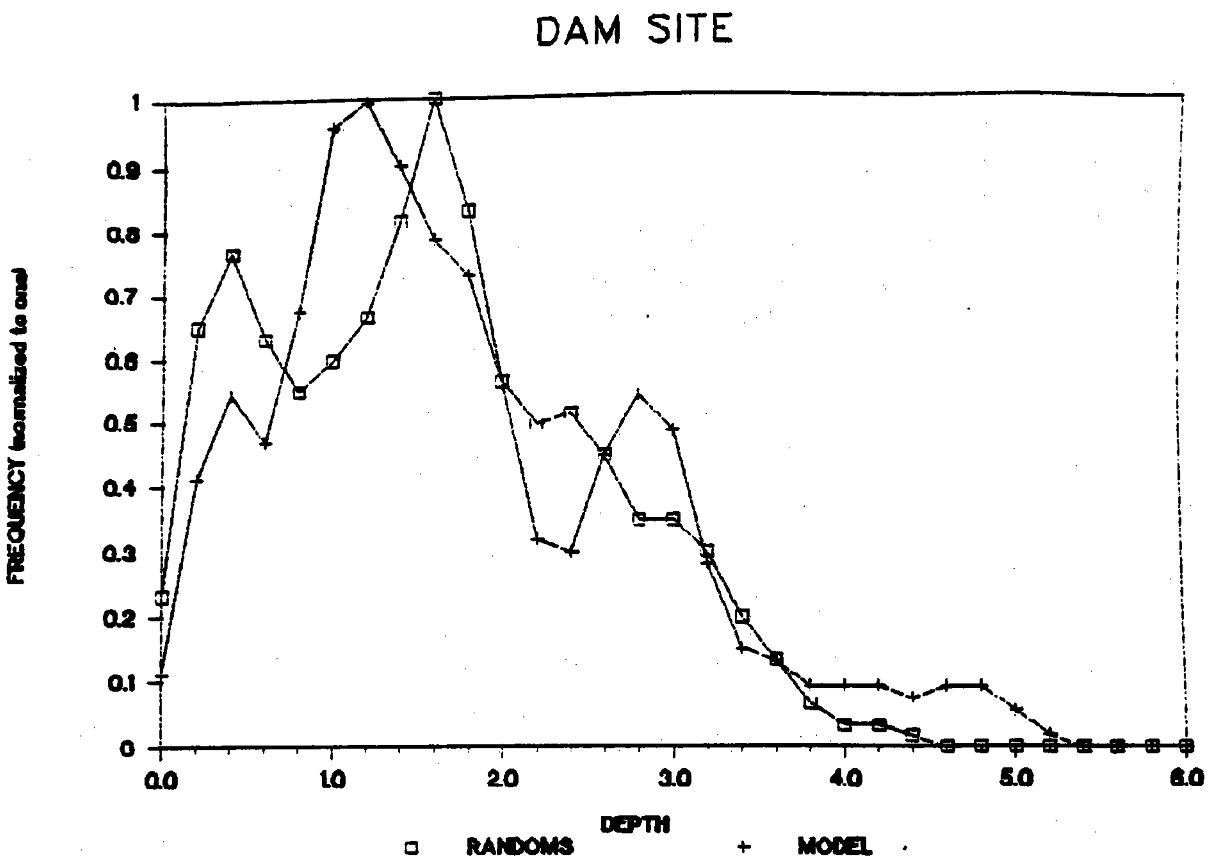
After two years of data collection 1,319 random habitat availability measurements have been taken.

Estimates of habitat availability have been calculated for the upper six study sites, from Lewiston Dam downstream to Steiner Flat. At each of the sites available habitat curves have been constructed for total depth and mean column water velocity from both the random sampling method and the selection of verticals from the IFG-4 model. The curves are drawn together on the same graphs for easy comparisions (Figures 15 - 20).

## Discussion

When comparing the two habitat availability estimates, one generated by random sampling and one generated from selection of verticals off of the IFG-4 model, the available habitat curves for velocity are similiar for each study site except for the Lewiston Dam and Bucktail sites.

At the Lewiston Dam site there is an inverse relationship displayed for velocities between 0.8 ft/sec and 2.2 ft/sec. The velocity curves generated from the model show an available habitat value of 0.9 at a velocity of 1.0 ft/sec and a value of 0.3 habitat available at 1.8 ft/sec, while the random sampling shows a lower value 0.3 at 1.0 ft/sec and a greater value 0.8 for 1.8 ft/sec. A possible explanation for the models deviation from the random lies in the weighting factor values which are assigned each transect within the IFG-4 methodology. The lowest possible weighting factor that can be assigned a transect is 0.1. When assigning a weighting factor to a riffle transect, for example, a factor of 0.1 may be overestimating the habitat represented by the riffle. In these cases a weight factor below 0.1 would be more representative. Should this be the case, too many random verticals would be selected from these riffle transects, thus creating more available habitat at velocities associated with riffles, approximately 1.0 ft/sec. In turn, this overestimation of velocities associated with riffles would cause an underestimation of higher velocities (2.0 ft/sec) found in the more abundant shallow runs, which are present at the dam site.



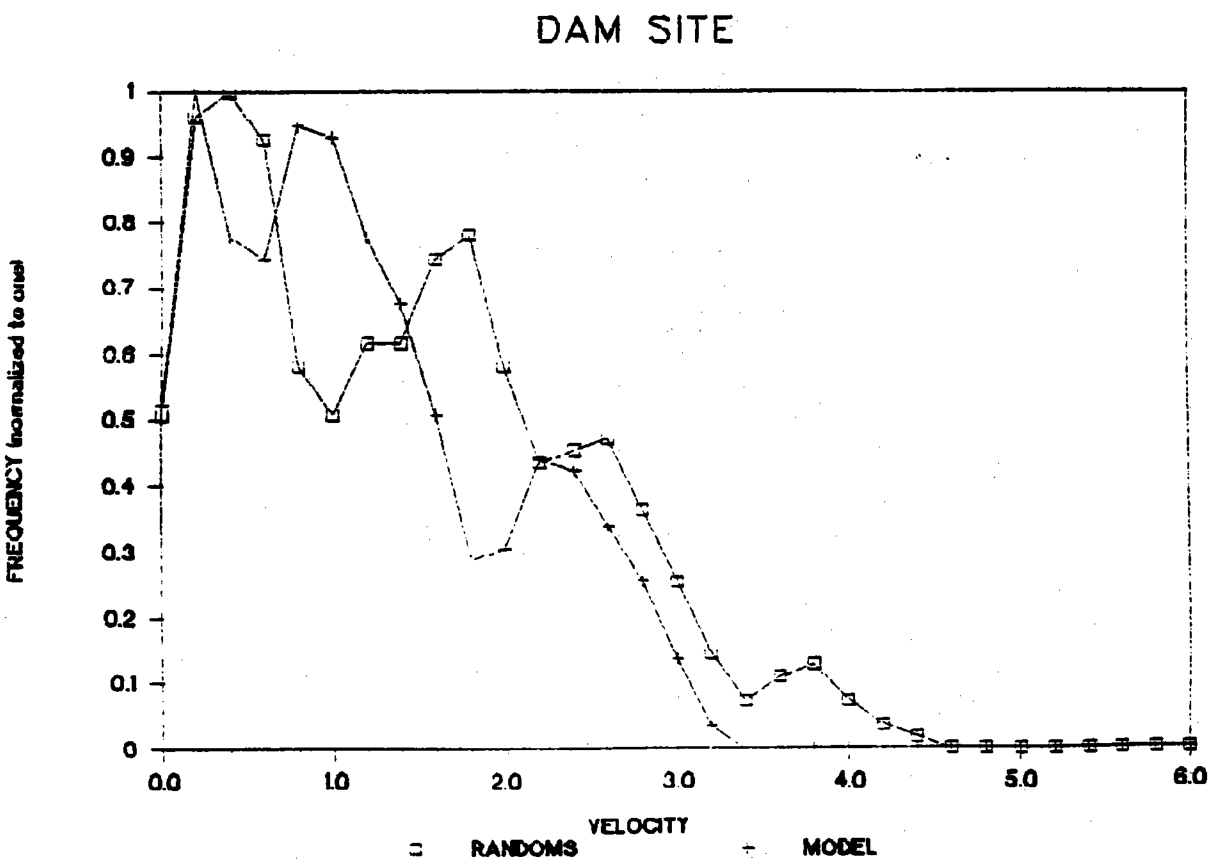
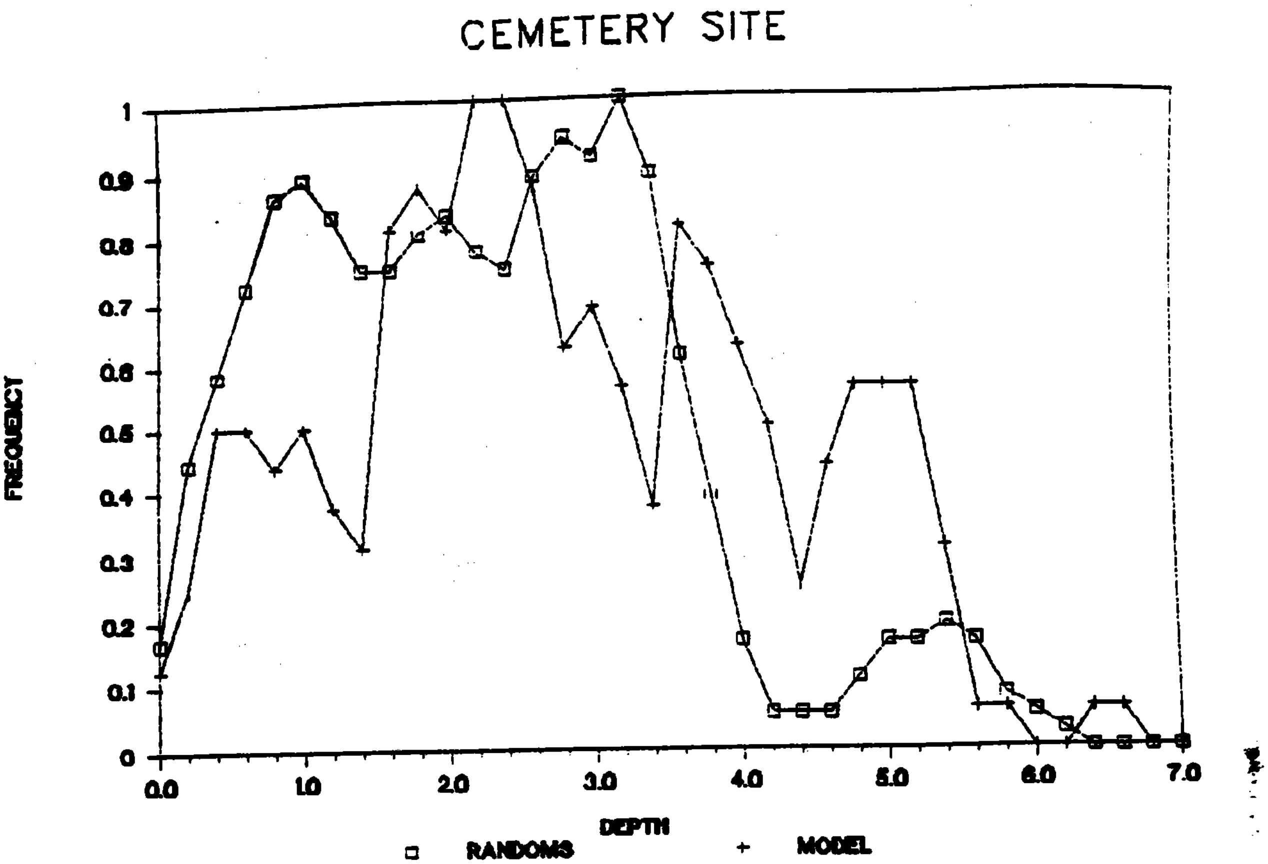




Figure 15. Available Habitat for the Lewiston Dam study site, Trinity River Flow Evaluation Study, 1986.



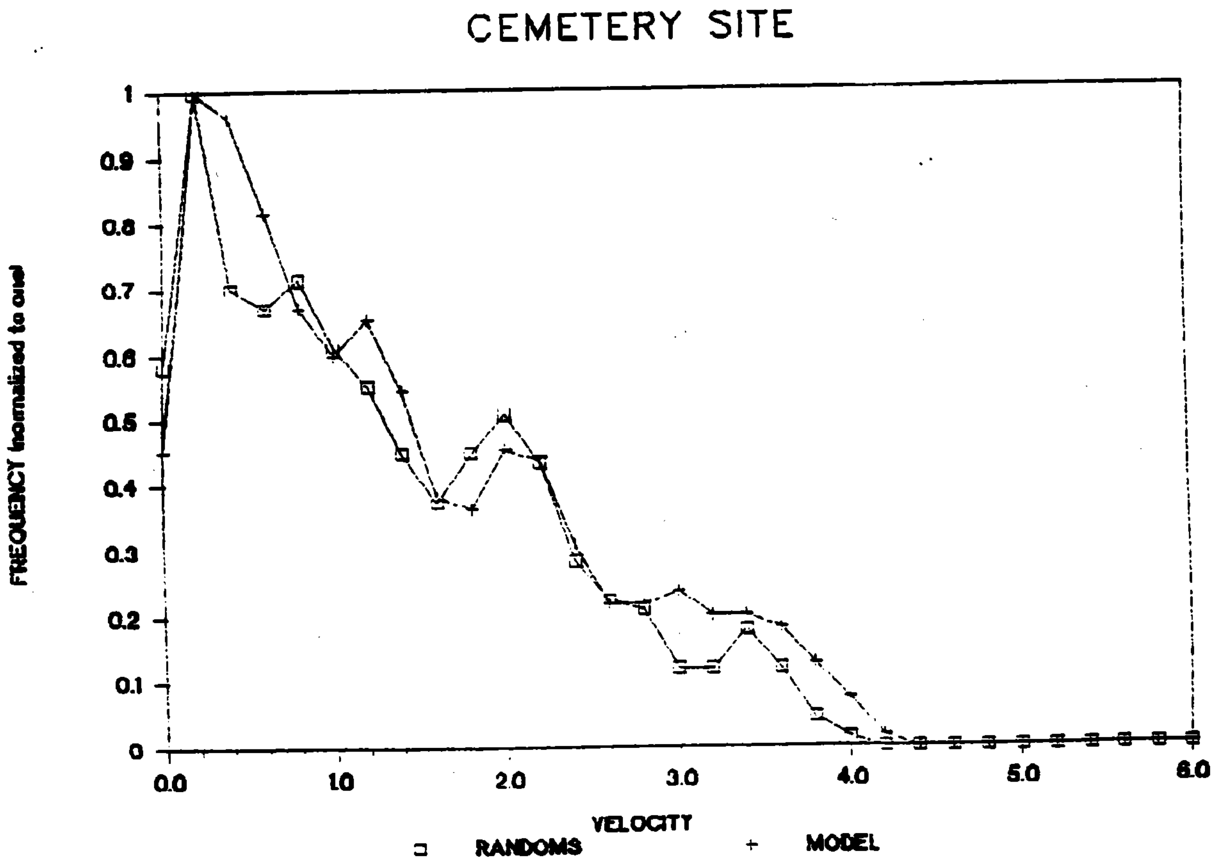
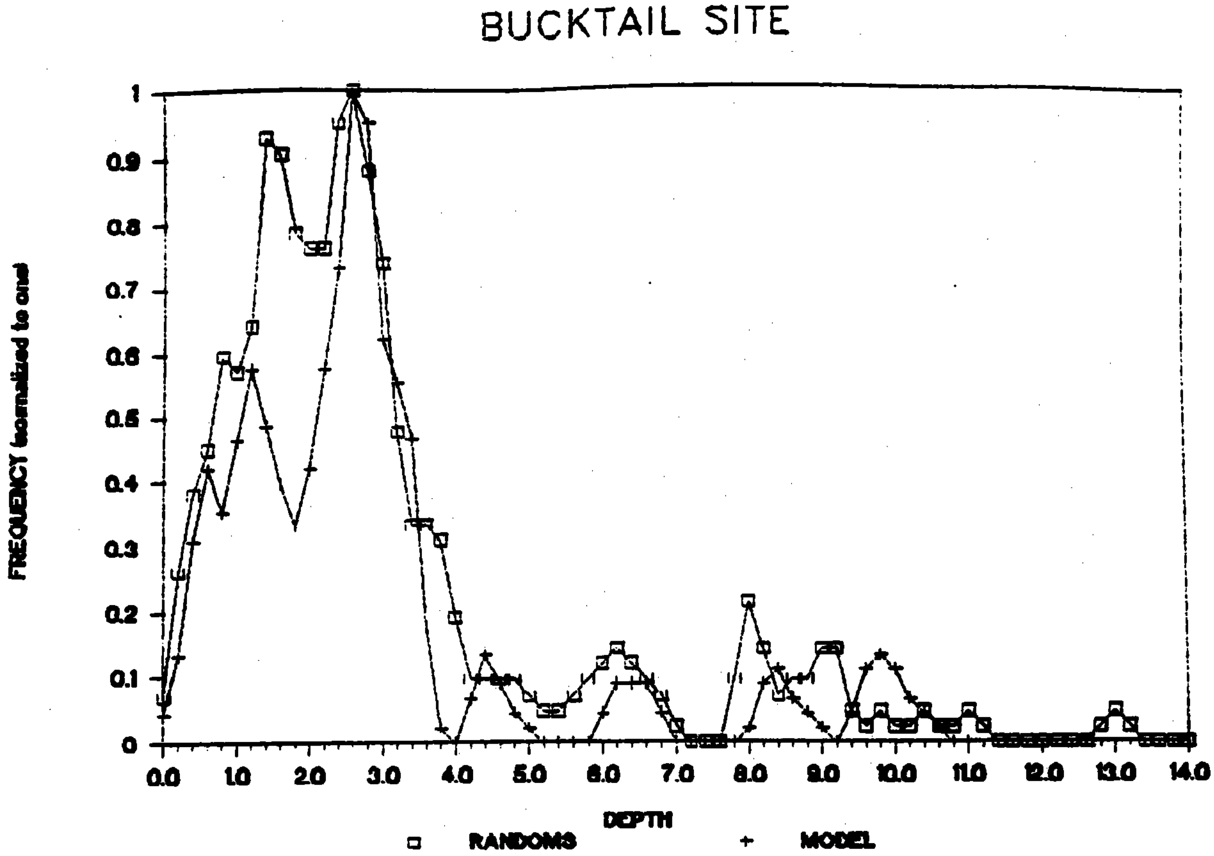




Figure 16. Available Habitat for the Cemetery study site, Trinity River Flow Evaluation Study, 1986.



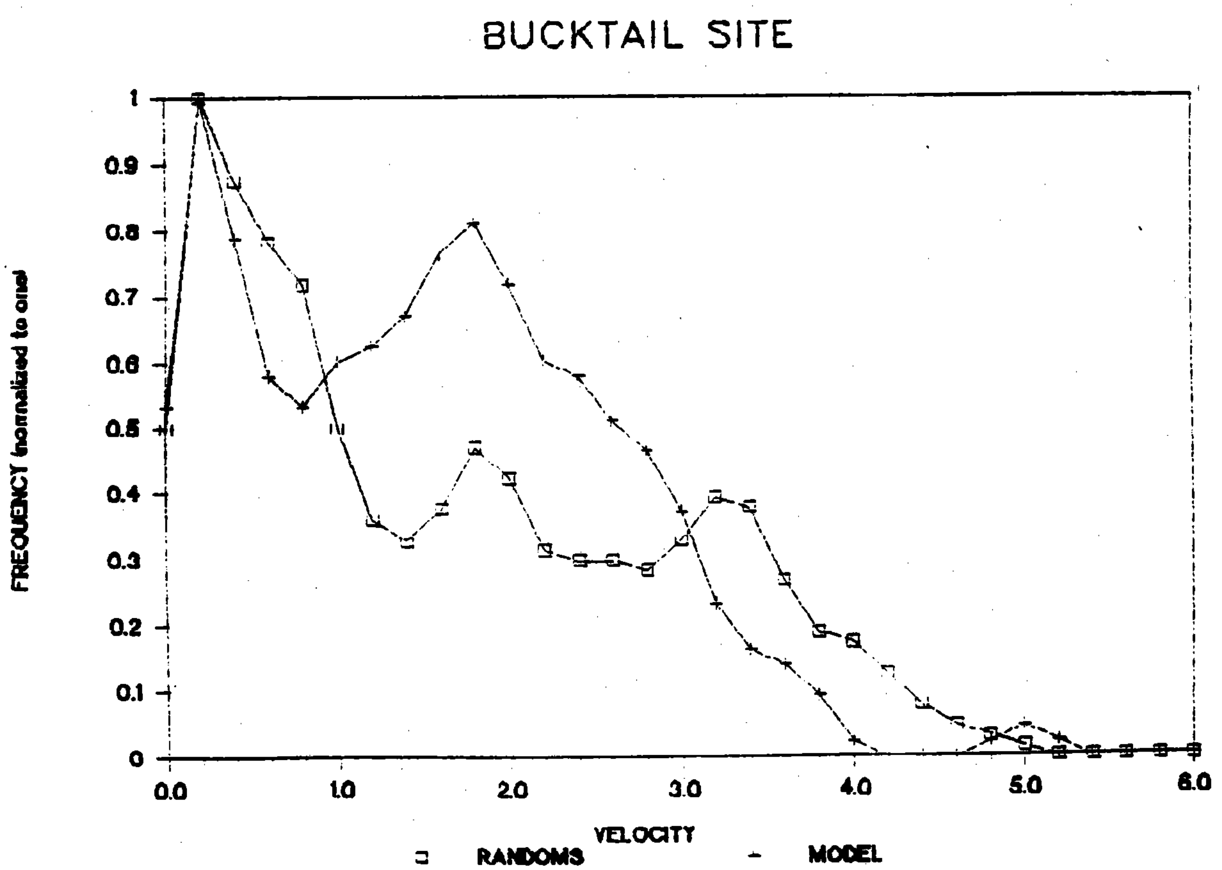




Figure 17. Available Habitat for the Bucktail study site, Trinity River Flow Evaluation Study, 1986.

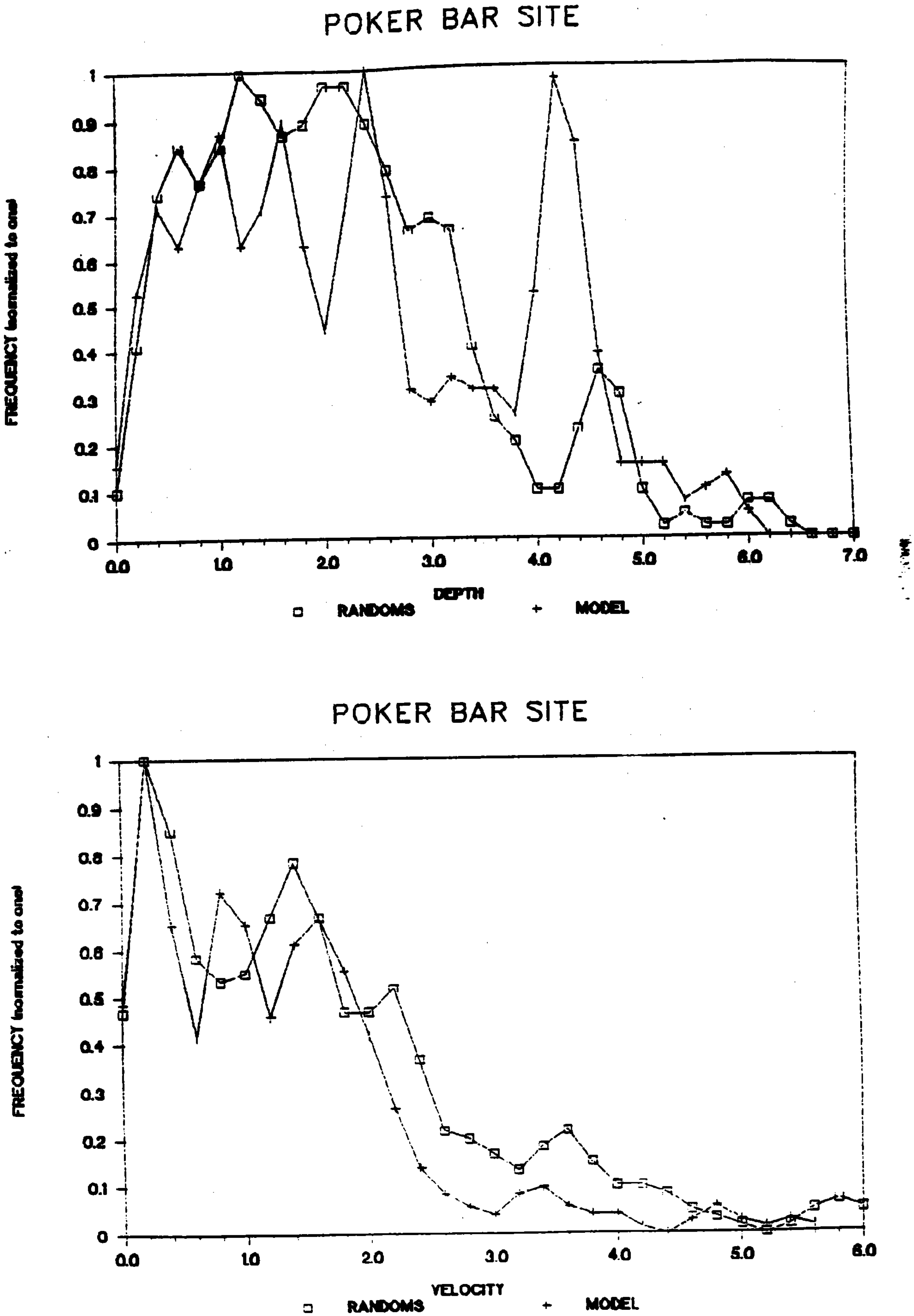
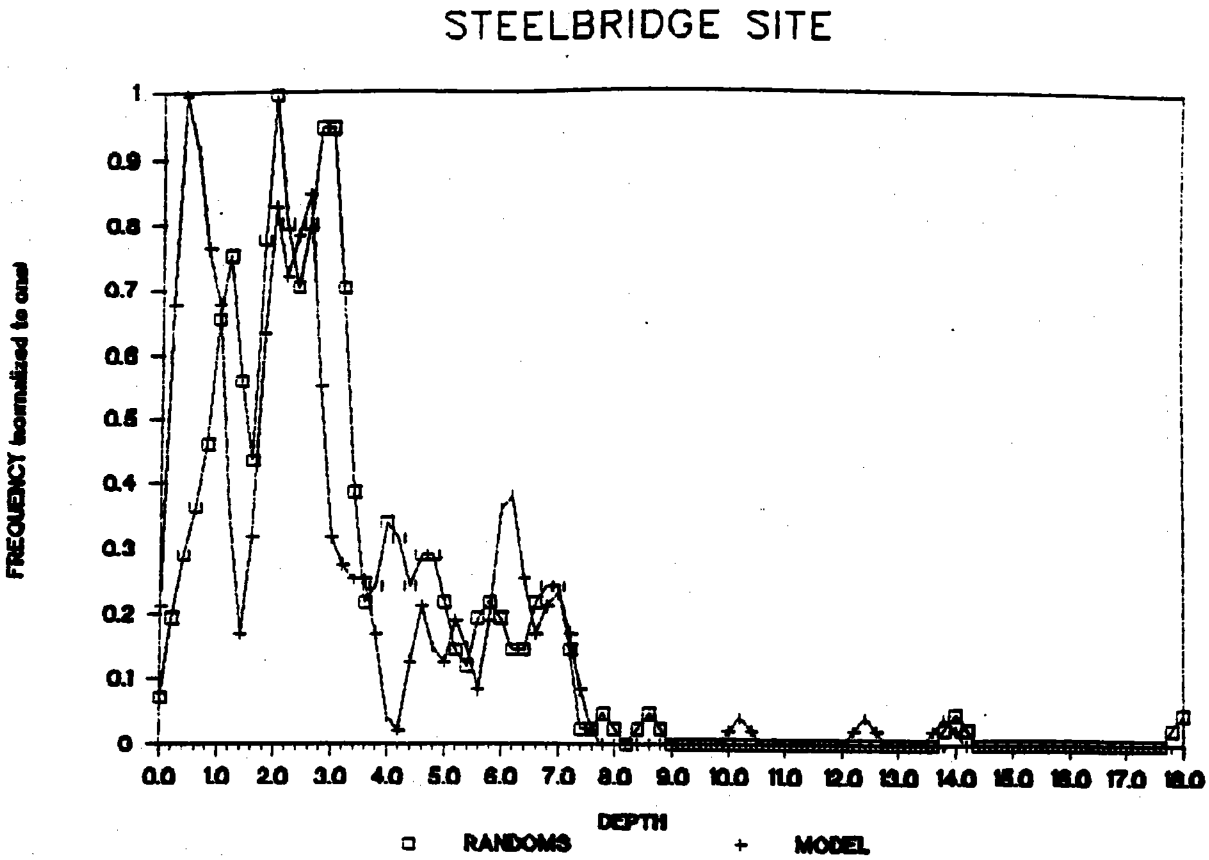



Figure 18. Available Habitat for the Poker Bar study site, Trinity River Flow Evaluation Study, 1986.



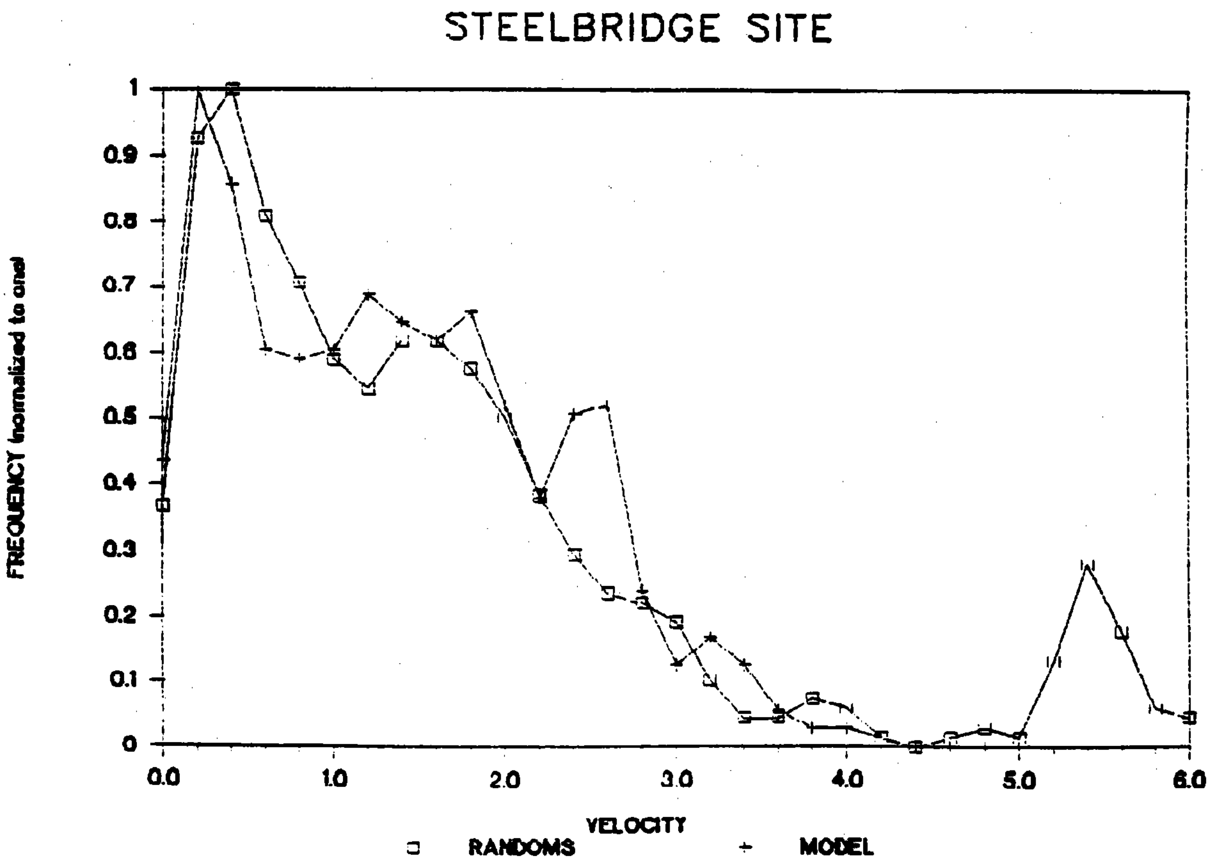
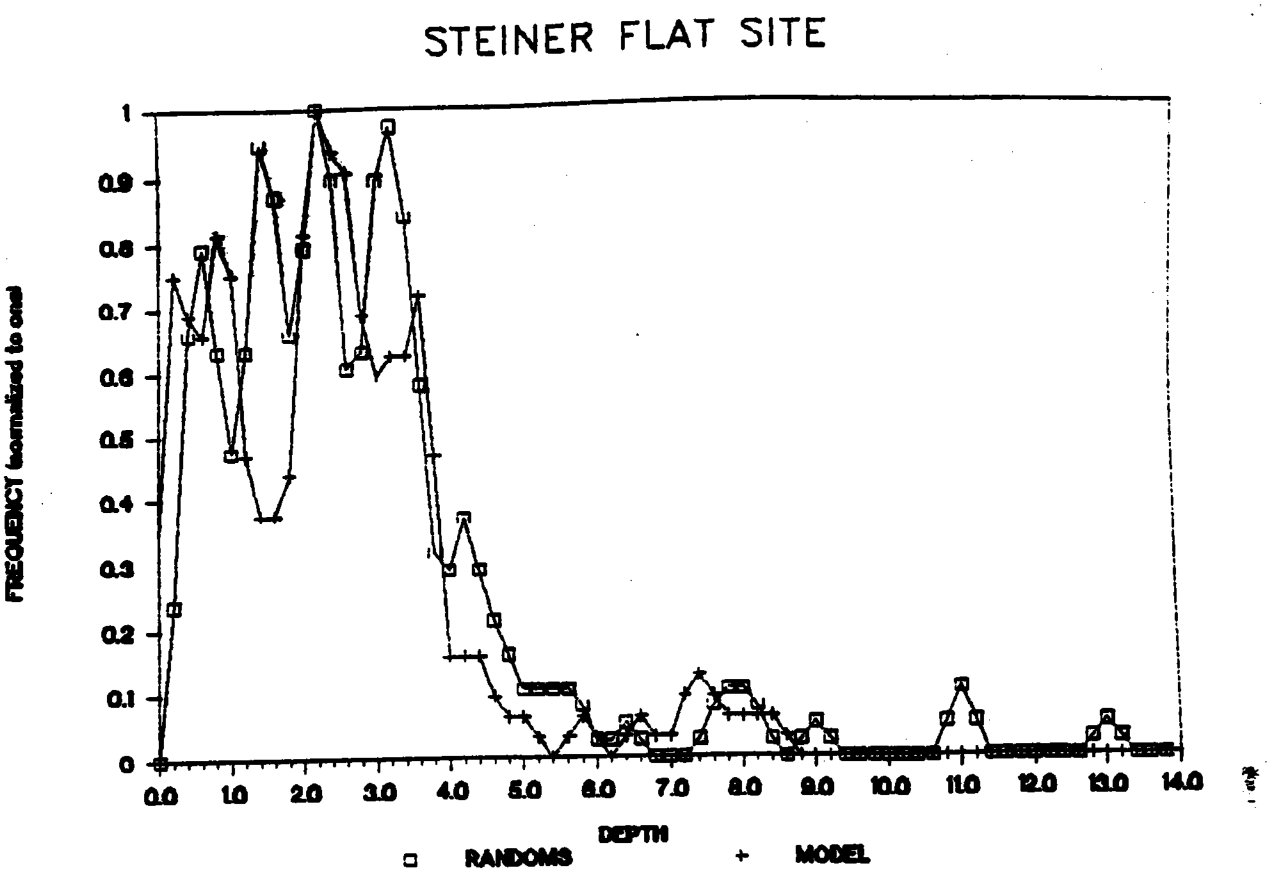




Figure 19. Available Habitat for the Steelbridge study site, Trinity River Flow Evaluation Study, 1986.



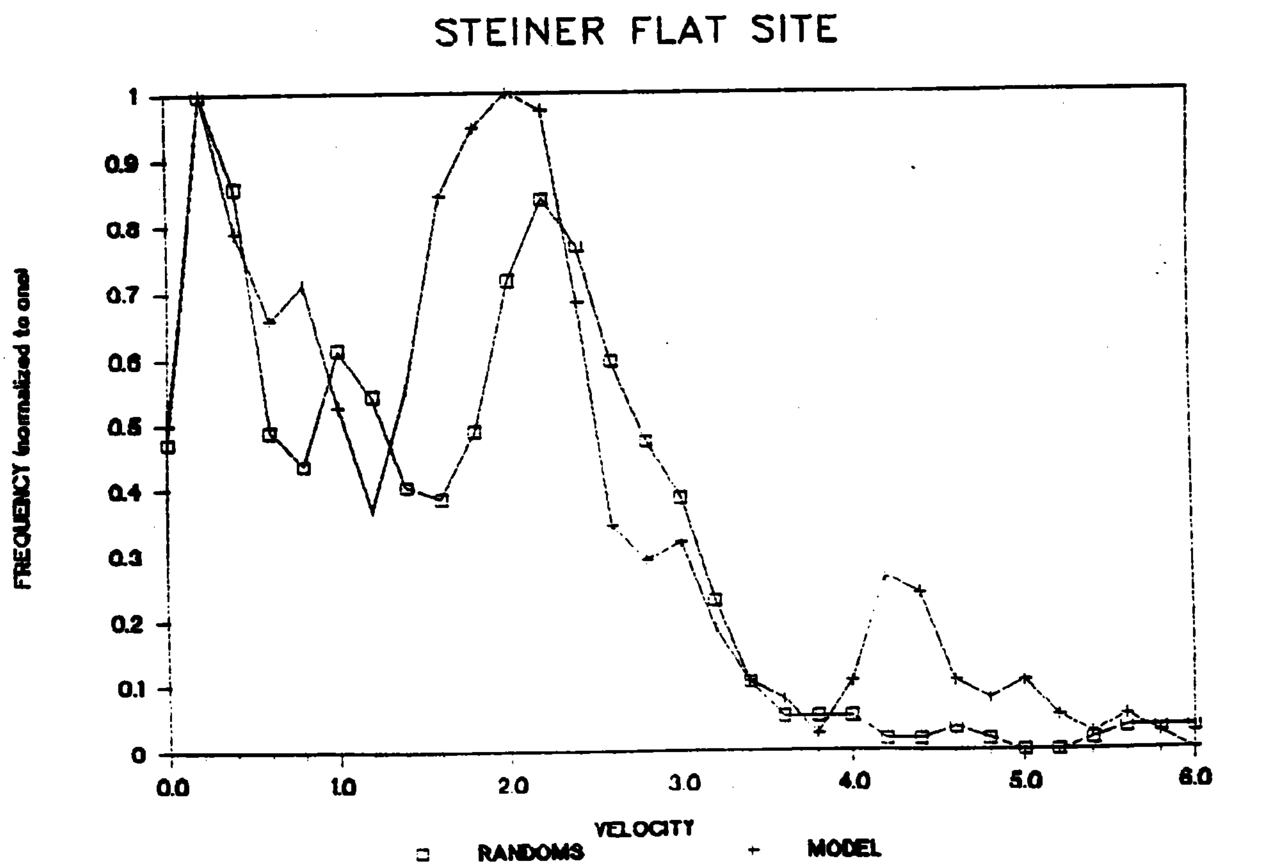




Figure 20. Available Habitat for the Steiner Flat study site, Trinity River Flow Evaluation Study, 1986.

The two velocity curves for available habitat at the Bucktail site differ between 1.0 ft/sec and 3.0 ft/sec. In this velocity range the model shows a greater value of available habitat than was observed. In this case three IFIM transects were located in a pool below a chute in the middle of the study site. While random sampling at the Bucktail site, this section of habitat was not sampled because of the inability of the snorkeler or the raft and equipment to get observations because of deep and relatively fast water velocity. The IFIM model is able to sample these areas because of proper equipment (boat, sounding gear, and cable). This may be an explanation of why the model generated available habitat is greater than the random generated available habitat at these velocities. The model generated available habitat for velocity is therefore probably a better estimate for the Bucktail site.

The habitat availability curves for depth generated from the two sampling methods display similiar habitat available estimate values at all but two sites. The available habitat curves for depth at the Cemetery site differ greatly. This may be explained by the fact that the area sampled by the random observation method is greater in length than the river length within the upper and lower transects of the IFIM study site. What is difficult to expain, however, is why the velocity curves for the Cemetery site so closely resemble one another.

The model generated available habitat curve for depth at Poker Bar shows a much greater amount of habitat at depths between 4.0 and 4.6 feet. Random habitat sampling was not conducted on the right channel of a long island located in the center of the study site, because preference data collection has not been collected in this area. However, the model did simulate this channel. If not for this discrepancy, the two available habitat curves from each method would probably be very similiar.

It appears that the major difference between available habitat curves generated from the two sampling methods are mainly caused by the inability of a snorkeler and raft to sample both deep water or swift water effectively, whereas, the Instream Flow Methodology with better equipment and greater manpower can effectively sample such habitat types. Another problem evident here is that the preference study site boundaries were defined before the selection of IFIM transects, therefore the preference study sites are sometimes larger than the area defined by the upper and lower boundaries of the IFIM transects. Elimination of this study site boundary discrepancy in future studies will certainly justify the use of habitat availability curves generated by the IFIM model for preference curve development. The only problem found with using habitat availability curves generated from the IFIM model may be the overestimation of some habitat types because of inaccurate weighting factors. This problem may be resolved by inserting more transition type transects into the study site.

# HABITAT AVAILABILITY AND NEEDS (TASK 3)

## Introduction

As part of the Trinity River Flow Evaluation Study, an Instream Flow Incremental Methodology hydraulic flow analysis was undertaken in the summers of 1985 and 1986. Our chosen method was to use the IFG-4 computer program to simulate hydraulic conditions throughout the river from Lewiston to Hoopa at a range of flow releases from Lewiston Dam, and to run the results, with added measures of river substrate, through the HABITAT program for an evaluation of the habitat available for anadromous trout and salmon at various flows.

The IFG-4 hydraulic simulation model requires a set of velocity and depth measurements taken at several transects at each study site over a range of flows. During 1985 and 1986 we measured river flows at three Lewiston Dam release levels, at 350, 450 and 800 cubic feet per second (cfs). These data were than used in a series of single-flow IFG-4 models based on each measured discharge and on water surface elevations taken during the three evaluation releases and a fourth release of 300 cfs from Lewiston.

## Study Sites

To order our analysis, we divided the Trinity River, which runs approximately 110 miles from the upper end of our study area at Lewiston Dam to its confluence with the Klamath at Weitchpec, into an upper, middle, and lower segment.

The upper segment, running from Lewiston Dam to the North Fork of the Trinity, is the most important for trout and salmon production. The majority of its substrate is sand, gravel, and cobbles, with little bedrock. This area has been heavily affected by the control of the river at Trinity Dam, and its dominant structure is a series of relatively uniform, steep- sided runs, bordered by thick growths of alders and willows. Its tributaries, many of them major steelhead spawning areas, include Deadwood Creek, Rush Creek, Grass Valley Creek, Indian Creek, East Weaver Creek, Reading Creek, Brown's Creek, Dutch Creek, Soldier Creek, and Canyon Creek. Many of the upper creeks and gulches, Grass Valley Creek notable among them, drain watersheds high in decomposed granite soils, and contribute a major sediment load of coarse sand to the river during high runoff.

We chose eight study sites in this segment, each representing a sub-set of upper river habitat conditions. The upper site, which runs adjacent to Trinity River Hatchery from just below Lewiston Dam downstream to the second pool above the old fish weir, represents essentially itself, an area where there has been intensive rehabilitaion work, including gravel importation and riffle construction. In many years, most of the river's spawning occurs here. The second site, adjacent to the cemetery area in Lewiston, represents conditions from Lewiston to the mouth of Rush Creek, which includes a reconstructed riffle. The third site, which centers on the run-pool-riffle sequence above Bucktail hole, represents the river between Rush Creek and Grass Valley Creek. Poker Bar, about a mile below Grass Valley creek, represents the heavily sedimented reach from the creek to Lime Kiln Gulch. The fifth site, at Steelbridge campground, also represents an area heavily influenced by decomposed granite sediments, from Lime Kiln Gulch to Douglas City.

There is a major change in stream character at Douglas City, where the river enters a canyon with higher gradient and increasing exposed bedrock, and flows past several important spawning tributaries. This area is represented by a site below the BLM campground on Steiner Flat Road. Below the canyon and above Junction City, the gradient lessens and the river runs in a fairly homogeneous sequence of broad meanders toward the area of flood-plain constriction just above the North Fork. This reach is represented by two sites, one on the gravel bar just below Oregon Gulch, and a second at Junction City campground below Canyon Creek, a major tributary.

The middle reach of the river, running from the North Fork to the South Fork, is followed throughout its length by Highway 299, and will be familiar to most readers. It generally follows a bedrock channel, with short rapids and deep pools interspersed at most flows with longer deep glides. From China Slide to Grays Falls the river runs through a steep, white-water gorge, then flows into a series of milder chutes and gravel bars, meandering across a narrow flood plain between steep canyon walls to the South Fork. A large ungauged tributary, the New River, enters the Trinity in this segment, contributing to a change in character above and below the gorge. Our study sites here are located at Del Loma, in a varied stretch of chutes to pools and riffles that are the lowest known area of salmon spawning,and at Hawkins Bar below the gorge.

The lower river segment runs from the South Fork of the Trinity to Weitchpec. Our site at Tish-Tang campground represents its upper reach of deep pools and glides alternating with riffles, narrow, fast chutes, and eddying backwaters. Our lowest site, just below Highway 299 bridge in Hoopa, represents the valley reach of riffle and run meanders, with broad gravel and cobble bars on the insides and swifter water on the outsides of bends.

## Methods

We used field methods based on USFWS Instream Flow Group recommended procedures as described in Instream Flow Information Paper No. 5 (FWS/OBS-78/33, June 1978). At each study site we chose from six to nineteen transects proportionally representing the range of hydraulically-defined habitat available, and available proportionally throughout the river reach the site described. Instream observations of habitat utilization and populations had shown that much of the best fish habitat in the Trinity River occurs in areas that do not coincide with the best areas for hydraulic modeling, and which do not easily lend themselves to necessary measurements and computer input formats. Transverse water surface profiles bulge in the middle or are higher at one side than the other, or may go up and down across an important spawning riffle. Water runs in changing directions with varying flow across riffles; some of the most-used juvenile salmon habitat is in or at the edge of swirling eddies, or near large boulders or rock outcrops that create varying degrees of flow reversal. Where these conditions occurred, we opted to place transects to measure the significant habitat, at the probable expense of hydraulic modeling much beyond the flows we could measure.

We measured water depth and velocity at enough points along each transect to ensure that less than ten percent of total flow occurred between points. We used the same modified Brusven substrate index employed for our habitat utilization curves to characterize the substrate in cells corresponding to the flow measurement points. The majority of 1986 velocity measurements were taken with Marsh- McBurney inductive current meters, although on occasion we used a Price AA meter. In 1986 we used Price meters for all measurements except those requiring sounding equipment. We measured distances across transects with fiberglass or steel tapes zeroed on iron pins, and thalweg distances either with the tape or by tacheometry. We determined water surface elevations through differential leveling from benchmarks with a spirit level and fiberglass leveling rod.

Approximately half of our transects included water over wading depth, and for these, in 1985, we used either an aluminium boat with a USGS sounding reel and cable, anchored to shore with a steel cable, or a six-foot top-setting wading rod used off the edge of a rubber raft hand-held to a static rescue rope stretched across the river. In 1986 we adapted the USGS equipment to a rubber raft and used it instead of the metal boat. In shallower swift areas, we used the rope by itself as a wading aid.

Field measurements were recorded on data sheets photocopied onto 8 1/2 by 11 inch waterproof paper, one set to each transect, since the great number and wide variety of our transects, and the necessity of using several crews with varying personnel throughout the day, precluded the use of a single field-book.

Data was entered directly from field notes into computer files organized with a packaged accounting program, dBASE II, in field- note format. The dBASE data files were then proof-read, and all necessary arithmetic, such as the calculation of bottom elevations and reduction of Price meter records to velocities, was done on the computer. We then translated each dBASE data file to a standard data matrix and used a microprocessor BASIC program to sort it into IFG-4 data decks, which were transmitted to main-frame computers as batch files.

We used provisional habitat utilization curves developed through TASK 2 (previously described).

This report includes an evaluation of habitat availability for chinook salmon spawning, fry, and juveniles at study sites from Hawkins Bar upstream to the hatchery, and for chinook juveniles alone at Tish-Tang and Hoopa Valley.

We have evaluated available habitat for coho salmon fry,juveniles and spawning from Steiner Flat upstream to the dam, for coho fry and juveniles at Oregon Gulch and Junction City, and for coho juveniles from Del Loma down.

Steelhead fry and juvenile habitat is shown from Lewiston to Junction City, and steelhead juvenile habitat from Del Loma to Hoopa Valley. Since we have not yet obtained sufficient data to develop steelhead spawning curves, we have not evaluated steelhead spawning habitat.

## Results

Results of the IFG-4 simulation are shown in Figures 21 through 46. The habitat curves shown for sites from Lewiston Dam to Steiner Flat respresent output from simulations based on two sets of data. Habitat available at flows from 200 to 500 cfs is output from a simulation based on flows measured at Lewiston releases of 350 and 450 cfs. Habitat available at flows from 550 to 900 cfs is output from a simulation based on depths and velocities measured at a Lewiston release of 800 cfs, and on transect water surface elevations measured at releases of 600 and 300 cfs. Thus the estimates of available habitat shown can be considered good at about 350, 450, and 800 cfs. Above, below, and between these points the habitat estimates are valid as far as the hydraulic model is valid. The relatively abrupt changes that occur at several sites between 500 and 550 cfs are the result of the mixture of two sets of field observations. The curves could be smoothed in various ways, but since the jumps do not change trends in habitat/flow relationships, we have chosen not to do this.

At sites from Oregon Gulch to Hoopa Valley, the curves show the results of our 1986 800 cfs release simulation. We used only one set of measurements here because the floods of 1985-86 changed channel morphologies at these sites, complicating the task of melding two sets of data.

Figure 21 shows the availability of habitat, expressed as square feet per 1000 linear feet of river, for chinook and coho salmon fry and for steelhead trout fry at the hatchery site. Habitat decreases with increasing flow, probably as a result of increasing velocities that are not tolerable to these small fish.

Figure 22 shows the availability of habitat for juveniles at the hatchery site. Chinook and coho habitat again decreases steadily with increasing discharge. Steelhead juvenile habitat increases to a peak at 450 cfs and then decreases, again probably as a result of increasing velocities.

In Figure 23, coho and chinook spawning habitat are shown peaking at between 350 and 550 cfs.

Figure 24 through 31 show habitat values for the Cemetary, Bucktail, Poker Bar, Steelbridge, and Steiner Flat sites. At most of these sites, there is a tendency for fry and juvenile habitat to decrease with increasing discharge. The exceptions are at the Cemetary site and at Bucktail, two reaches which include major low-gradient side-channels which are progressively inundated with low-velocity water at higher flows. It is probable that without these side-channels, which are a relatively minor component of both sites, rearing habitat would decrease with increasing flow as it does elsewhere. But once the side- channels fill, they provide increasing amounts of optimum habitat that compensates for the sluice-box effect that occurs in the steep-sided main channel.

Chinook and coho spawning habitat in these sites show varied responses to discharge, with a general decrease after early peaks except in the Cemetary site, where increased habitat provided by the complex side-channels probably accounts for a generally increasing spawning habitat availability. The major drops in spawning habitat at Poker Bar and Steelbridge between 500 and 550 cfs may show the result of accumulations of sand brought down by the high winter flows of 1986. These sites are the first two below Grass Valley Creek, which produced major amounts of sand between our two data-gathering periods. This could have affected spawning habitat, which is highly sensitive to changes in the concentration of sand in the substrate.

Figures 32 through 38 show habitat values at Oregon Gulch and Junction City, based on the 800 cfs release data. Fry and juvenile habitat show minor response to flow changes, probably because these sites, especially Oregon Gulch, represent river reaches that though channeled into a trapezoidal shape, still have some gently-sloping gravel and cobble bars that provide rearing habitat when inundated. This compensates somewhat for the higher main-channel velocities that accompany increasing discharge.

The riffles in the Oregon Gulch-Junction City reach are optimum for chinook spawning at low flows, becoming deep-water runs with higher discharge, as shown in Figure 34.

Figures 39 through 43 show habitat/flow relationships at Del Loma and Hawkins Bar. Rearing habitat decreases with increasing discharge, probably because of increasing velocities. Both of the river reaches represented by these sites are generally bordered on one side by steep bedrock walls, and by cobble or heavily-vegetated steep banks on the other, and flow increases tend to increase velocities and provide little extra rearing habitat.

Chinook spawning habitat increases with increasing discharge at Del Loma, where there are wide areas of suitable gravel that are inundated at higher flows. At Hawkins Bar, spawning habitat rises to a peak at 300 to

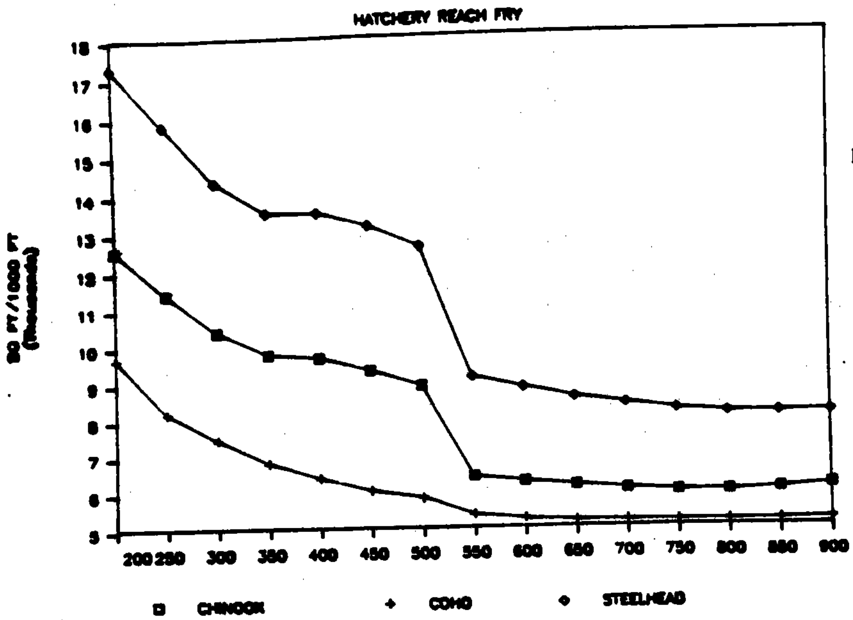



Figure 21. Predicted Weighted Usable Area of Habitat for Chinook Salmon fry, Lewiston Dam (Hatchery) Study Site, 1986.

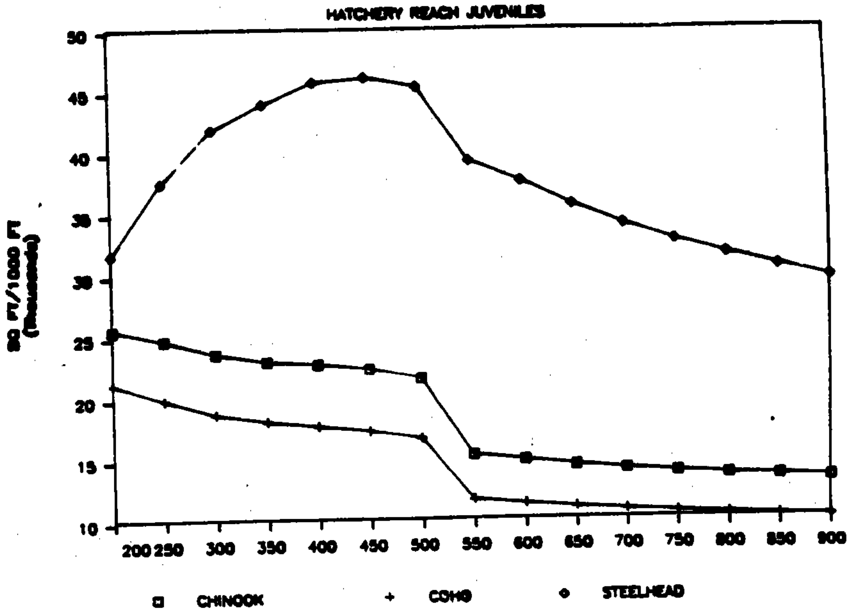



Figure 22. Predicted Weighted Usable Area of Habitat for Chinook Salmon juveniles, Lewiston Dam (Hatchery) Study Site, 1986.

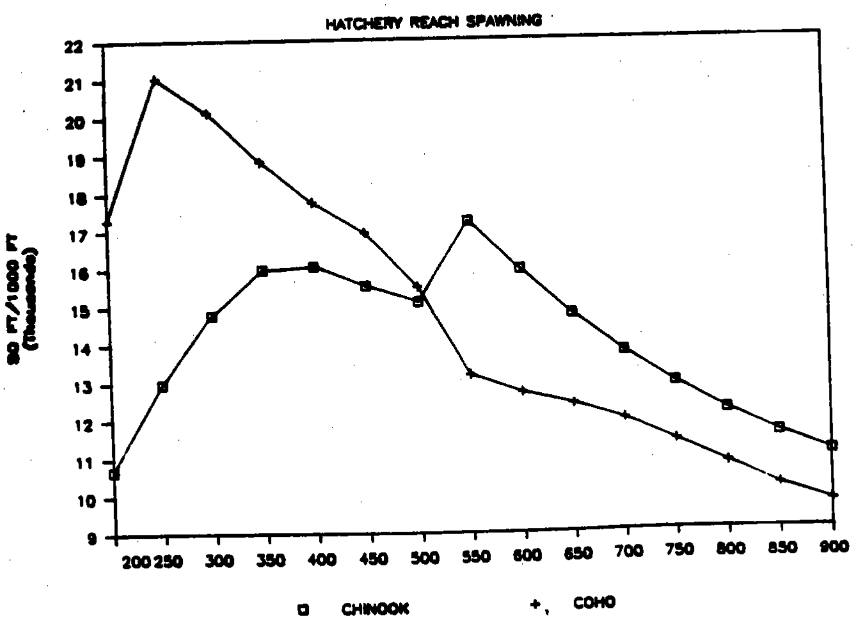



Figure 23. Predicted Weighted Usable Area of Habitat for Chinook Salmon spawning, Lewiston Dam (Hatchery) Study Site, 1986.

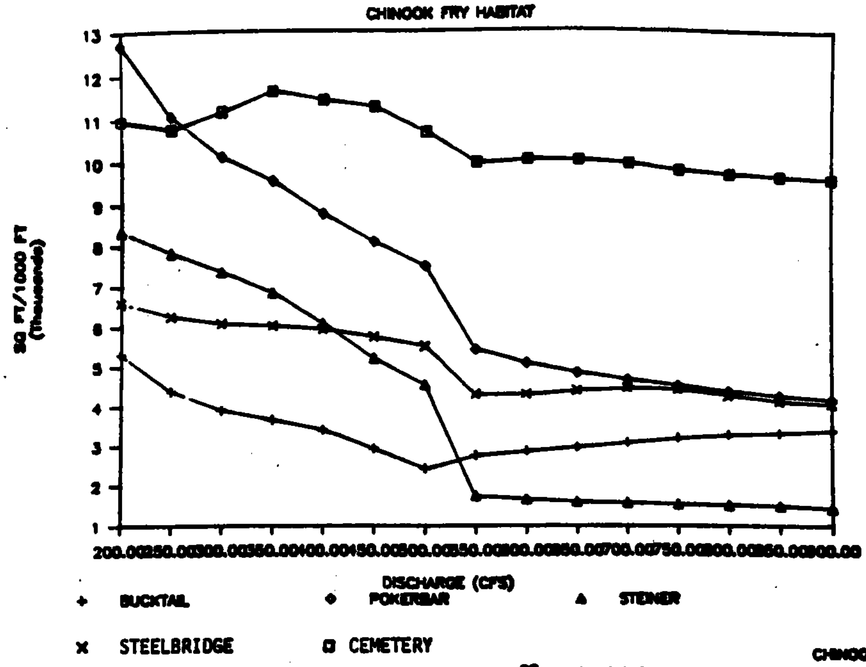



Figure 24. Predicted Weighted Usable Area of Habitat for Chinook Salmon fry, Cemetary to Steiner Flat Study Sites, 1986.

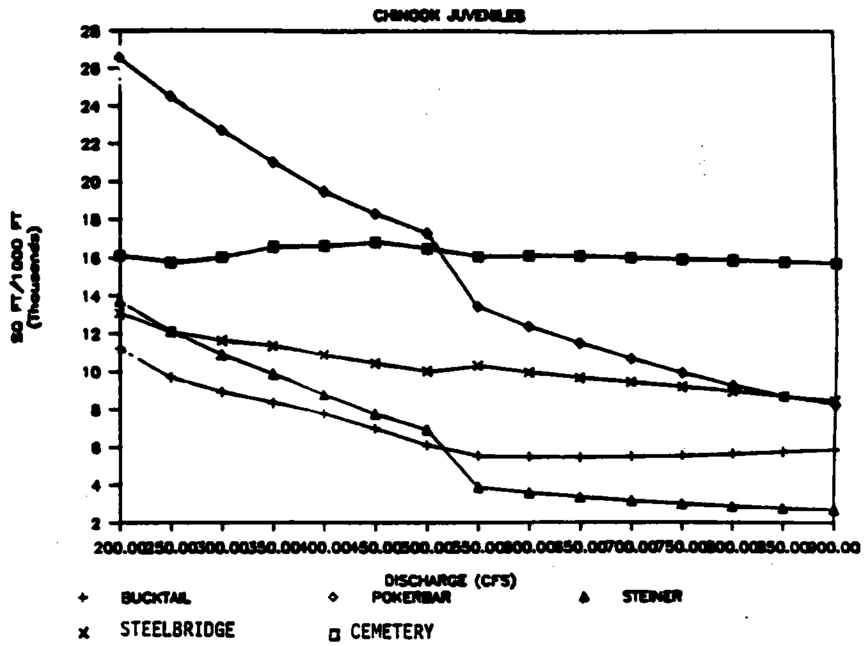



Figure 25. Predicted Weighted Usable Area of Habitat for Chinook Salmon juveniles, Cemetary to Steiner Flat Study Sites, 1986.

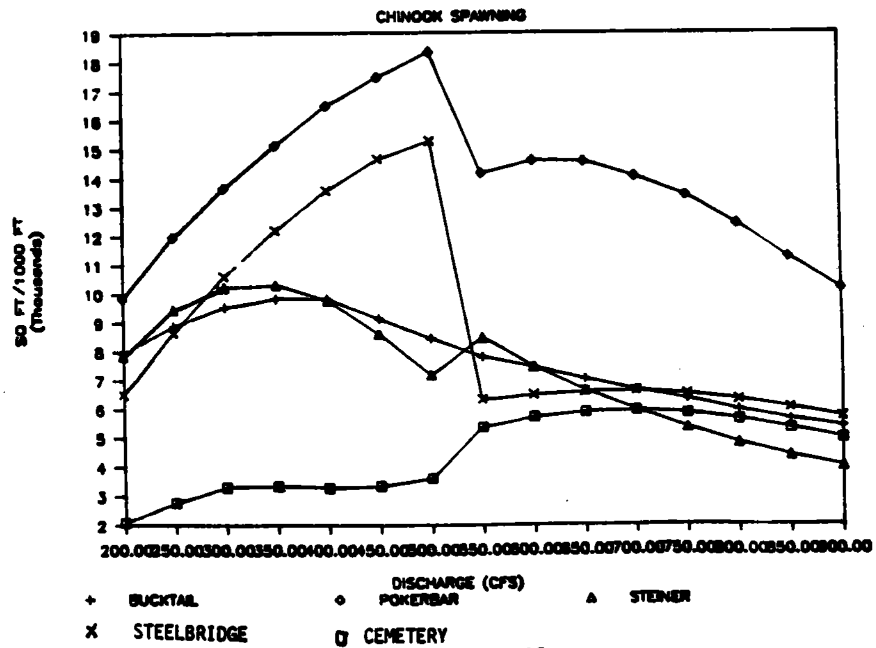



Figure 26. Predicted Weighted Usable Area of Habitat for Chinook Salmon spawning, Cemetary to Steiner Flat Study Sites, 1986.

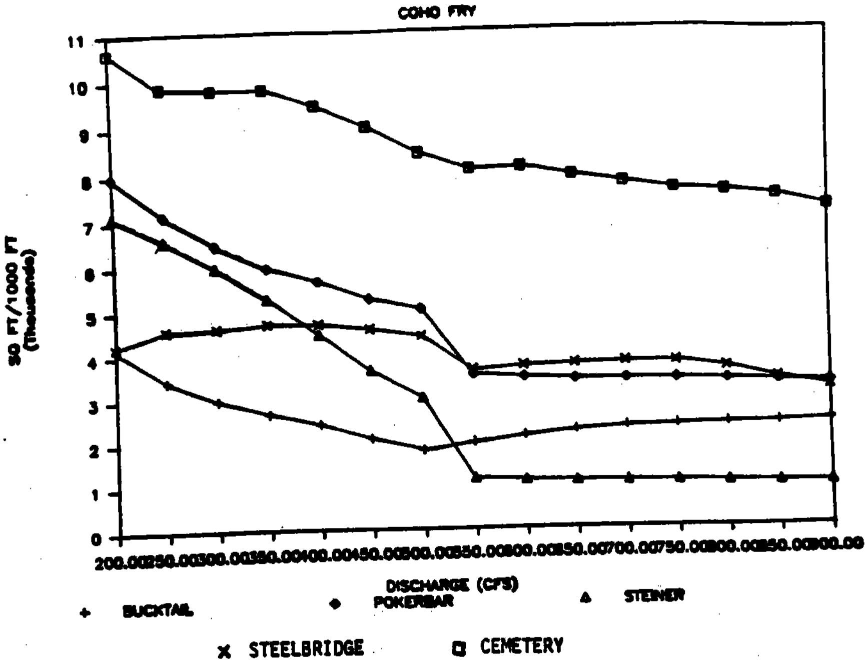



Figure 27. Predicted Weighted Usable Area of Habitat for Coho Salmon fry, Cemetary to Steiner Flat Study Sites, 1986.

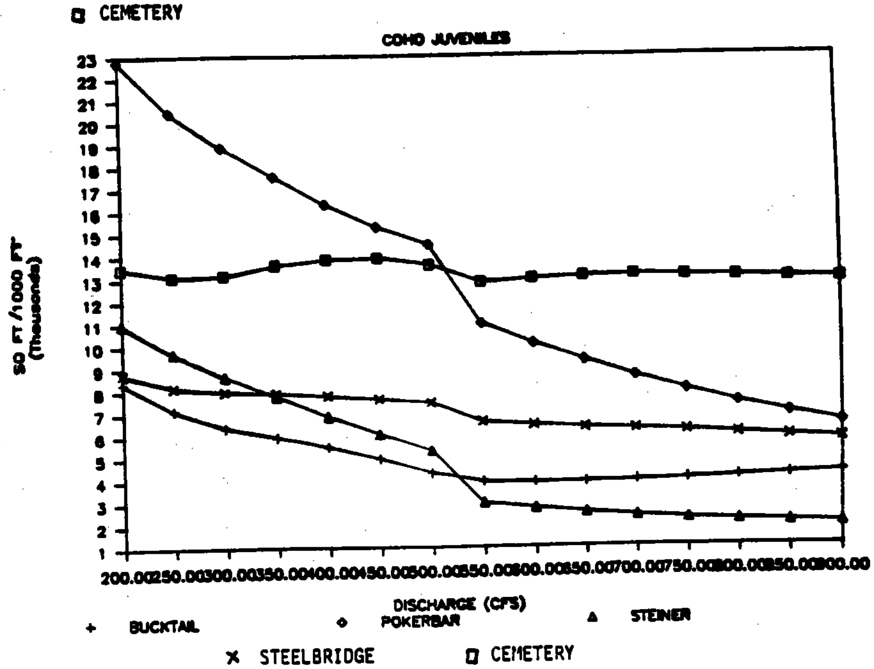



Figure 28. Predicted Weighted Usable Area of Habitat for Coho Salmon juveniles, Cemetary to Steiner Flat Study Sites, 1986.

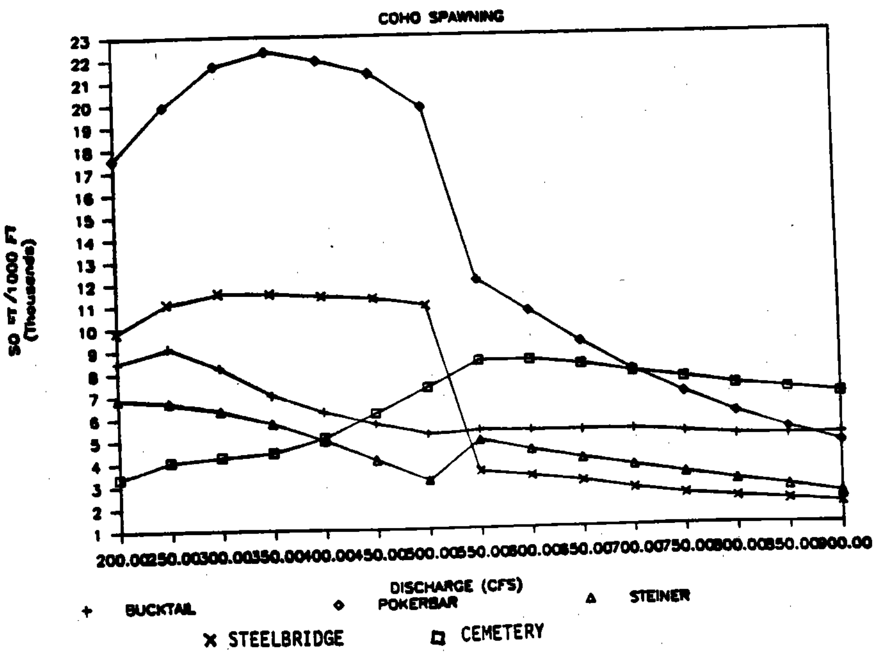



Figure 29. Predicted Weighted Usable Area of Habitat for Coho Salmon spawning, Cemetary to Steiner Flat Study Sites, 1986.

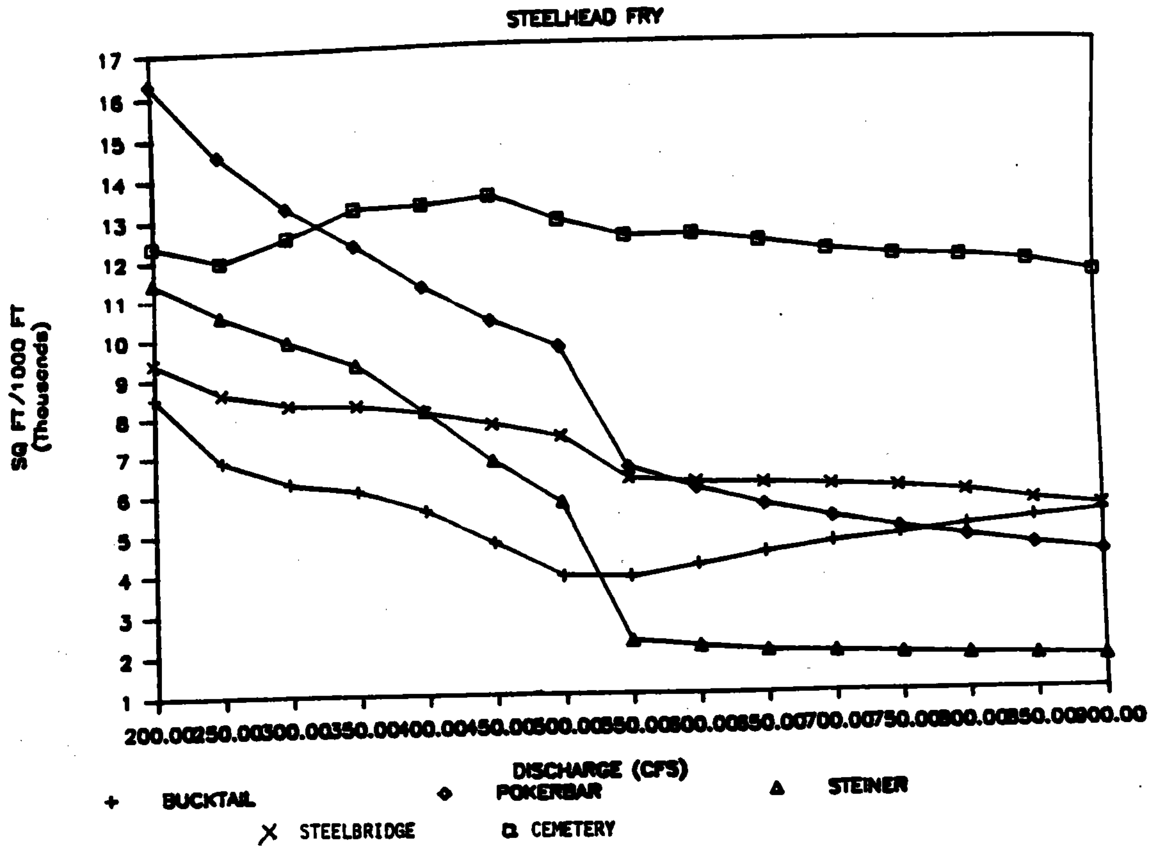



Figure 30. Predicted Weighted Usable Area of Habitat for Steelhead Trout fry, Cemetary to Steiner Flat Study Sites, 1986.

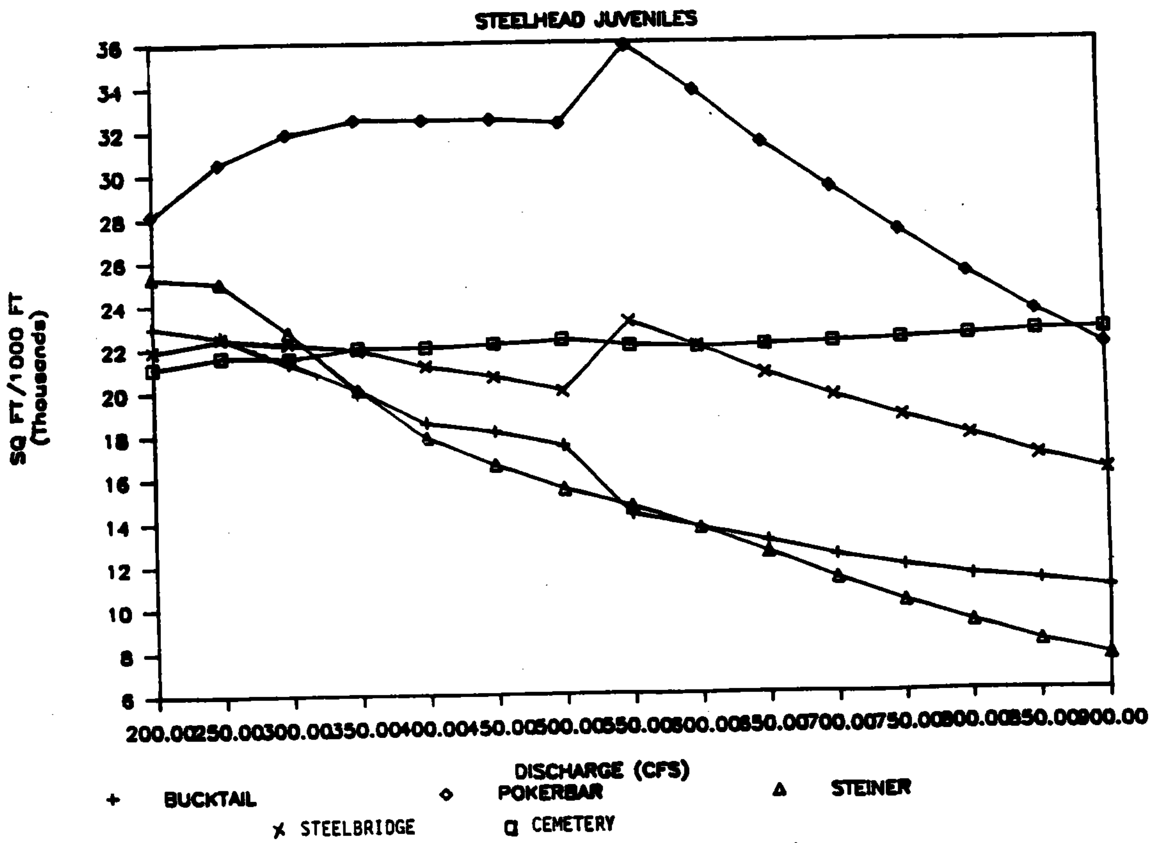



Figure 31. Predicted Weighted Usable Area of Habitat for Steelhead Trout juveniles, Cemetary to Steiner Flat Study Sites, 1986.

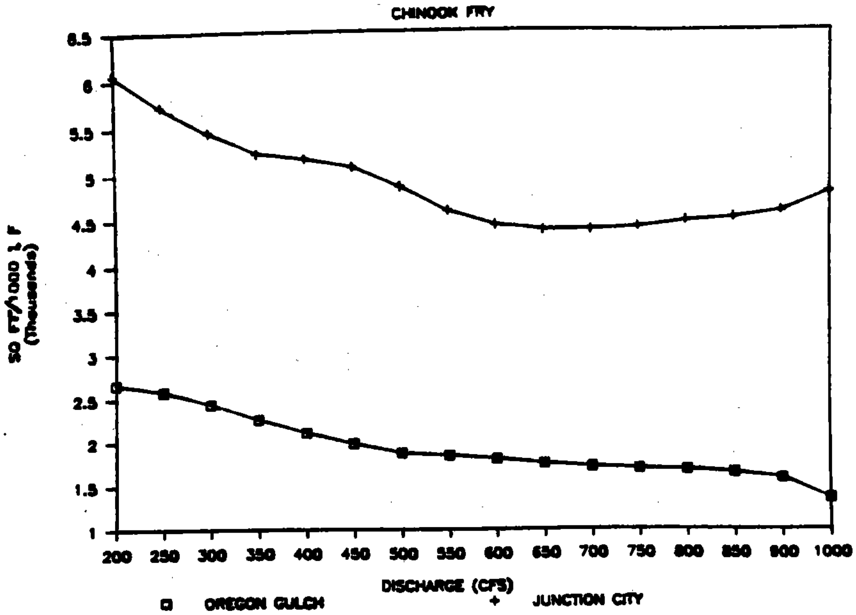



Figure 32. Predicted Weighted Usable Area of Habitat for Chinook Salmon fry, Oregon Gulch and Junction City Study Sites, 1986.

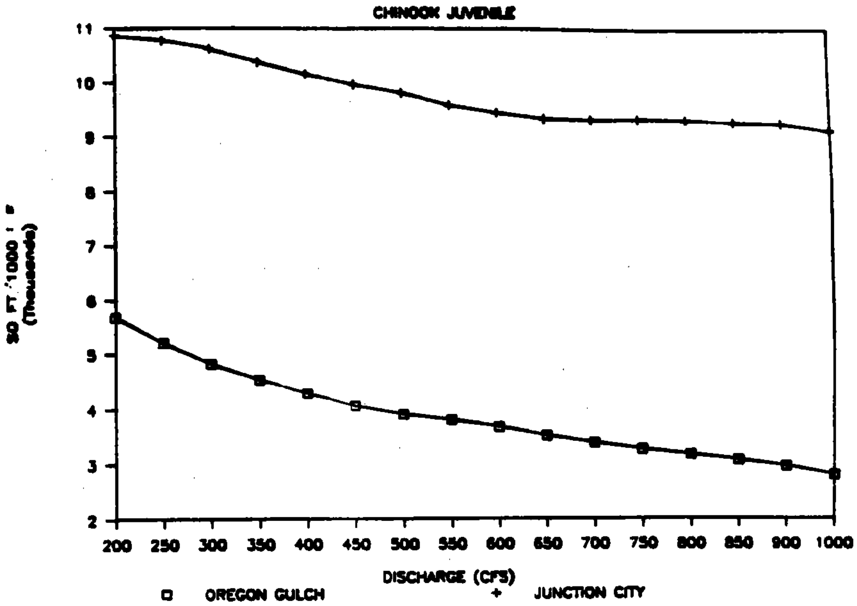



Figure 33. Predicted Weighted Usable Area of Habitat for Chinook Salmon juveniles, Oregon Gulch and Junction City Study Sites, 1986.

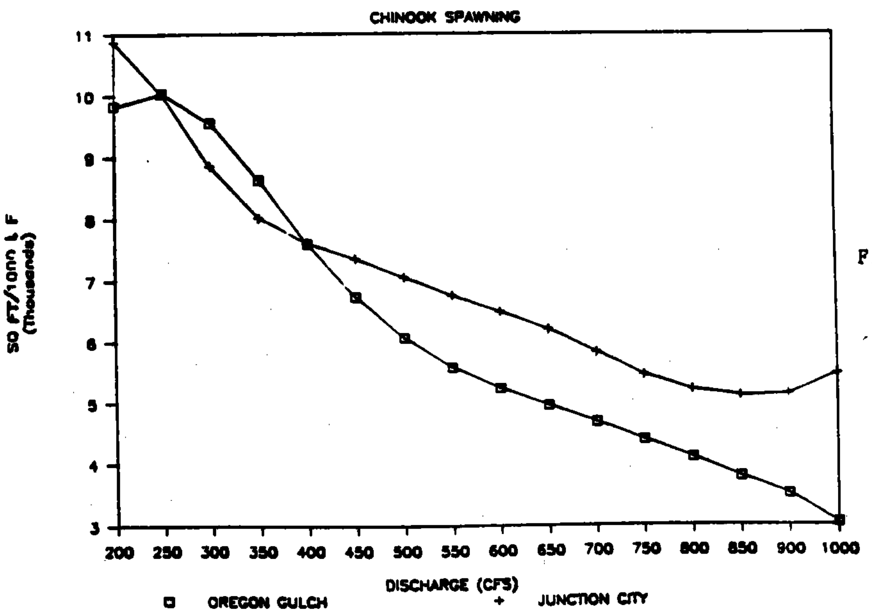



Figure 34. Predicted Weighted Usable Area of Habitat for Chinook Salmon spawning, Oregon Gulch and Junction City Study Sites, 1986.

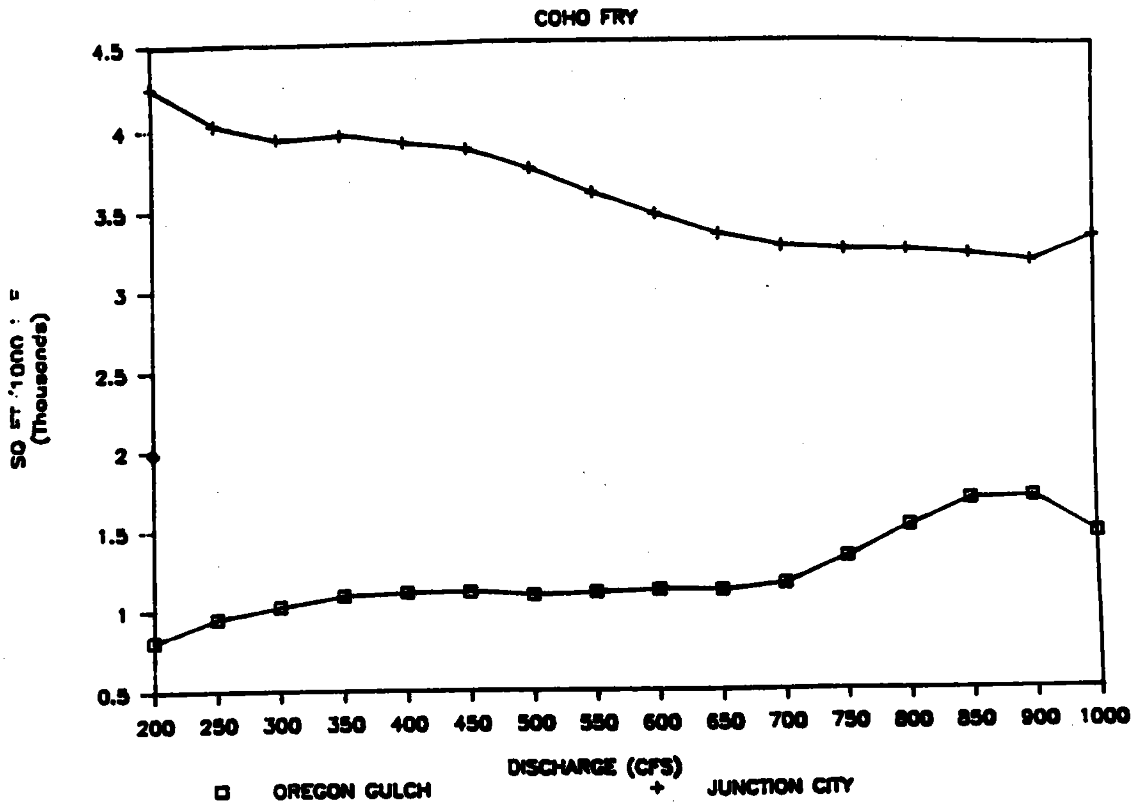



Figure 35. Predicted Weighted Usable Area of Habitat for Coho Salmon fry, Oregon Gulch and Junction City Study Sites, 1986.

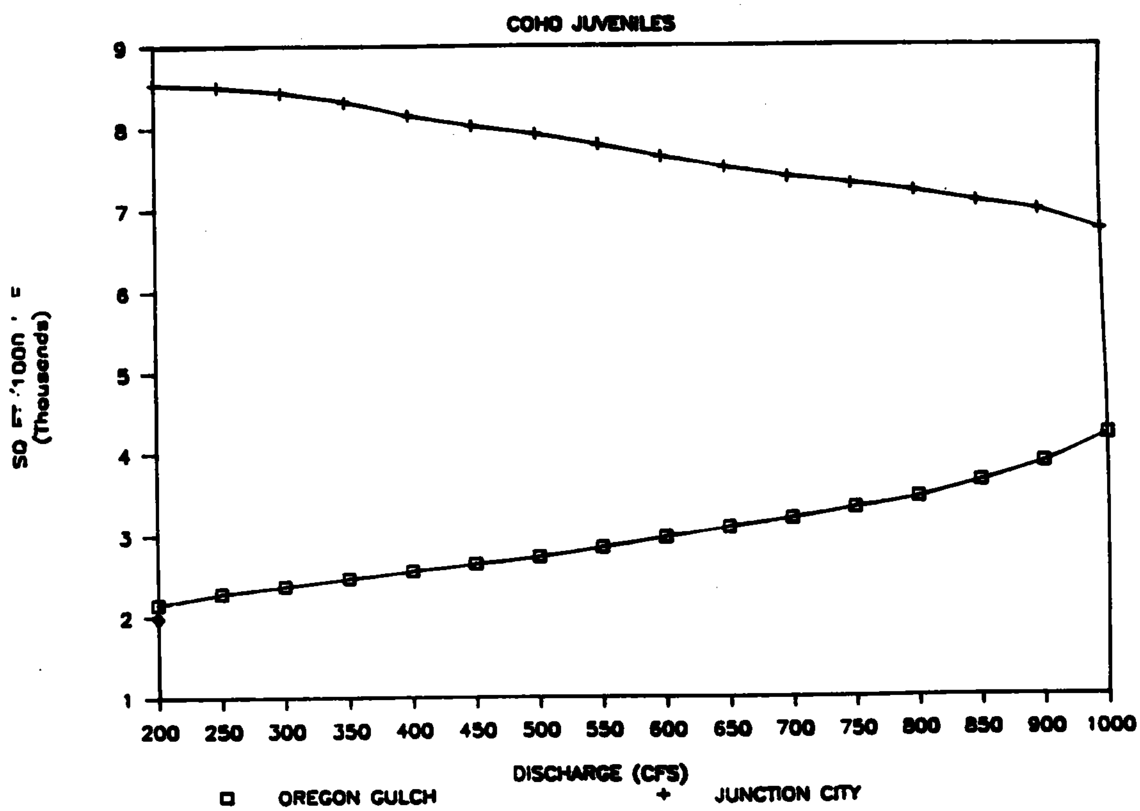



Figure 36. Predicted Weighted Usable Area of Habitat for Coho Salmon juveniles, Oregon Gulch and Junction City Study Sites, 1986.

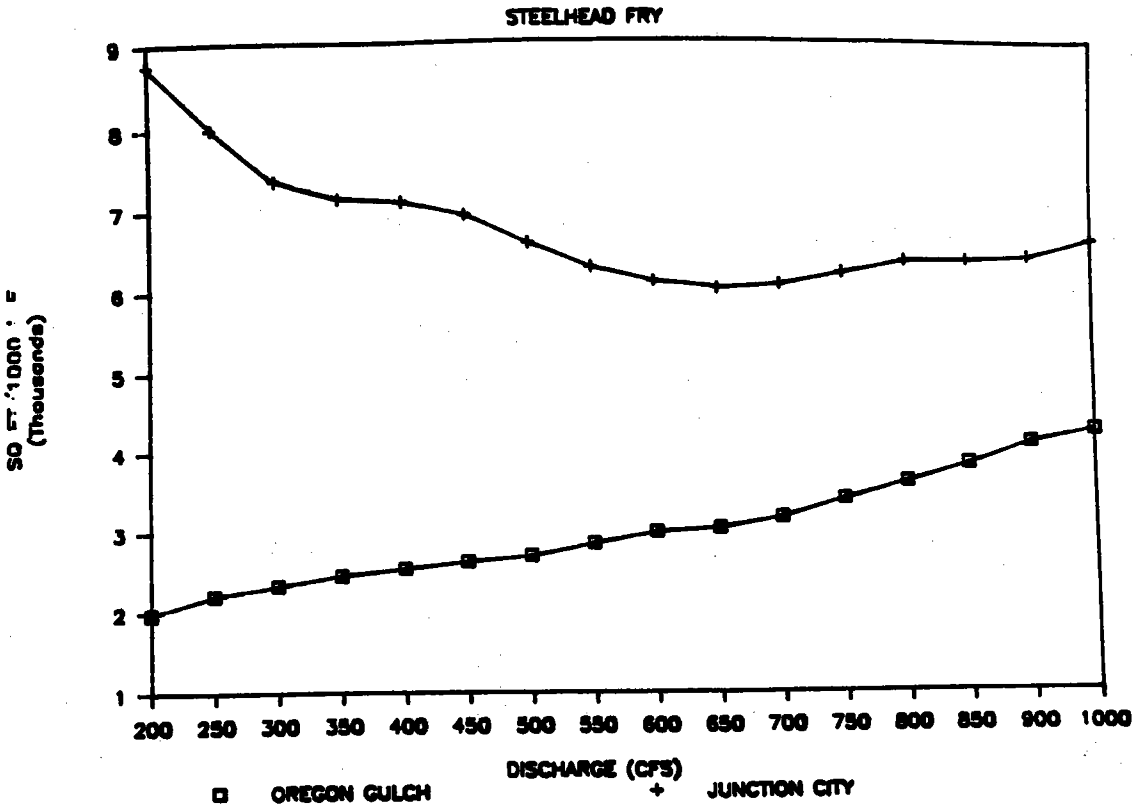



Figure 37. Predicted Weighted Usable Area of Habitat for Steelhead Trout fry, Oregon Gulch and Junction City Study Sites, 1986.

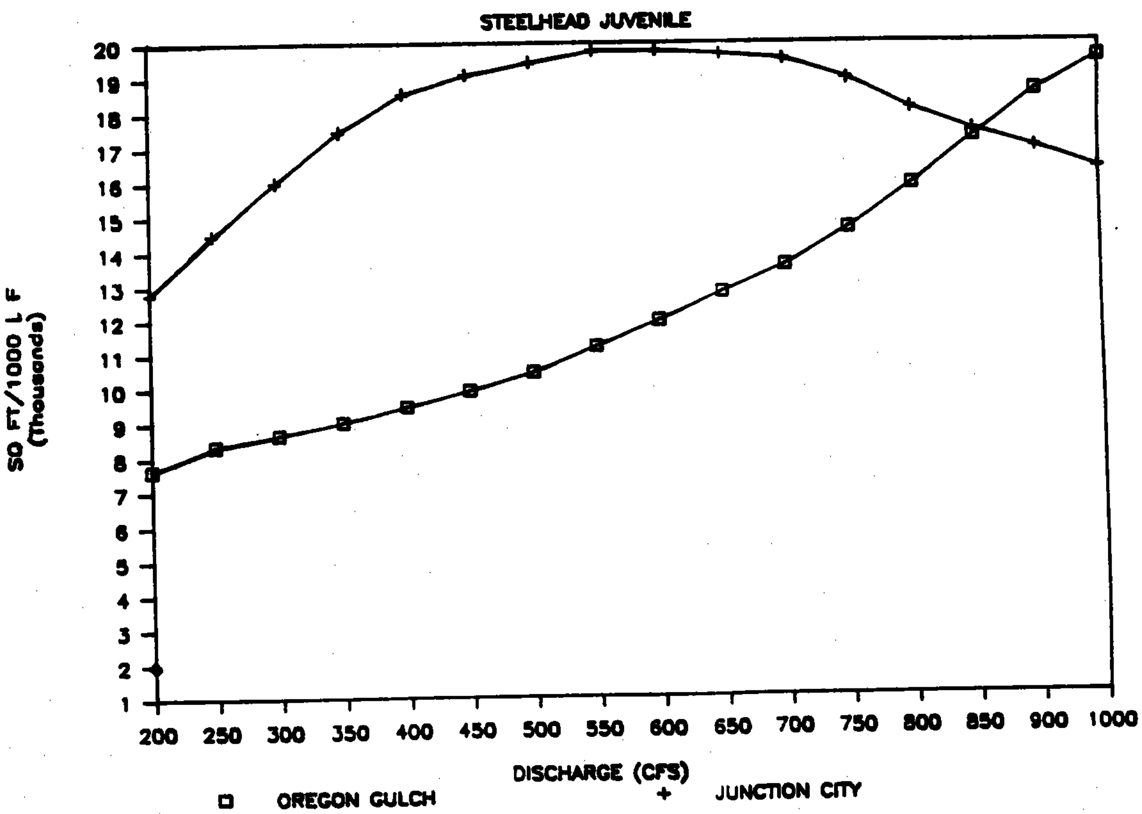



Figure 38. Predicted Weighted Usable Area of Habitat for Steelhead Trout juveniles, Oregon Gulch and Junction City Study Sites, 1986.

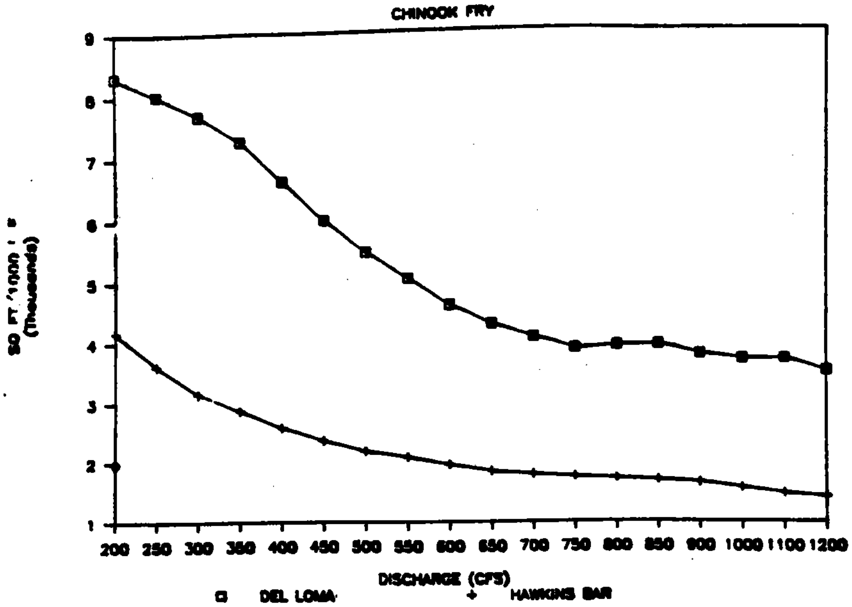



Figure 39. Predicted Weighted Usable Area of Habitat for Chinook Salmon fry, Del Loma and Hawkins Bar Study Sites, 1986.

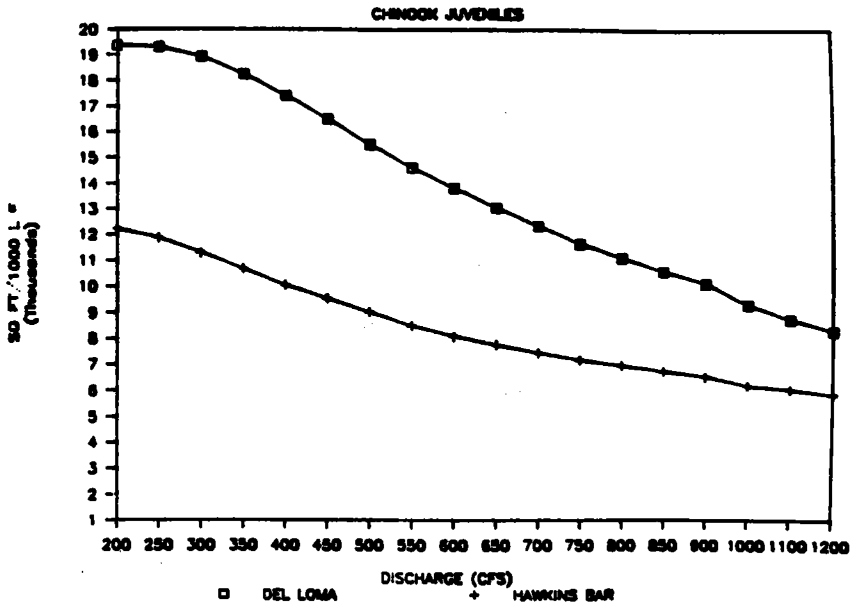



Figure 40. Predicted Weighted Usable Area of Habitat for Chinook Salmon juveniles, Del Loma and Hawkins Bar Study Sites, 1986.

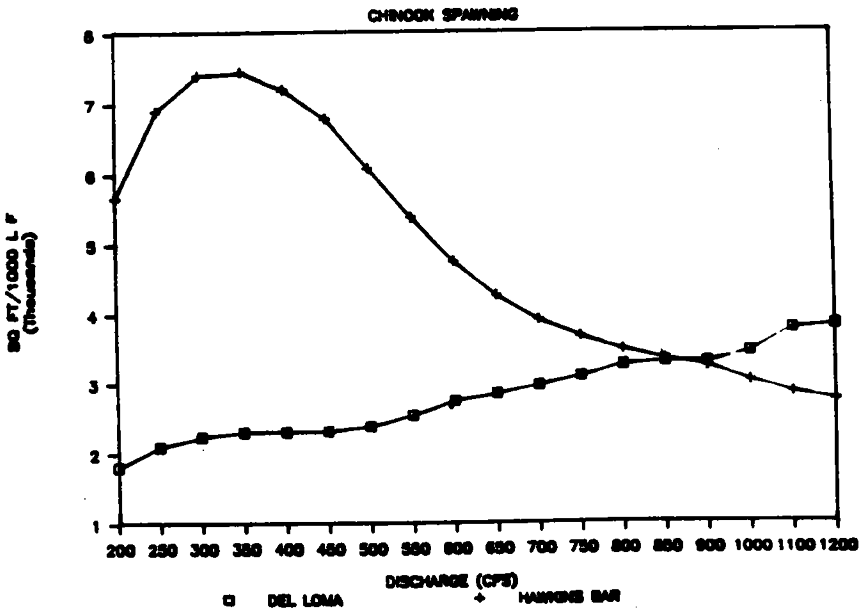



Figure 41. Predicted Weighted Usable Area of Habitat for Chinook Salmon spawning, Del Loma and Hawkins Bar Study Sites, 1986.

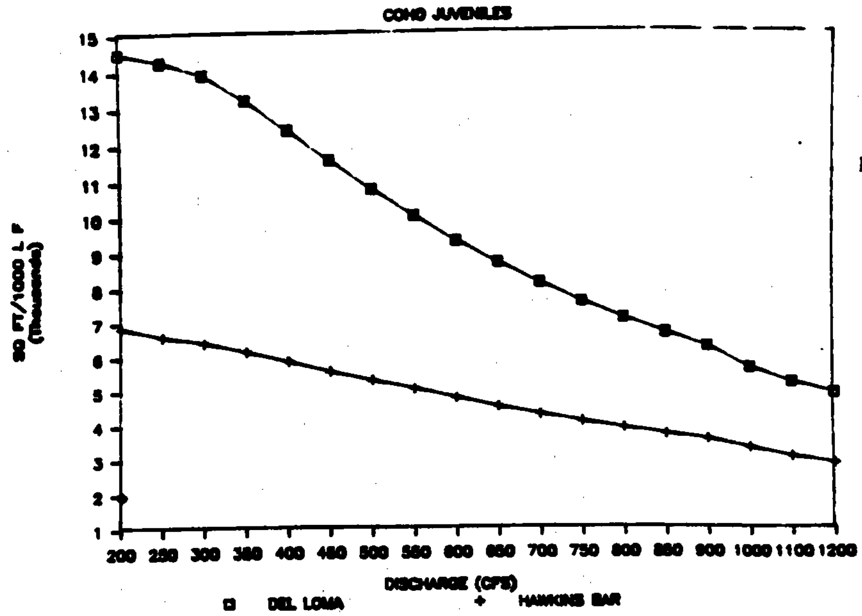



Figure 42. Predicted Weighted Usable Area of Habitat for Coho Salmon fry, Del Loma and Hawkins Bar Study Sites, 1986.

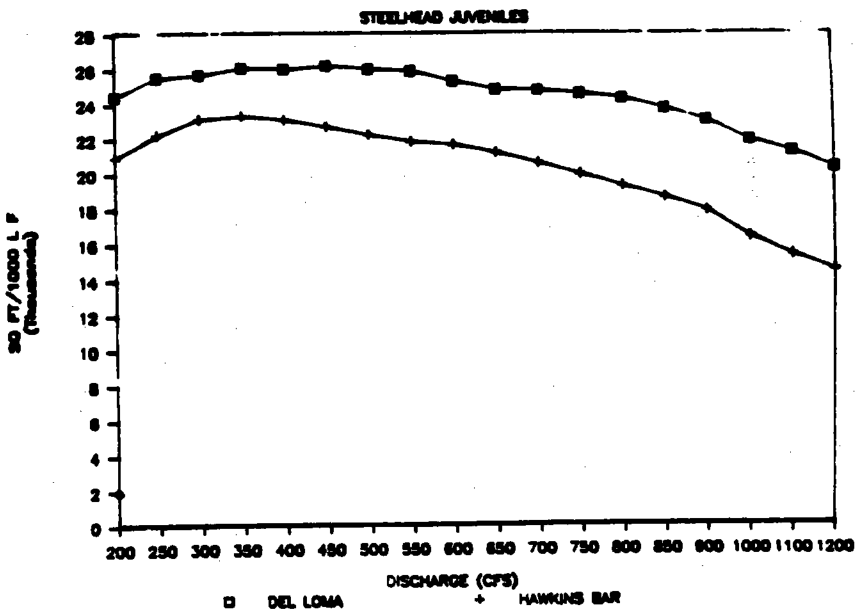



Figure 43. Predicted Weighted Usable Area of Habitat for Steelhead trout juveniles, Del Loma and Hawkins Bar Study Sites, 1986.

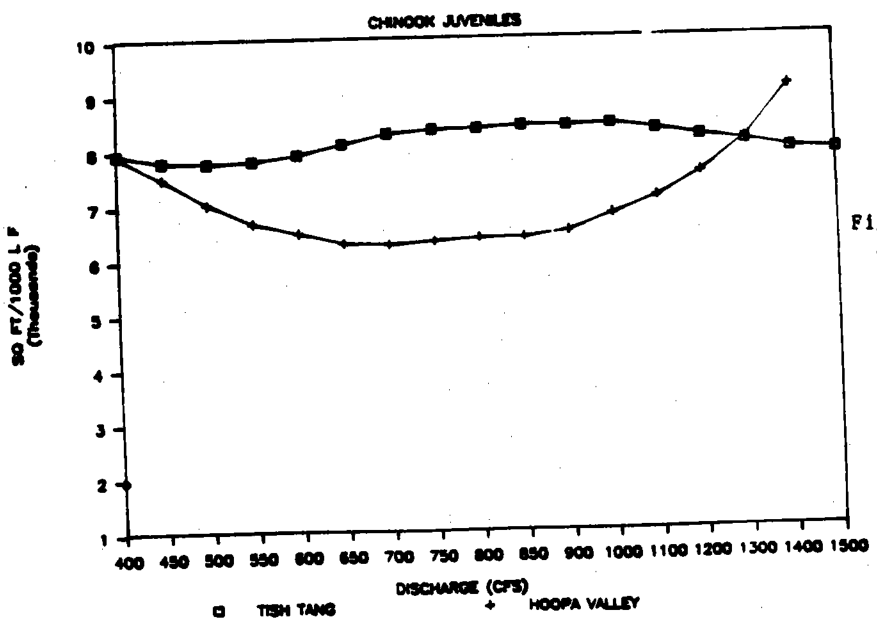



Figure 44. Predicted Weighted Usable Area of Habitat for Chinook Salmon juveniles, Tish-Tang and Hoopa Valley Study Sites, 1986.

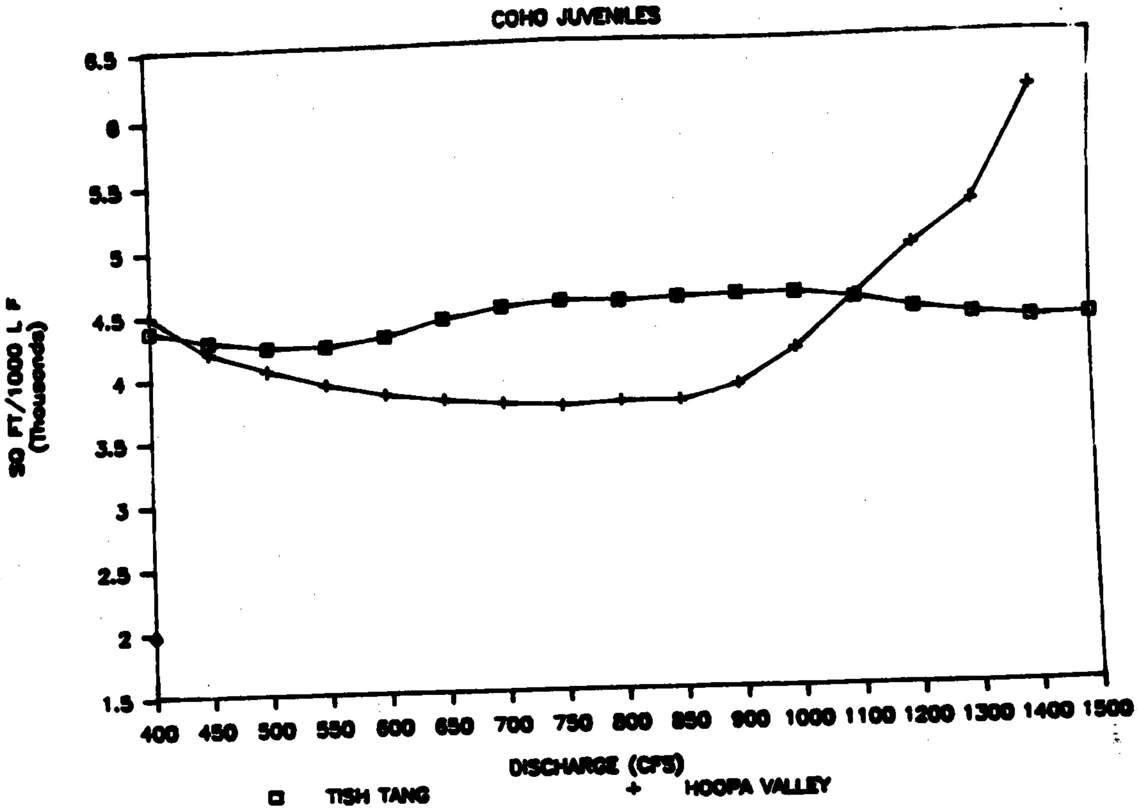



Figure 45. Predicted Weighted Usable Area of Habitat for Coho Salmon juveniles, Tish-Tang and Hoopa Valley Study Sites, 1986.

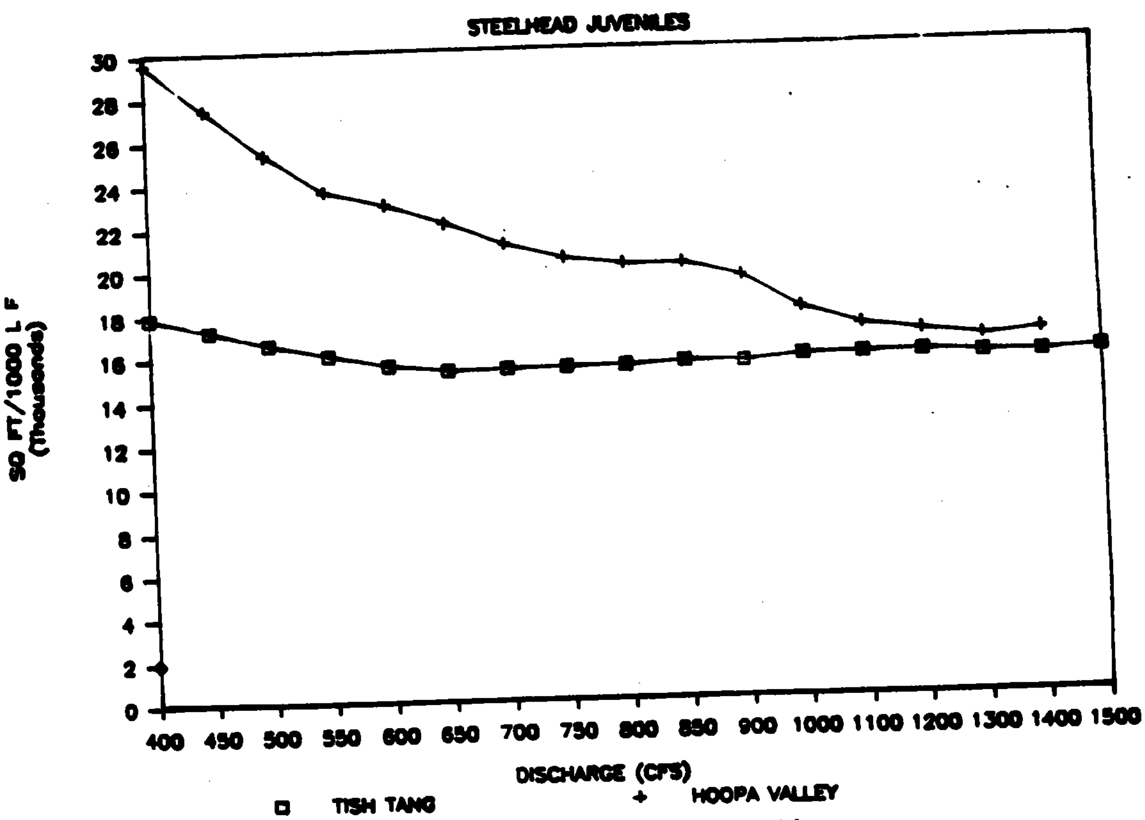



Figure 46. Predicted Weighted Usable Area of Habitat for Steelhead trout juveniles, Tish-Tang and Hoopa Valley Study Sites, 1986.

350 cfs, dropping with increasing flow that obscures the riffles there.

Figures 44 through 46 show rearing habitat availability at Tish-Tang and Hoopa Valley. There is little response to flow changes at Tish-Tang, perhaps because the river channel there is benched, so that increasing discharge, while reducing some habitat by increasing velocities away from the river's edge, also opens up habitat areas along the river margins. In Hoopa Valley, where there are wide, gently-sloping bars of homogeneous substrate, increased flow results in increased salmon rearing habitat, and in decreasing habitat for steelhead, which require faster water.

## Discussion

These preliminary findings suggest that, except for spawning, habitat for important anadromous salmonid life stages tend to decrease in availability with increasing flows over about 200 cfs in the upper river segment. Spawning habitat tends to peak at minimal flows, and then decreases rapidly. Below Steiner Flat, the same trends generally occur, although there is a diminishing rearing-habitat response to flow change, and a trend reversal in some instances, notably at Hoopa Valley.

Results suggest that side-channels are now the most important rearing areas in the upper river. Our study sites include part of the most extensive existing side-channel system, at the Cemetary reach, as well as a high-flow side-channel at Bucktail. In these reaches, as increasing discharge diminishes habitat in the main channel, the increasing side-channel area maintains or increases overall rearing habitat availability, even though the side-channels cover a small linear proportion of the sites.

The Hoopa Valley rearing habitat curves are of interest, since the Hoopa Reach, relatively unaffected by flow regulation at Lewiston and unconfined by canyon walls, retains something of the morphology that seems to have predominated in parts of the upper river before diversion. Part of what made the Trinity River a productive salmon stream may have been its regular wide point bars in the valley reaches below Lewiston, which provided extensive salmon rearing habitat during high spring flows.

These results may require major reevaluation following additional IFIM study analysis, for several reasons. First, the IFG-4 procedure provides only provisional estimates of habitat, useful mainly within the range of discharges bracketed by the study flows. Thus potentially important changes in habitat availability occurring at lower and higher Lewiston releases may not be included in projections to date.

A second factor that may modify projections is the planned development of true habitat preference curves and the collection of additional preference data. The provisional curves used in these initial habitat modeling efforts are based on observed habitat use in the existing Trinity River, and may not represent actual preference for optimum habitat. For example, most juvenile chinook were observed over substrates high in fine material, and this may have inflated the estimate of rearing habitat at Poker Bar, the sandiest site (Figures 24 and 25).

A third major factor that may be of overriding importance on the availability of salmonid habitat is the effect of flow-related temperature changes. The relatively flat curves produced by hydraulic microhabitat and substrate modeling indicate a greater importance of the temperature component, which may be the major flow-related control on fish populations.

# FISH POPULATION CHARACTERISTICS AND LIFE HISTORY RELATIONSHIPS (TASK 4)

## Introduction

The purpose of Task 4, within the 12-year study, 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.

Through 1986 efforts have been initiated on all subtasks. However, work on subtasks 4A and 4F have not yet progressed far enough to warrant reporting at this time.

## Juvenile Salmonid Rearing Populations and Habitat Use, Trinity River Flow Evaluation Study, Spring 1986

### Introduction

To provide an initial index of juvenile salmonid populations and rearing habitat use in the Trinity River, we undertook a sampling program at four sites in the upper river during the spring of 1986. At each site, selected transects across the river, and near-shore areas extending below transects were sampled by direct underwater observation by one to three divers. Additional habitat use and population data were obtained through electrofishing and seining carried out primarily to collect fish for growth and food use studies.

### Sampling Sites

Our sampling sites were Instream Flow Incremental Methodology (IFIM) study reaches at Cemetery Hole, Steelbridge Campground, Steiner Flat Road, and Junction City Campground. At each site we selected several representative transects from those earlier chosen for IFIM hydraulic flow analysis and from one to four edge sampling reaches as described in Table 6.

We sampled transects by stringing a static rescue rope across the river, and ferrying divers across it on a rescue pulley and webbing sling. The observers could orient themselves and speed or slow their progess by adjusting their position in the current, and use mask and snorkel to examine the water ahead and at leisure. Since prior to the release of hatchery juveniles virtually no rearing salmonids are seen beyond about fifteen feet from the bank, we made no further refinements to the transect method.

For sampling river edges, the transect rope is left anchored at one end, and the other end brought downstream along the bank its full length of 200 feet. After a brief wait, divers work their way up the rope against the current with the aid of a Gibbs rockclimbing ascender, counting and identifying to species all fish that they pass. Numbers of chinook and coho salmon, steelhead, and brown trout less than a year old are entered on underwater slates. Yearling and larger fish are noted seperately.

Where it is possible, three divers ascend the rope in succession, in order to develop a bounded count estimate of actual populations (Regier and Robson, 1967). The second and third divers start when the preceding diver has ascended 100 feet of rope, usually about fifteen minutes.

Table 6. Direct observation sampling sites used for the juvenile salmonid rearing population and habitat use surveys, Trinity River Flow Evaluation Study, 1986.

| Reach | IFIM Transects | Edge Samples |
|---|---|---|
| Cemetery | XSEC 1 (run/riffle) | XSEC 1 - 200' downstream on left bank (brushy bank) |
| | XSEC 3 (run/pool) | XSEC 3 - 400' downstream on left bank (brushy bank) |
| | XSEC 7 (run/pool) | XSEC 7 - XSEC 9 (265') on left bank (gravel bar) |
| Steelbridge | XSEC 1 (pool) | XSEC 1 - 250' downstream on right bank (brushy bank) |
| | XSEC 6 (run/eddy) | XSEC 6 - 200' downstream on right bank (brushy bank) |
| | XSEC 8 (rocky eddies) | XSEC 8 - 200' downstream on right bank (rock & brush) |
| Steiner Flat | XSEC 1 (run) | XSEC 1 - 200' downstream on left bank (brushy bank) |
| | XSEC 4 (run/riffle) | XSEC 4 - 200' downstream on left bank (brushy bank) |
| | XSEC 7 (run/bar) | XSEC 7 - 200' downstream on left bank (gravel bar) |
| | XSEC 9 (deep/run) | XSEC 9 - 200' downstream on right bank (bedrock) |
| Junction City | XSEC 2 (run/riffle) | XSEC 2 - 200' downstream on left bank (bedrock) |
| | XSEC 5 (run/pool) | XSEC 5 - 200' downstream on left bank (bedrock,cobble,bar) |
| | XSEC 6 (riffle) | |

## Effects of Water Clarity

Our experience indicated that water clarity above a certain minimum level did not affect the efficiency of counting and identifying juvenile fish where they occurred in the upper Trinity. The minimum required visibility is somewhat variable, depending on light conditions and the type of habitat sampled, but is about four to five feet in most of our sampling areas. When the water is clear enough, it is possible to see and usually identify salmonids two to three inches in length at perhaps fifteen feet, but if the observer attempts this he is certain to miss many closer fish while losing track of, or double-counting many of the farther ones. Therefore, the diver's real upper range of useful visibility is about six feet, regardless of water clarity; at the lower limit of about four feet visibility, the diver's sight limitation is approaching the flight threshold distance of target species, and counts diminish rapidly in reliability.

## Fish Emergence and Sampling Schedule

In the upper river, chinook salmon started to emerge from spawning gravels in early February. After heavy winter storms, Lewiston dam flood-control spills started on February 16, and continued until March 24, 1986. Low water visibility continued until late April in the upper three sites, and our sampling missed both the probable peak of chinook emergence, and the start of coho emergence. At the lowest site, Junction City, visibility was not suitable until mid-May.

On June 3, the first releases of hatchery-reared chinook young-of-the-year took place, and after this we made no attempt to count this species at the upper sites. The released fish at 87 to the pound were about the size of some of the larger naturally-spawned chinook. Many collected along the river edges where natural fish had earlier held, and because of their large numbers it was impossible to effectively identify the few naturals among them.

Counts of coho, steelhead/rainbow trout, and brown trout were made only until mid-June, when other field studies required the full time of available staff.

## Fish Behavior and Response to Observation

Fish sensitivity to the divers' presence seemed to vary with species. Chinook salmon are least affected, generally moving off only a few feet at the diver's approach, and maintaining position as the diver passes. When an observer's foot or hand stirs up the substrate, chinook tend to concentrate just downstream, feeding on the invertebrates released into the water column.

Coho salmon are more wary, bunching up and moving closer to the bank and seeking cover, but they rarely move off more than a few feet. Small steelhead/rainbow trout under about three inches long seem more skittish than the salmon, but remain within the same general areas as they. Small brown trout hold close to the river bottom, generally keeping still and fleeing only on the close approach of a diver. Both species of trout, once they have grown over about three inches long, become more wary. Brown trout of this size are rarely seen, except at night or when taken by electrofishing or seine.

Juvenile chinook generally occur at the edge of any underwater or overhanging brushline ten to fifteen feet from the waters edge, depending on their size and the speed of the current.

Coho keep closer to shore, from the edge of any overhanging cover to the bank, if the water there is over a few inches deep. There are almost always a few coho in any group of chinook, and there may be rainbow and brown trout as well. In May and June we also saw numerous sticklebacks schooled with the chinook.

Beyond about fifteen feet from the waters edge there are negligible numbers of juvenile fish, and we saw virtually no young-of-the-year fish along transects across the river, except for hatchery steelhead and chinook moving downstream or holding in the eddies after releases started. Because of this it is possible to cover the major mainstem rearing areas by edge sampling, since an observer could carefully examine the river from its banks to about thirty feet out from shore by swinging out into the current or closer to the bank with the adjustment of body position.

The great majority of fish observed prior to hatchery releases of yearling steelhead and juvenile chinook are either actively feeding or trying to hide from us. If watched long enough, fleeing or hiding fish return to feeding. Fish are usually oriented into the current, and show no tendency toward downstream movement except to flee a few feet as we pass them.

Night Sampling

We made one night sample, on April 30 at the Cemetery site, three days after sampling it by day. We used the same methods, with the addition of underwater flashlights.

Along the brushy edges that characterize most of the upper river, there is little difference in the numbers of young-of-the-year salmon and trout seen by night. We saw significantly more yearling and older brown trout, however. The fish seem to be experiencing whatever might be called sleep in a fish. When hit by the light, the salmon and smaller trout generally move off sluggishly. The larger brown trout and many rainbows flee immediately.

Night observation along transects revealed no young-of-the-year fish, but vast numbers of yearling steelhead, released that day from the Trinity River Hatchery two mile upstream. These fish were everywhere across the transects, especially in the faster water, seeemingly out of control, and going downstream.

Sample sites at the Cemetery reach include one of the few slow-water gravel bars in the upper river, and here night observation proved to be advantageous. We saw numerous fish resting on the bottom over the bar, where few had been counted by day. Evidently they school up by day and are able to avoid observation in the relatively large area of slow water available to them. Our overall daytime counts may therefore be biased by low counts on the gravel bar.

Electrofishing and Seining

Additional general indices of fish populations are obtained through electrofishing and seining carried out primarily to obtain data for fish growth and feeding studies. Since it is not possible to block off discrete areas of the river for this, standard methods of statistical population estimation cannot be applied.

FINDINGS

In order to get a fairly consistent estimate of the fish present on sample areas we used a bounded count estimator as described by Regier and Robinson (1967). In this method the estimated number present is two times the highest observation less the second-highest observation. Thus, if three divers sample the same area in succession, one counting ten chinook, one counting nine, and one counting five, the best estimate for chinook is twice ten minus nine , or eleven fish.

One hundred and forty nine diving observations have been made of various species with two or more divers repeating, and thus we had 149 pairs of direct observations and bounded counts. In Figure 47 diver observations are plotted against bounded counts. The least-squares equation, Y(1.39) * 10.34, is used to estimate population numbers for other counts where only one diver made the run.

The resulting estimated juvenile salmonid populations within each of the four study sites are reported in Figures 48 to 51 as fish densities observed per linear foot of river. Note that chinook salmon are not counted at the last site visits at the upper two sites, Cemetery and Steelbridge, and note that the X-axis scale differs from graph to graph.

Our observations show a generally decreasing density of salmonid juveniles downstream and over time, as would be expected from spawning distributions, which concentrate fish upriver, and the fact that juveniles migrated out of the upper river during our sampling period (Figure 52).

It is interesting to note that Coho salmon, which frequently rear for a year in fresh water, show much less population change with time, and a greater concentration of individuals toward the higher sites.

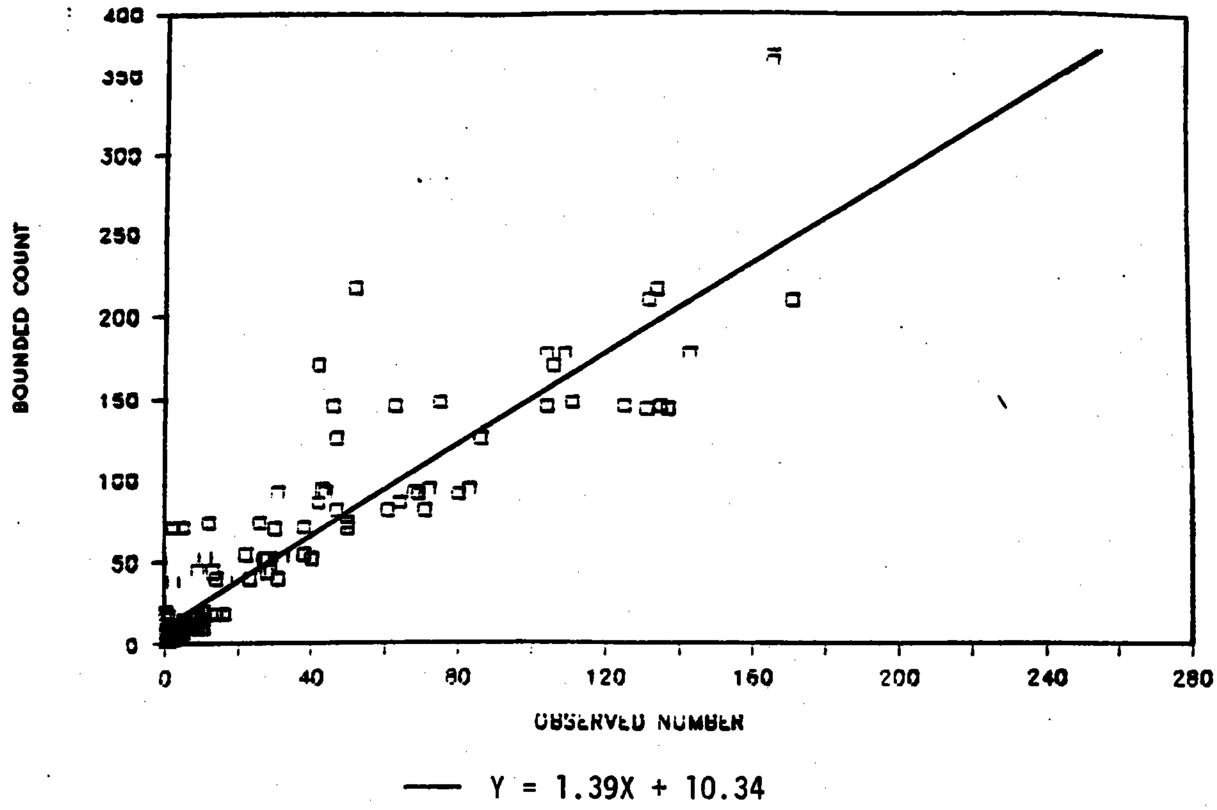



**Figure 47. Diver observations and bounded counts to estimate juvenile salmonid population numbers.**

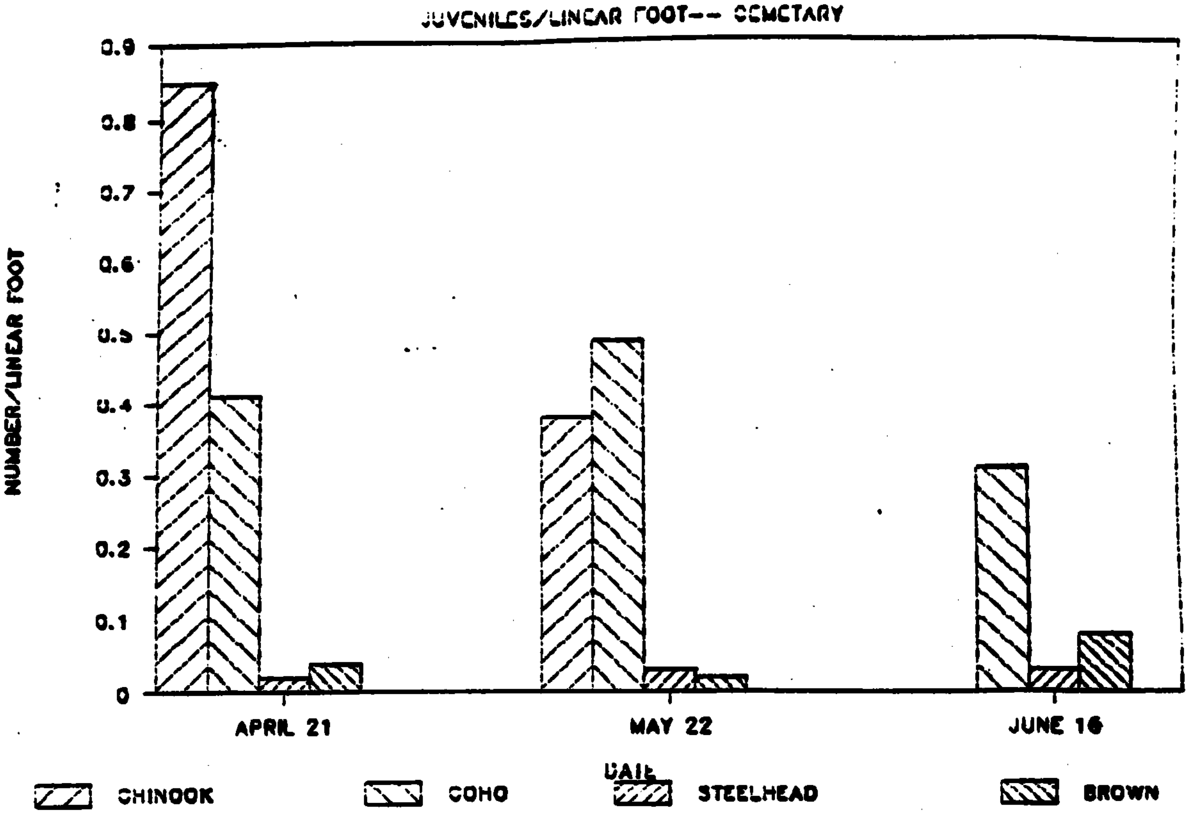



**Figure 48. Esitmated density, expressed as juveniles per linear feet, for juvenile salmonids at the Cemetary Study Site, 1986.**

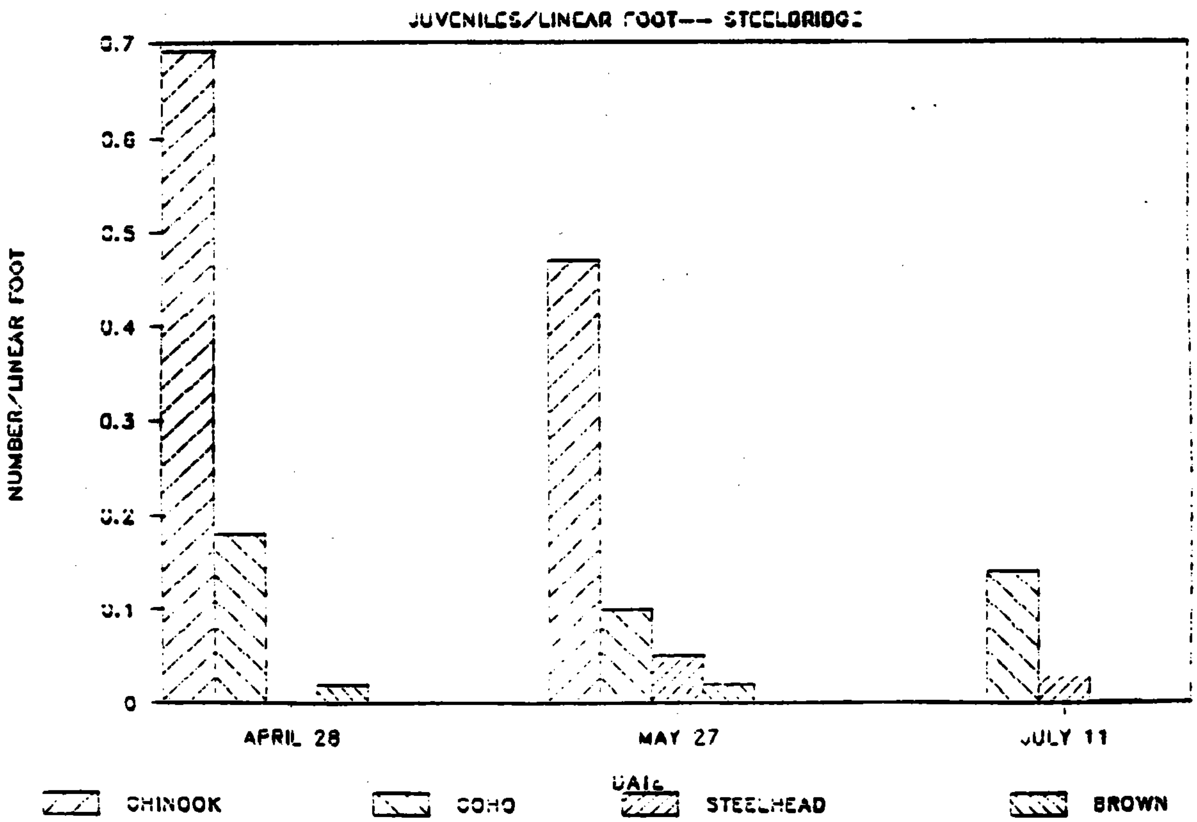



**Figure 49. Estimated density, expressed as juveniles per linear feet, for juvenile salmonids at the Steelbridge Study Site, 1986.**

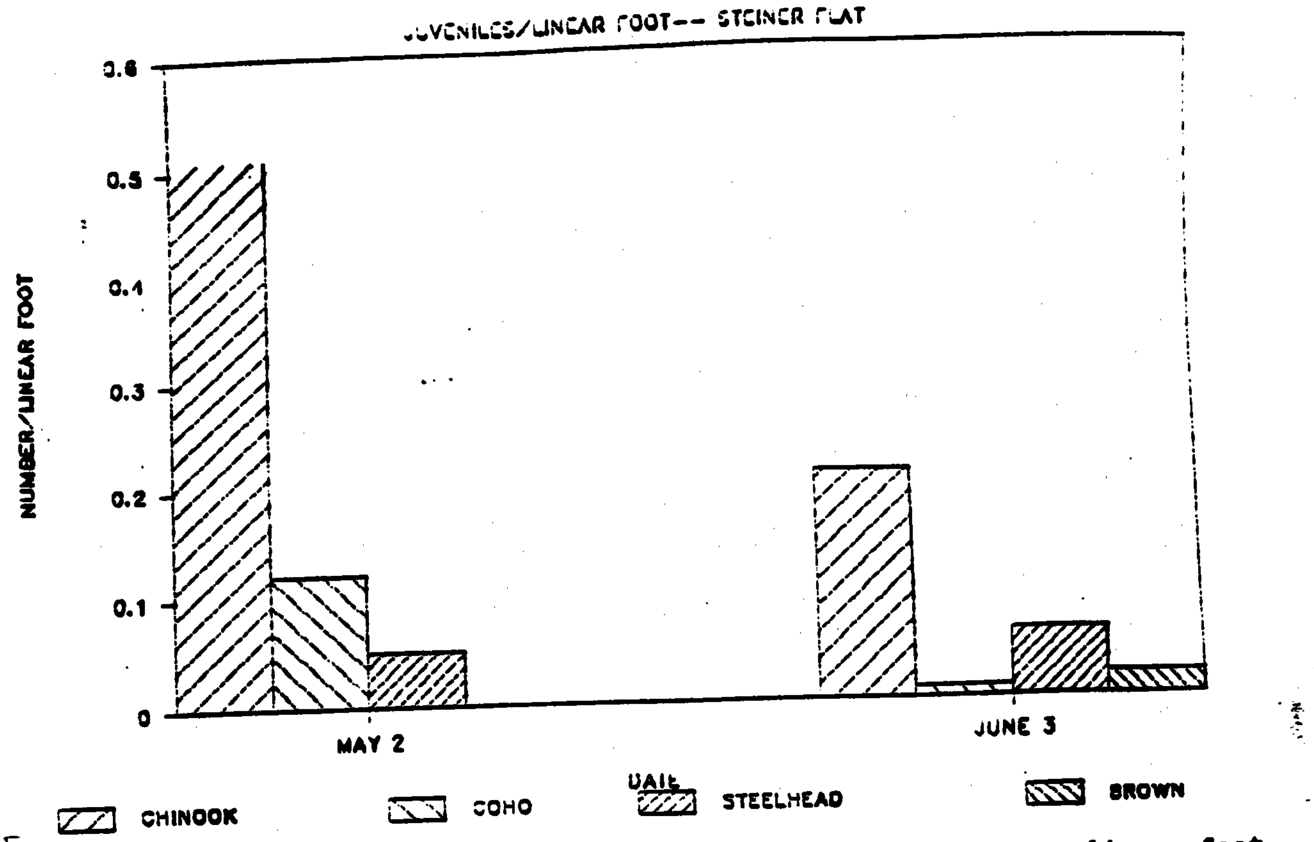



**Figure 50. Esitmated density, expressed as juveniles per linear feet, for juvenile salmonids at the Steiner Flat Study Site, 1986.**

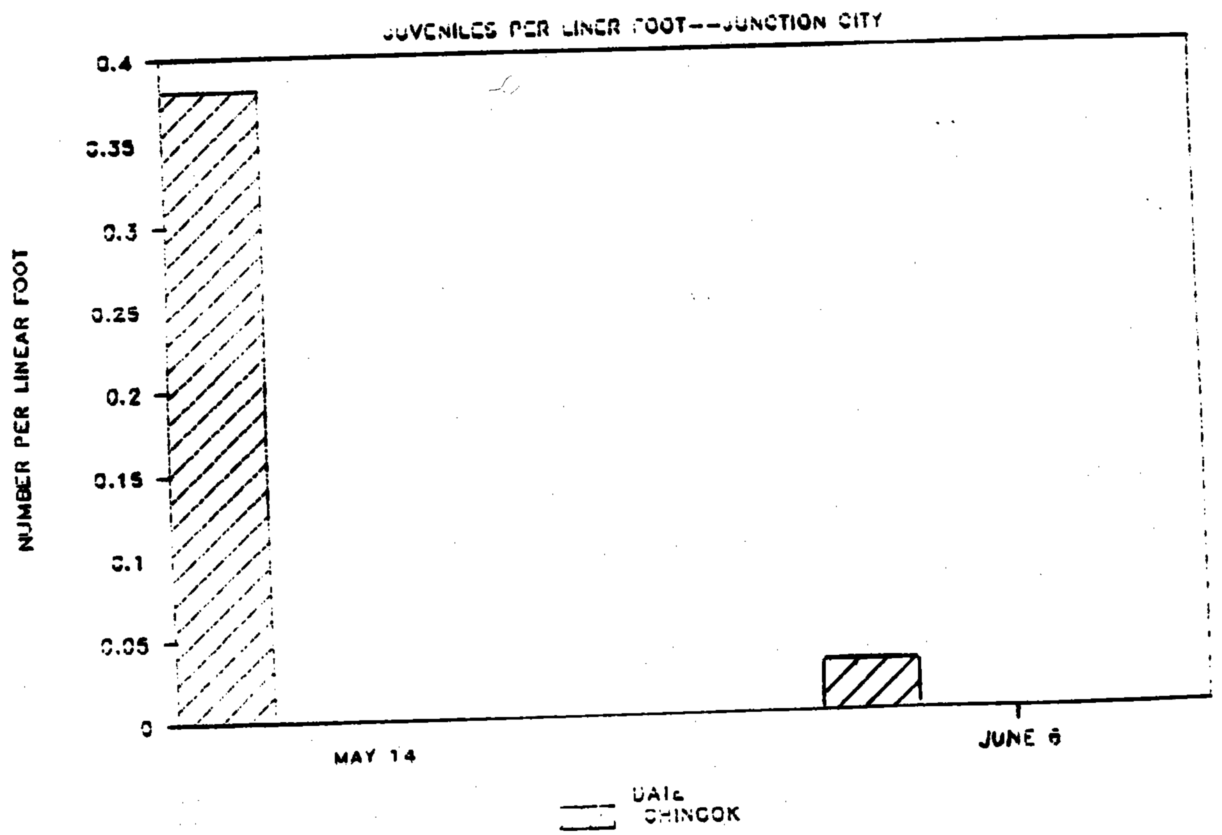



**Figure 51. Esitmated density, expressed as juveniles per linear feet, for juvenile salmonids at the Junction City Study Site, 1986.**

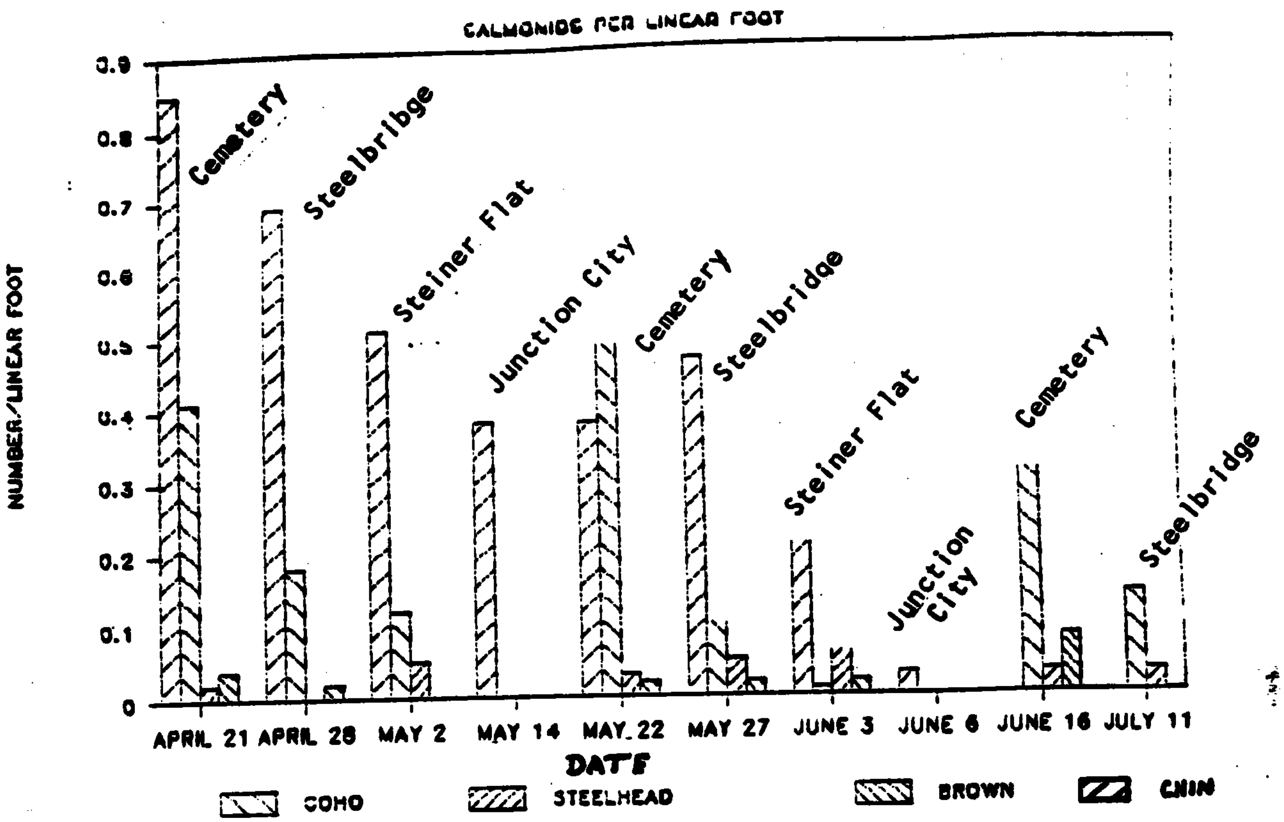



Figure 52. Esitmated density, expressed as juveniles per linear feet, for juvenile salmonids at four study sites and 3 observation periods during 1986.

Results of electrofishing and seine data (Figures 53 to 61) show similar though more variable results in the upper river. Electrofishing also measured the burst of hatchery chinook accompanying spring releases, with chinook out-migrants showing up as far down-river as Tish-Tang, below Willow Creek, in June.

The highest species population density we found was in late April and is 0.85 chinook juveniles per linear foot at the Cemetery site, or, considering both edges of the river equal as rearing habitat, 1.7 fish per foot of river. At this density, the Trinity in the 39 miles between Lewiston and the North Fork could produce about 350,000 juveniles chinook. April chinook, at about 45 millimeters, should weigh about 600 to the pound. By contrast, the Trinity River Hatchery, which releases chinook at a minimum 90 to the pound, grew from about 800,000 to 7,000,000 fingerling chinook per year between 1960 and 1977 (Fredericksen and Kamine, 1980). It seems evident that for 1985-86, at least, in- river rearing will not contribute a high percentage of Trinity River salmon production.

Salmon spawning is relatively high in the fall of 1985 with fish working suitable gravels down to the known historical lower limit of chinook spawing at Del Loma, and with much superimposition of redds in the river above Douglas City. However, high flows at peak fry emergence ofr both chinook and coho may have carried many fish out of the river that would otherwise have reared in our study areas, so we do not know if these areas are fully seeded. Future repetitions of rearing surveys should provide information to better show if in-river rearing is limited by the restriction of suitable habitat to a narrow strip along river margins, or by the recruitment of fry from spawning gravels.

Our surveys showed all rearing resticted to river edges, with no juvenile fish toward the center of the river. The upper river has lost its gravel bars, and has taken the shape of a trapezoidal canal with suitable rearing velocities restricted to a narrow band along abrupt banks. Since there is no way to reshape the main river, our results support the management concept of developing side channels, which provide rearing habitat.

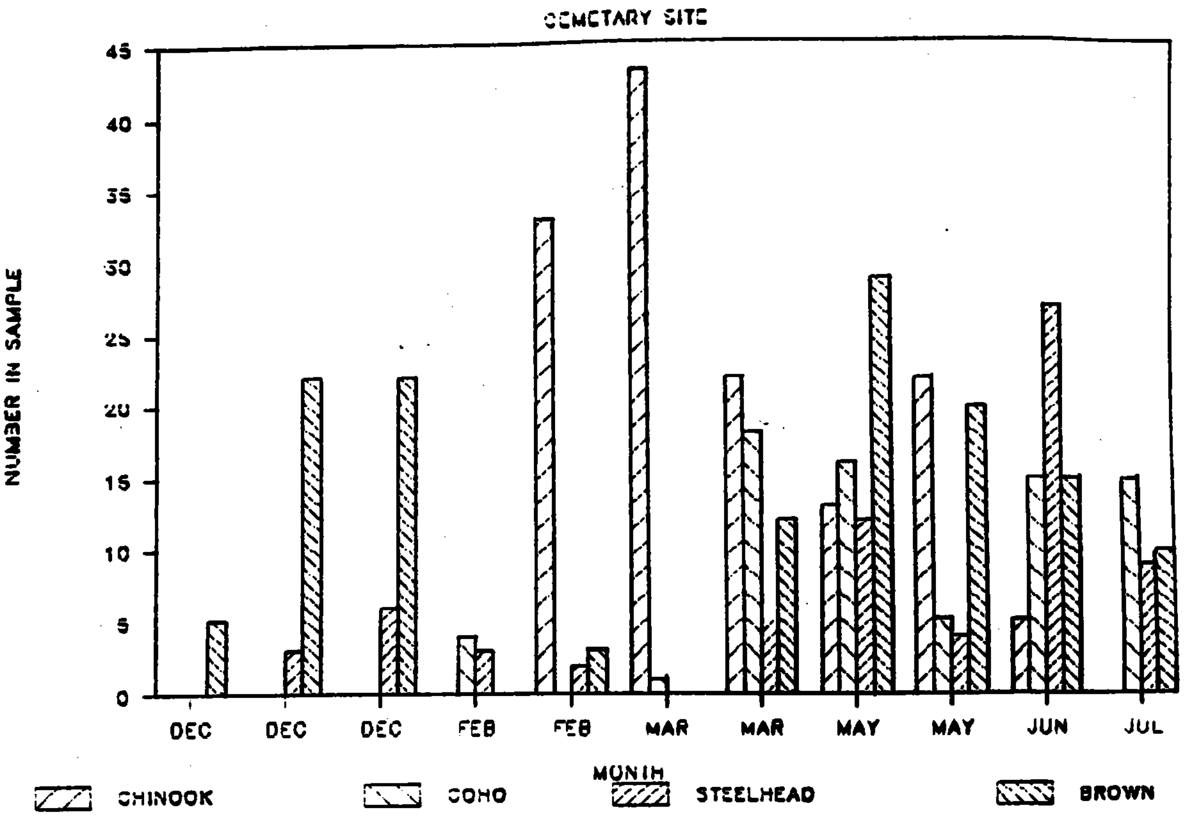



Figure 53. Results of electrofishing and seine collection for the Cemetary Study Site, 1986.

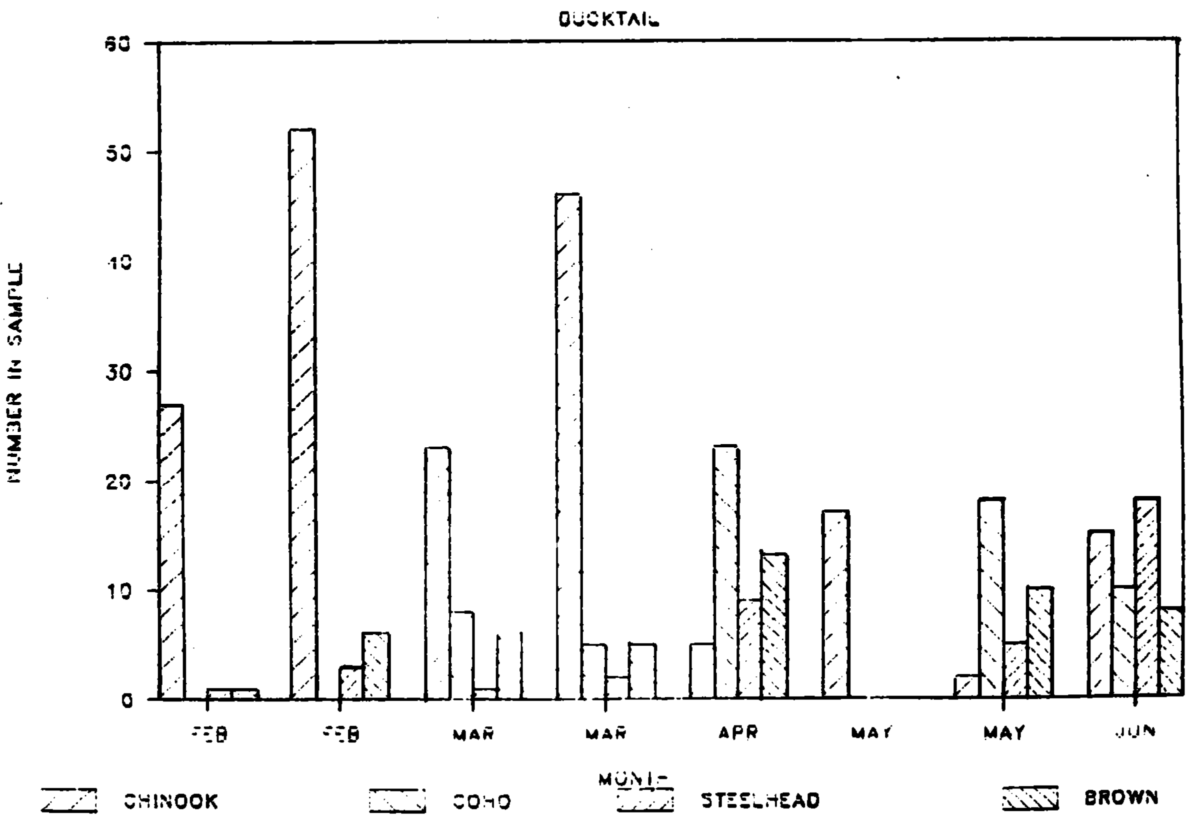



Figure 54. Results of electrofishing and seine collection for the Bucktail Study Site, 1986.

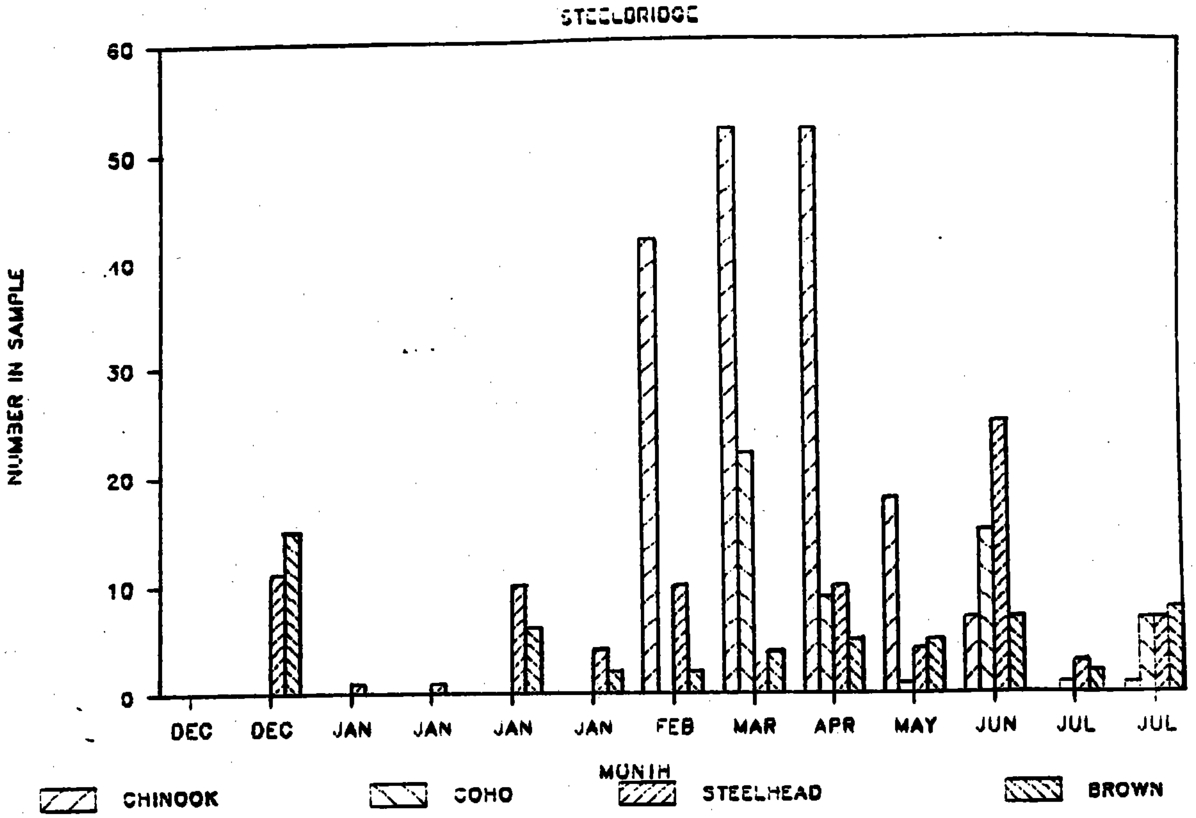



Figure 55. Results of electrofishing and seine collection for the Steelbridge Study Site, 1986.

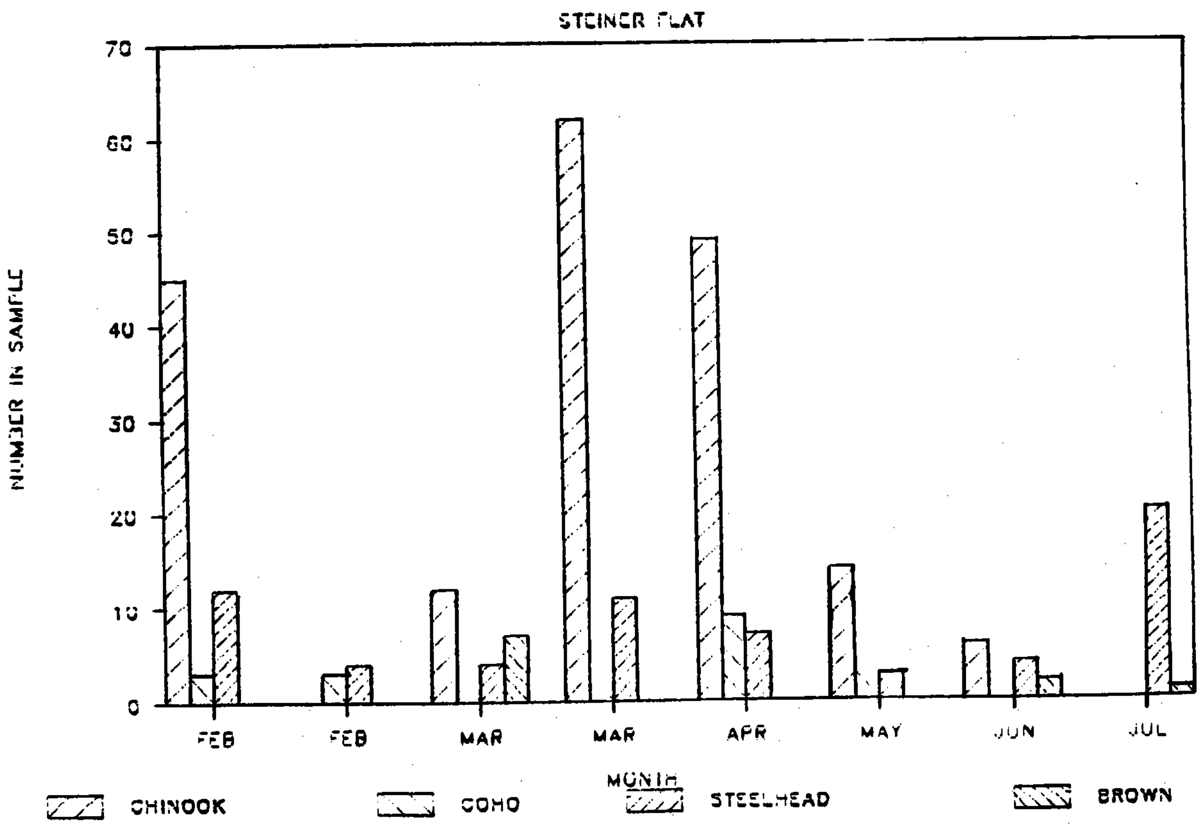



Figure 56. Results of electrofishing and seine collection for the Steiner Flat Study Site, 1986.

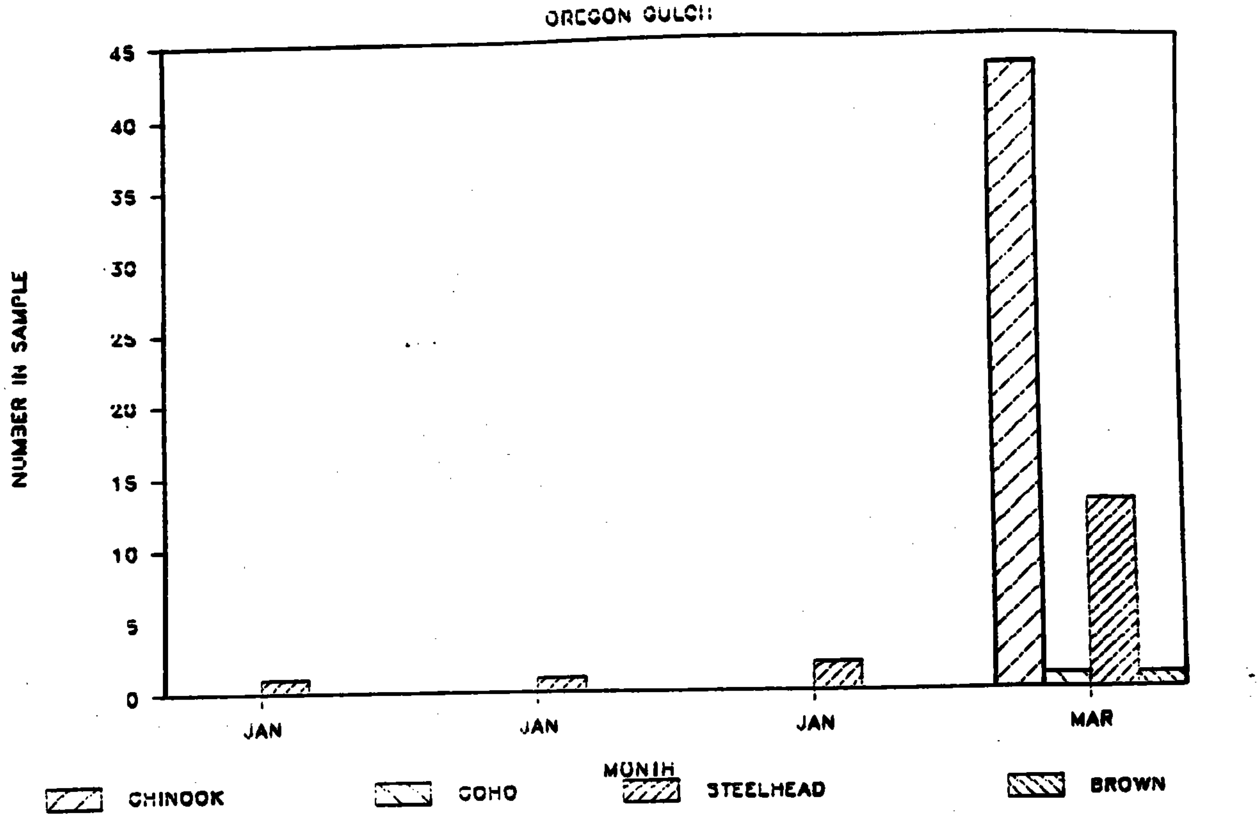



Figure 57. Results of electrofishing and seine collection for the Oregon Gulch Study Site, 1986.

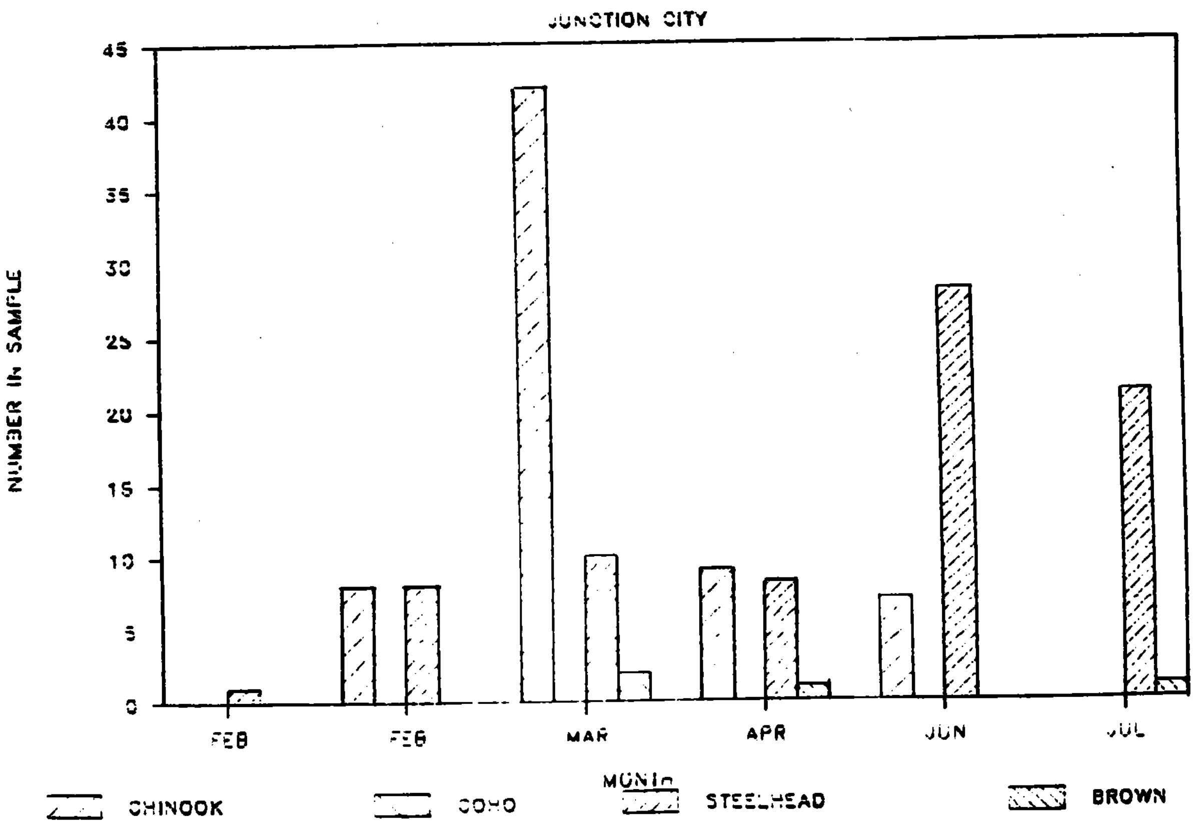



Figure 58. Results of electrofishing and seine collection for the Junction City Study Site, 1986.

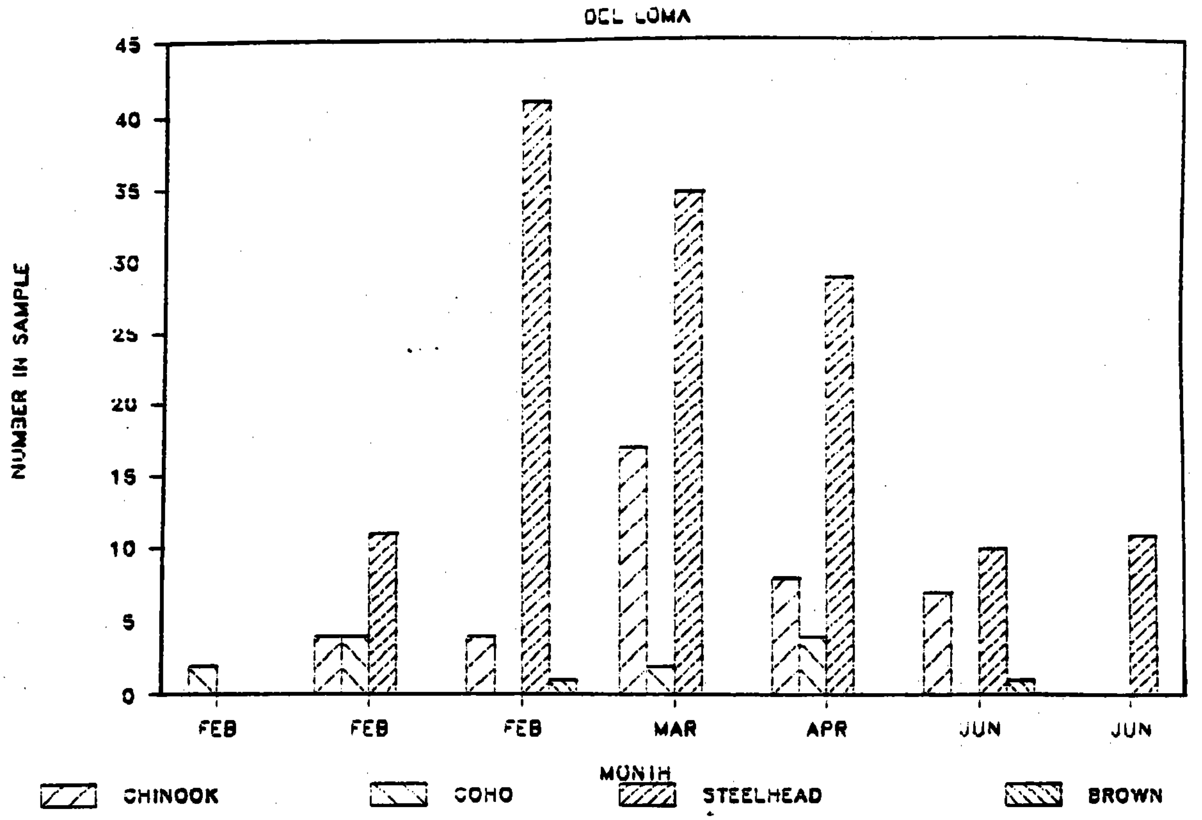



**Figure 59. Results of electrofishing and seine collection for the Del Loma Study Site, 1986.**

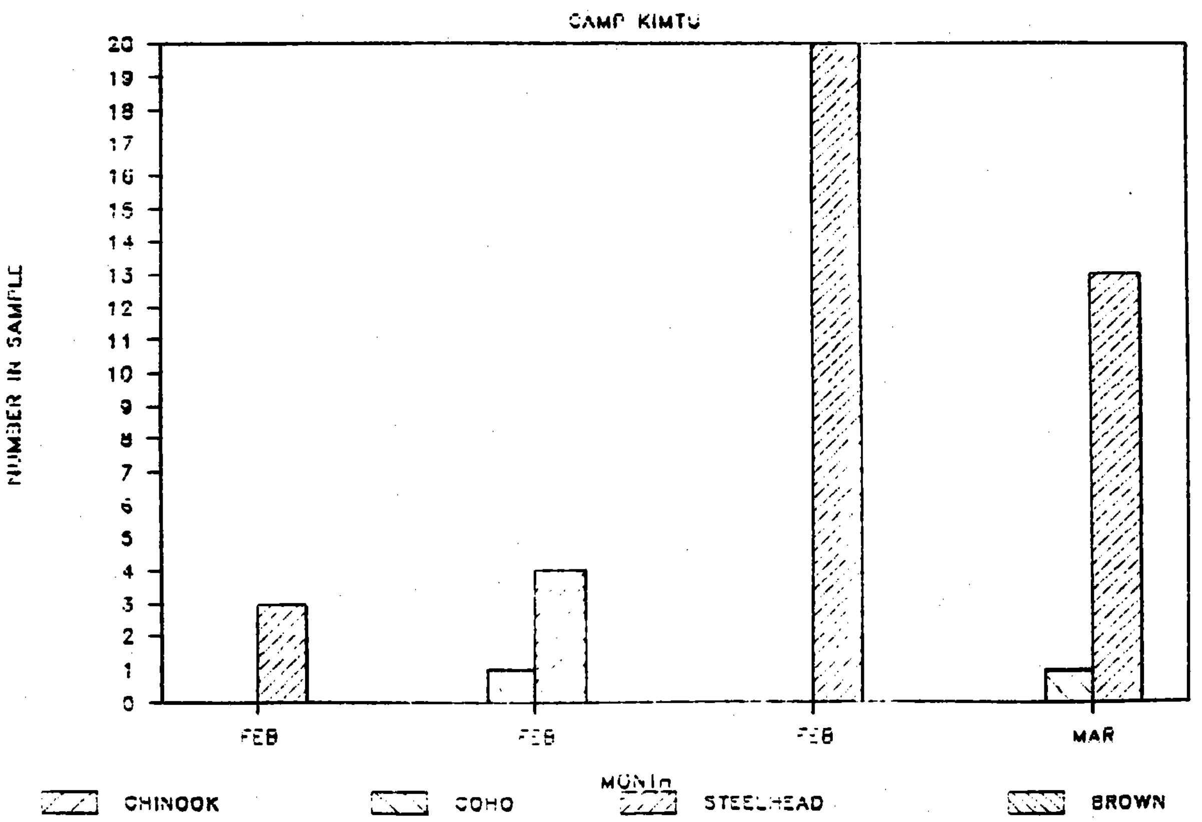



**Figure 60. Results of electrofishing and seine collection for the Camp Kimtu Study Site, 1986.**

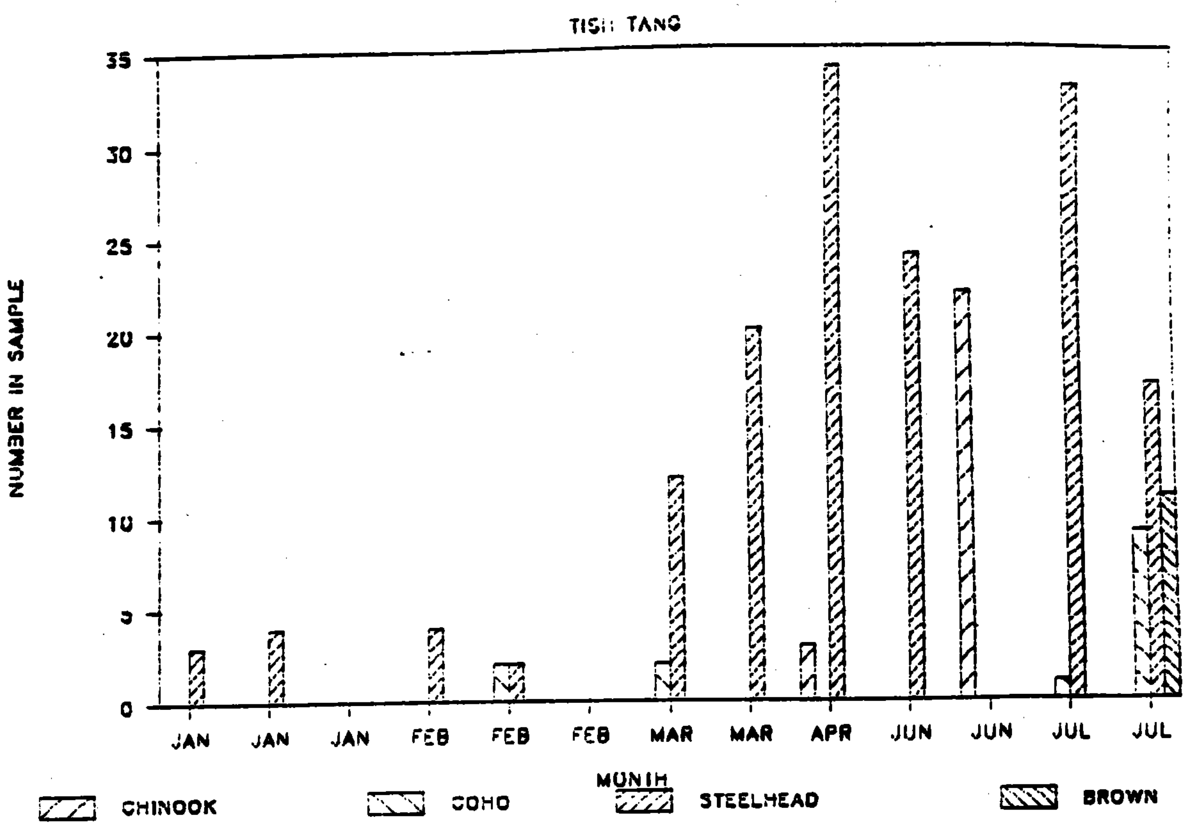



**Figure 61. Results of electrofishing and seine collection for the Tish-Tang Study Site, 1986.**

## Salmonid Egg and Juvenile Survival

One of the major probable causes of depressed trout and salmon populations in the Trinity River is decomposed granite sand. This material has been washed into the mainstem and tributary streams from increasingly logged and developed watersheds in amounts far exceeding the transport capacity of the flow left in the main river after diversion to the Central Valley through the Trinity River Division, Central Valley Project. Decomposed granitic sand collects in the voids between larger gravel and cobbles, reducing the amount of intra-gravel habitat available for young fishes, reducing the amount and diversity of habitat for fish-food organisms, and effectively cementing gravel substrates that adult fish must dislodge and move in order to spawn. Sand and silt in spawning gravels slows intra-gravel flow, reducing the amount of oxygen available to incubating eggs and yolk-sac fry, and slowing the transport of wastes. Once fry have developed to the swim-up stage and need to leave the gravel, course sand impedes their progress to the upper water column, and may prevent their emergence completely.

For the evaluation of fishery habitat rehabilitation in the Trinity River, the Trinity River Flow Evaluation Study includes an investigation of habitat needs at various life stages. It is hoped that this will provide an overall picture of the variety and relative amount of physical habitat conditions, either singly or in combination, that are necessary for a healthy fishery. We need to know what the limiting factors are on salmon and trout production, and in what quantities the various kinds of spawning, rearing, and food production habitat should be available to ensure optimum production. An important factor is the quality of egg and fry incubation habitat.

Direct observation in 1985, the first year of our flow evaluation, showed a surprising number of juvenile chinook salmon, and significant amounts of naturally-spawned coho salmon, steelhead trout, and brown trout fry in the upper river. Later in the year, fish were seen spawning in extremely degraded, sandy substrates, where little or no reproductive sucess would be expected based on reports of laboratory studies of salmon and trout incubation and emergence in fine material. To find out what contribution spawning in degraded riffles might make to the observed fry production, and to increase our understanding of what occurs in the gravel, we undertook a sampling program to collect incubating eggs, and determine, if possible, their survival rates.

### Methods

To collect fish eggs from redds, we used a water injector made from half-inch galvanized pipe and fittings, connected to a one-horsepower, 1350 GPH portable water pump. The injector, about six feet long with a T-handle at the top, could with considerable effort be worked into the gravel to the depth of egg deposition, usually from six to eighteen inches. If eggs were encountered, they would be dislodged by the stream of water pumped through the pipe, and boil to the surface where they could be collected with dip nets. Once an estimated 100 eggs had been dislodged and collected we would cease collection and examine them for mortality. Eggs were classified as either dead, live eyed, and live uneyed, dead eggs being obvious by their milky color. Although an uneyed, developing egg is indistinguishable from an unfertilized egg, they are included in our results because uneyed pink eggs collected would almost always be mixed with varying proportions of dead, decaying eggs, giving an indication of the number of possibly suffocated eggs present.

At each successfully sampled redd, depths and water velocities at the egg mound were recorded and the substrate was characterized following the modified Brusven index used for our Task 2 and 3 habitat measurements (see Table 2). This three digit system classifies substrate into dominent and subdominant types, followed by the percent embeddedness of the dominent materials in fines less than 4mm in size and are presented as DS.E. The two numbers before the decimal point represent the dominent and subdominent gravels present.

This system is a measure of surface conditions only, and is used because evaluation of the surface material is the only practical way to model spawning habitat conditions with existing available computer programs (e.g. PHABSIM).

We sampled many redds or mass-spawning areas where no eggs were collected, probably because of the difficulty of probing the exact location of each egg pocket rather than decay and dissociation of eggs. Judging from observation of hatchery eggs and our observations in the field, dead eggs persist in recognizable form at least until development of sac fry from the same brood, in the 40 to 50 F winter waters of the upper Trinity River.

We found redds in water shallow enough to sample at six locations. These were upper Lewiston above the old bridge, mid-Lewiston adjacent to the Sawmill wildlife area, lower Lewiston in the riffle above the Rush Creek fishing access, Sand Flat, and at Poker Bar and Steelbridge, below Grass Valley Creek.

Results

Eighteen chinook salmon redds provided useable results, another thirty to fifty, depending on an unknown degree of spawning superimposition, giving up no eggs. Results, tabulated as numbers of dead and live eyed or uneyed eggs, and percent survival to each stage, are shown in Table 7. Modified Brusven substrate classifications are also shown.

Intra-gravel survival to the eyed stage averaged 70 percent, with a range from zero to 100 percent, and no apparent overall relationship to longitudinal location in the river or surface substrate characterization. The zero and 100 percent survival rates were noted on the same day in redds approximately 20 feet from one another. An egg-pocket with 14 percent

Table 7. Chinook salmon egg survival observations, Trinity River, California, 1986.

| Location | Substrate | Dead Eggs | Live Uneyed | Percent Survival | Eyed Eggs | Percent Survival |
|---|---|---|---|---|---|---|
| Mid-Lewiston | 32.6 | 15 | 0 | 0 | 0 | 0 |
| Poker Bar | 32.4 | 8 | 21 | 72 | 0 | 0 |
| Poker Bar | 32.4 | 10 | 36 | 78 | 0 | 0 |
| Upper-Lewiston | 32.4 | 16 | 163 | 91 | 0 | 0 |
| Mid-Lewiston | 43.3 | 5 | 105 | 95 | 0 | 0 |
| Mid-Lewiston | 32.5 | 0 | 150 | 100 | 0 | 0 |
| Steel Bridge | 43.6 | 232 | 0 | 0 | 38 | 14 |
| Sand Flat | 43.0 | 34 | 0 | 0 | 7 | 17 |
| Upper-Lewiston | 32.0 | 11 | 0 | 0 | 6 | 35 |
| Lower-Lewiston | 32.1 | 44 | 0 | 0 | 58 | 56 |
| Sand Flat | 43.0 | 25 | 0 | 0 | 55 | 68 |
| Steel Bridge | 54.1 | 3 | 0 | 0 | 16 | 84 |
| Upper-Lewiston | 43.0 | 18 | 0 | 0 | 107 | 85 |
| Upper-Lewiston | 32.1 | 2 | 0 | 0 | 16 | 88 |
| Poker Bar | 43.2 | 5 | 0 | 0 | 64 | 92 |
| Lower-Lewiston | 32.2 | 2 | 0 | 0 | 23 | 92 |
| Poker Bar | 43.5 | 2 | 0 | 0 | 40 | 95 |
| Steel Bridge | 54.8 | 3 | 0 | 0 | 82 | 96 |
| Total | | 435 | 475 | | 512 | |

survival to the eyed stage was approximately 100 feet upstream from a redd which had a 96 percent survival rate of strongeyed, large eggs.

Most of the dead eggs collected were uneyed, suggesting that they had died within about five weeks of depostion. One sample, however, included 25 shells or membranes, 175 dead un-eyed eggs, 32 dead eyed eggs, and 38 live eyed eggs. In another sample, we turned up 18 dead eggs, and eight dead and seven live sac fry. This progressive mortality suggests that whatever factors contributed to the death of the eggs, the effects continued over time, and that overall mortality rates may be much greater in the end than the rates we found in spot samples.

While hatchery fall chinook salmon survival rates to the eyed stage run about 90 to 95 percent, it seems improbable that even the 70 percent rate we found is applicable to the majority of fertilized eggs in the Trinity. Our fairly high rates may be due in part to sampling exigencies. We generally collected most eggs at well-defined, recognizable salmon redds, and these redds were always the last to be dug in a given spawning riffle.

Salmon tended to spawn in a sequential upstream movement, the first to arrive on a riffle digging at the edge of the drop-off into deeper water below. Later arriving fish tended to start redds just upstream from those already present, casting sand and lighter gravel into them and obscuring their shape to the observer. As the spawning season progressed, easily recognizable redds were ususally either isolated or at the head of what had become mass-spawned areas of small fines and churned-up gravel. A few eggs might always be turned up here and there in these areas, but it was difficult to locate a substantial egg pocket, something which could usually be done at the top redds. So we successfully sampled mainly the latest or last, and therefore the cleanest redds. We could not obtain eggs from the older redds just downstream, which would often be covered with layers of pure decomposed granite sand, cast back by later spawning fish.

Egg development and survival to the swim-up stage must be followed by emergence from the gravel to complete recruitment of fry to the water column, and sand has been shown in several studies to depress emergence increasingly at greater concentrations (for a summary, see Reiser and Bjornn, Habitat Requirements of Anadromous Salmonids, USDA Gen. Tech. Rpt. PNW-96, 10/79, pps 21-22.) Our planned emergence studies in 1985-86 depended on visual observation, but winter storms and turbid water coinciding with the emergence period eliminated direct observation of emergants, and distributed fry throughout the upper river so that comparative population evaluations will not be made this year.

In summary, it is evident that apparently healthy development of salmon eggs can occur regardless of surface substrate composition and both above and below major Trinity River sediment sources. But the most successful egg development may be limited to a few late spawners in any area, and the extent to which fry are able to emerge from gravel is unknown.

Findings

Further information is needed on the effects of sand on fry emergence in the Trinity River, but this information is difficult to obtain. Past efforts to trap emerging fry have been unsuccessful, apparently because of migration of fry through the gravel, which cannot be controlled. Laboratory studies are useful in determining the effects of sand, but these do not necessarily mirror actual conditions in the river, nor can they be related to the surface conditions which are the basis of substrate characterizations used in modeling habitat. Probably the best way to find out relative rates of emergence in the river is to monitor fry populations associated with various spawning areas, in a year such as 1985, when there is significant spawning throughout the upper river. This is currently being done to an extent with electrofishing and seining studies, and will continue with visual observation as water conditions permit.

## Downstream Migration and Fish Production in an Isolated Side Channel

Planned field studies to gather information on the timing of downstream salmon migration and on the survival of hatched juveniles were washed out by high flood releases from Lewiston Dam during the late winter and early spring of 1986. We did, however, encounter some relevant information on these topics through an incidental evaluation of salmon reproduction in a small spawning channel formed by the construction of a hatchery rearing pond tail-race adjacent to our offices in Lewiston.

### Study Site and Methods

The tail-race is accessory to a series of rearing ponds built in 1984 to allow reconstruction of the main Trinity River Hatchery facilitites. These ponds have been used prior to reconstruction in an effort to increase production of yearling salmonids spawned at the hatchery. The tail-race drains through a lengthy settling basin below the rearing ponds, dropping from the basin's lip 2.05 feet in elevation to the remnants of a beaver pond 450 feet downstream. It follows the edge of an old river braid through placer mine tailings, cut into the old channel in a trapezoidal shape about the width of a bulldozer blade. Until salmon started spawning in it in the fall of 1985, its bottom was regular, with no defined thalweg or riffle and pool sequence, and its bed was of two to six inch rocks 50 to 70 percent embedded in sand.

Water enters the rearing ponds through a French drain, a permeable ridge of cobble and gravel designed to restrict fish passage, adjacent to a major river side-channel. Flow is controlled at the lower end of the ponds by a drop culvert that releases about 8.0 cfs at normal river flows. Once it enters the steeper section of the tail-race, which is sloped at about 0.5 percent, the water runs at an average depth of 0.6 feet at velocities from one to two feet per second. We measured cross-section elevations every 50 feet over the length of the channel on November 4,1985, when the bottom had developed minor irregularities caused by redd-building salmon (Table 8).

Shortly after the tail-race was built, beavers dammed its lower end, creating a pond about 75 feet long, thirty feet wide, and deep enough to require waders instead of hip boots to cross it.

In the summer of 1985, biologists and anglers crossing to the river over the dam caused a small breach in it, which by mid-September had widened to create a small waterfall with a clear chute below it leading to the main river.

So in late September, 1985, the tail-race was a fairly homogeneous long and narrow riffle, watered through a screening ridge of gravel, with an attraction flow running free to the main-stem Trinity, a resting pool at its lower end, a larger pool at its upper end and water running at a depth and velocity suitable for salmon spawning over gravel suitably

Table 8. Area section profile of the side channel used for spawning adjacent to the Cemetery Study Site, 1986.

| Station | Left Elev. | Depth | Center Elev. | Depth | Right Elev. | Depth | Water Elev. | Wetted Width |
|---|---|---|---|---|---|---|---|---|
| 0+00 | 98.86 | 1.00 | 98.54 | 1.32 | 98.66 | 1.20 | 99.86 | |
| | | start of spawning riffle | | | | | | |
| 0+50 | 99.21 | 0.63 | 99.13 | 0.74 | 99.04 | 0.80 | 99.84 | 16.00 |
| 1+00 | 99.17 | 0.63 | 98.99 | 0.81 | 99.10 | 0.70 | 99.80 | 14.00 |
| 1+50 | 99.11 | 0.47 | 99.00 | 0.58 | 99.11 | 0.47 | 99.58 | 12.00 |
| 2+00 | 98.87 | 0.36 | 98.73 | 0.50 | 98.53 | 0.70 | 99.23 | 13.00 |
| 2+50 | 98.43 | 0.48 | 98.46 | 0.45 | 98.50 | 0.41 | 98.91 | 13.00 |
| 3+00 | 98.22 | 0.54 | 98.02 | 0.74 | 98.15 | 0.61 | 98.76 | 11.00 |
| 3+50 | 97.84 | 0.85 | 97.75 | 0.94 | 97.95 | 0.74 | 98.69 | 12.00 |
| 4+00 | 97.99 | 0.25 | 97.71 | 0.53 | 97.81 | 0.43 | 98.24 | 10.00 |
| 4+50 | 97.25 | 0.49 | 97.25 | 0.49 | 97.80 | 0.44 | 97.74 | 10.00 |
| 5+00 | 97.01 | 0.59 | 97.10 | 0.50 | 97.11 | 0.49 | 97.60 | 14.00 |
| Averages | | 0.53 | | 0.63 | | 0.58 | | 12.50 |

Average side slopes: 1 1/2 : 1

sized for spawning, but embedded in sand. It had been built to no design specification other than that of minimizing construction costs while channeling water through the typical bottomlands of the Trinity.

On September 25, 1985, we noticed five chinook salmon redds evenly distributed over the 450 feet of the tail-race riffle, and one adult salmon holding at edge near its center. We again observed the tail-race on October 2,3,8, and 9, and saw a general widening and reworking of the original five redds, the development of two new redd areas, and numerous spawning, holding, dying, and dead salmon. On November 1 we saw fourteen new redds, and counted 33 salmon. Overall, by the end of the spawning season we estimated that 30 pairs of salmon, including 25 chinook pairs and five coho, had spawned in the tail-race.

Since the tail-race is conveniently located adjacent to our office, and provided a ready-made microcosm of upper-river conditions, we set a fish-trap at its lower end to determine what the production might be from thirty salmon redds, and to monitor the time of migration out of spawning areas. The trap was a standard steel inclined-plane riffle trap borrowed from the California Department of Fish & Game Anadromous Fisheries Branch, with a ramp three feet wide at its upper end funneling into a turbulance baffle buillt into a 2' 10" x 1'6" steel box. We judged that the trap, set in a shallow, fast channel twelve feet wide, would catch a third of the fish that came down the tail-race.

We fished the trap from November 25, 1986 until June 6, 1986, checking it on most week-days. The trap was under water and ineffective from February 24 until March 25, which unfortunately coincided with the height of chinook emergence and initial downstream movement, and with the early coho emergence and migration.

Results

Numbers of trapped fish and fish eggs, in five-day periods, are shown in Figures 62 - 68. The first species to appear were ammocetes, larval lamprey, which were continuously present throughout the period of observation. In early to mid-December a total of 268 chinook eggs, most of them eyed, appeared in the trap, followed by a few smaller uneyed eggs we identified as those of the few coho slamon which continued to spawn over the chinook redds.

A few chinook sac-fry appeared in late January, followed between February 5 and 24 by a total of 617 chinook button-up fry and a peak movement of ammocetes larvae. By the time the trap washed out in late February, two coho fry had been caught, indicating the start of coho emergence from the gravel.

By March 25 it was possible to again fish the trap, and salmonid species caught were fairly evenly divided between chinook and coho until mid-May, when salmonid movement ceased, and numerous three-spined sticklebacks in spawning colors appeared.

Twenty-four chinook trapped on February 2 averaged 39mm in fork length. On March 27, four chinook averaged 41mm, and on April 11 the 12 chinook caught averaged 44mm. These relationships are shown in Figure 69, the increasing modal size over time indicating that the later fish caught had spent time after emergence rearing in the tail-race, or in the settling basin, before moving downstream.

The last salmon was caught on May 20. By this time snorkeling observations and electrofishing data in the main river were showing decreasing numbers of chinook, and relatively stable coho populations, with the chinook moving toward deeper and faster water, and the coho holding in slow water near the river margins. Evidently the shallow tail-race did not provide suitable habitat for the larger juveniles, and the residual fish moved out by late May. Numerous coho collected in the beaver pool below the tail-race, and reared there until beavers working above the rearing ponds cut off much of the channels flow for a few days in late summer.

We frequently opened the fish trap in the morning and afternoon the same day, to find out if fish migration follows any daily pattern. According to these observations, virtually all downstream movement was by night.

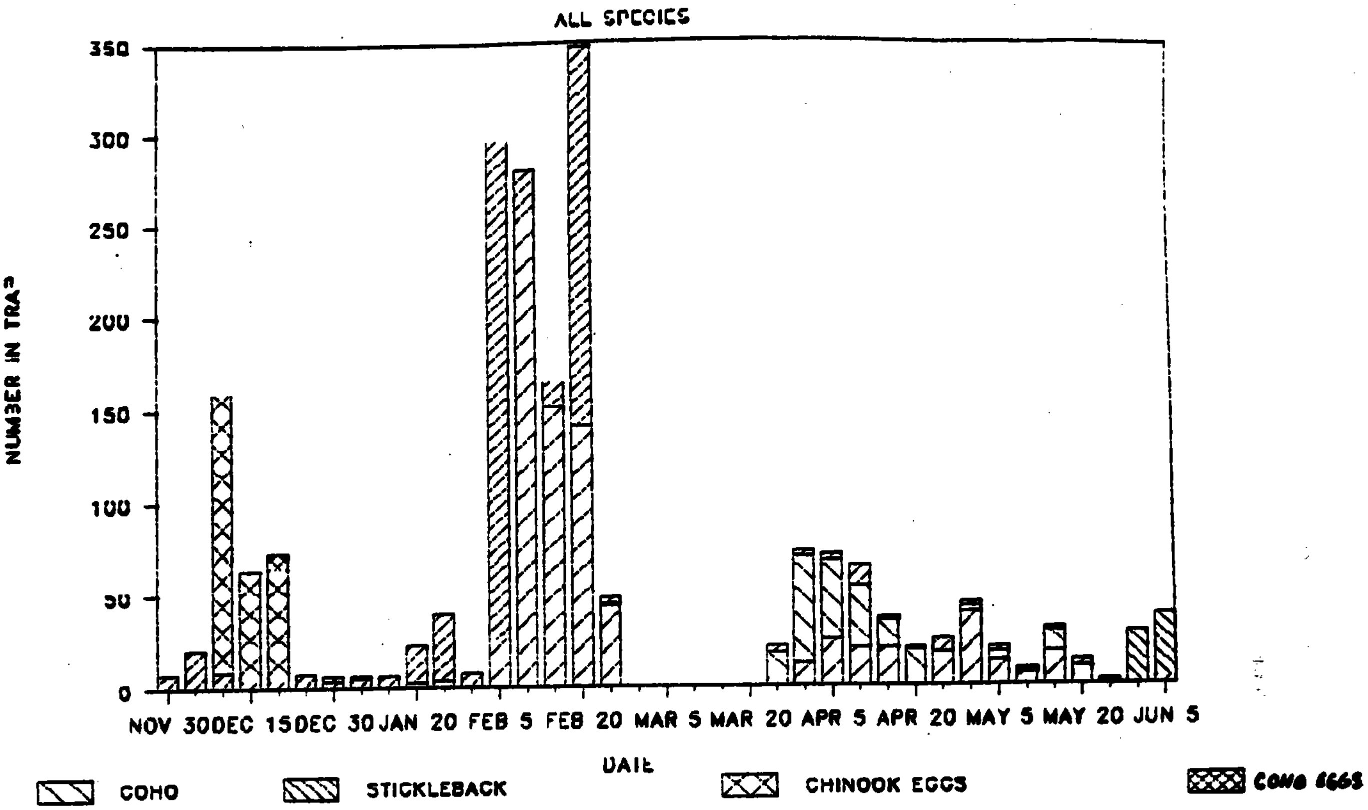



**Figure 62. Number of fish and eggs trapped in an isolated side channel of the Trinity River, November 1985 to June 1986.**

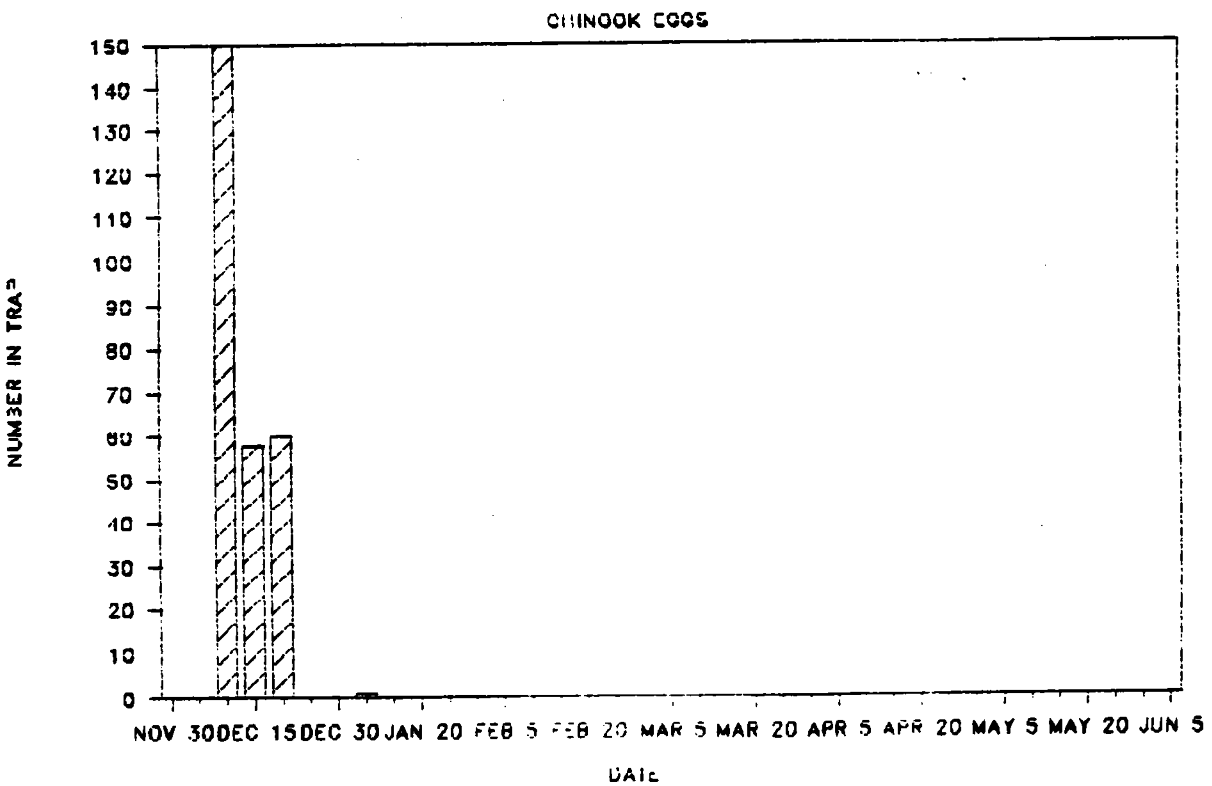



**Figure 63. Number of chinook salmon eggs trapped in an isolated side channel of the Trinity River, November 1985 to June 1986.**

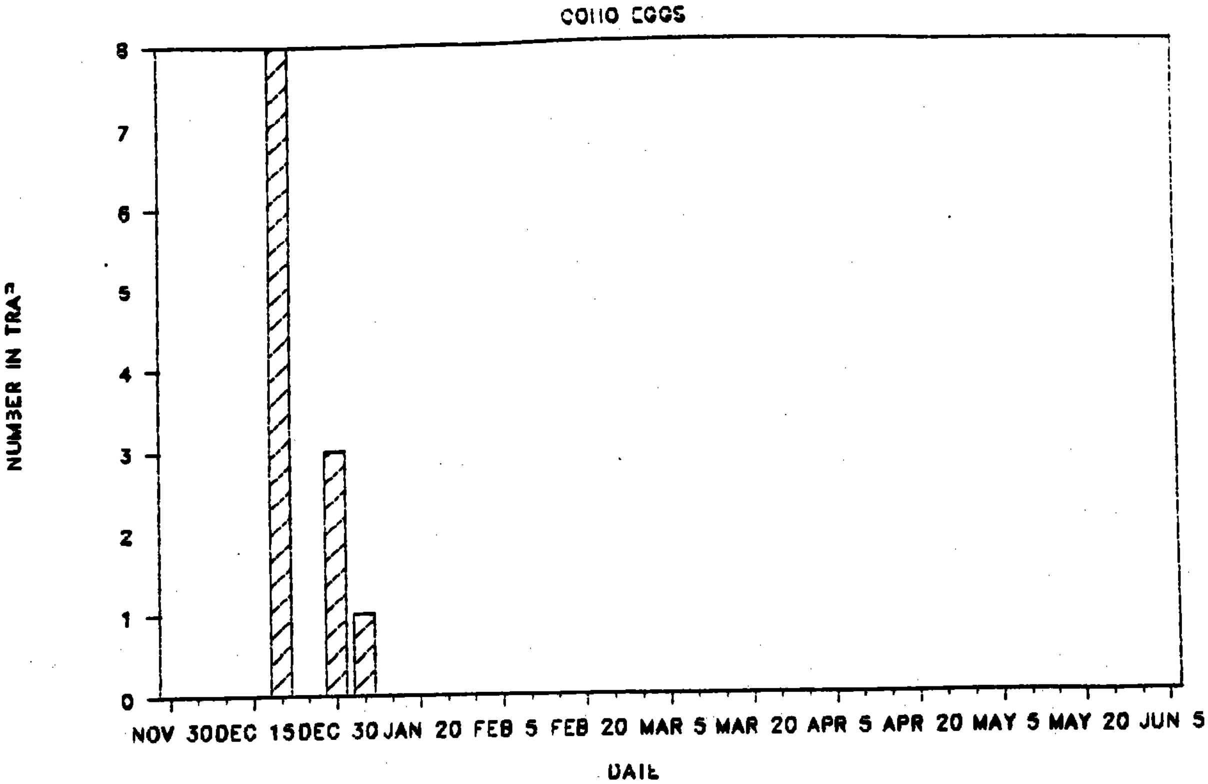



**Figure 64. Number of coho salmon eggs trapped in an isolated side channel of the Trinity River, November 1985 to June 1986.**

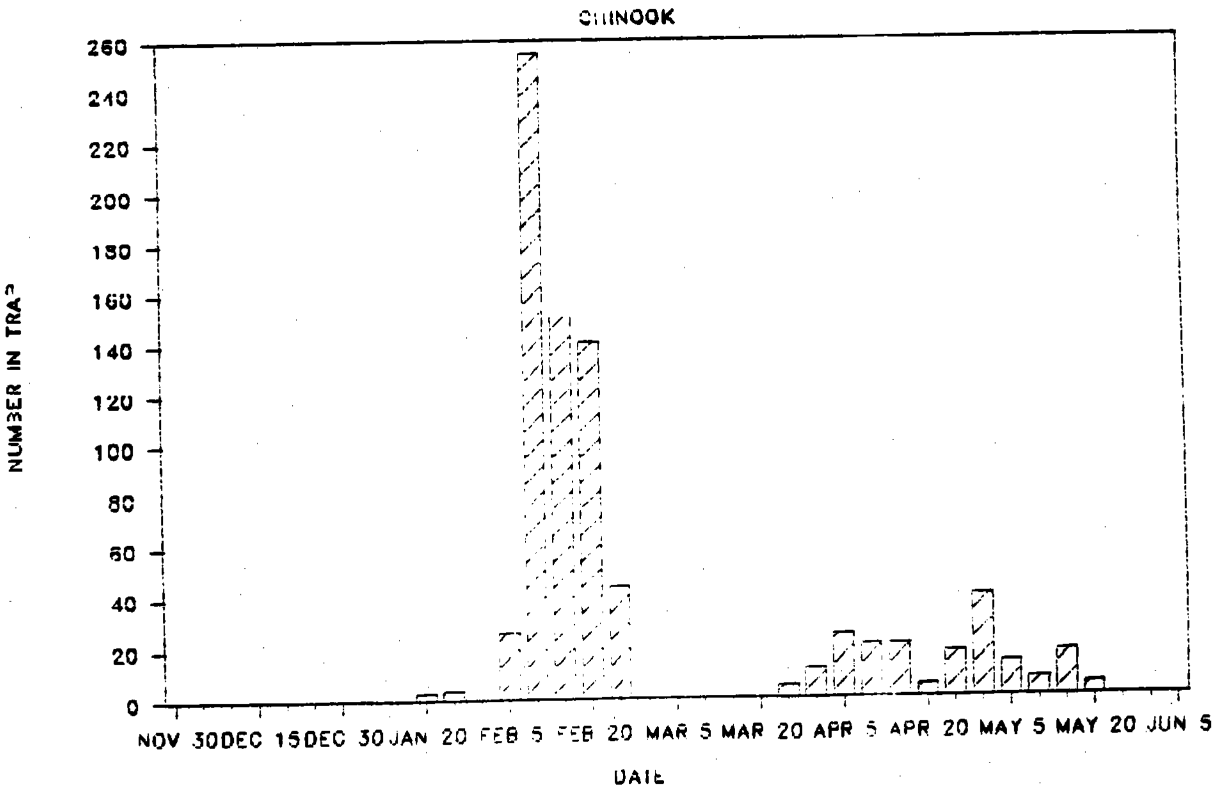



**Figure 65. Number of chinook salmon fry trapped in an isolated side channel of the Trinity River, November 1985 to June 1986.**

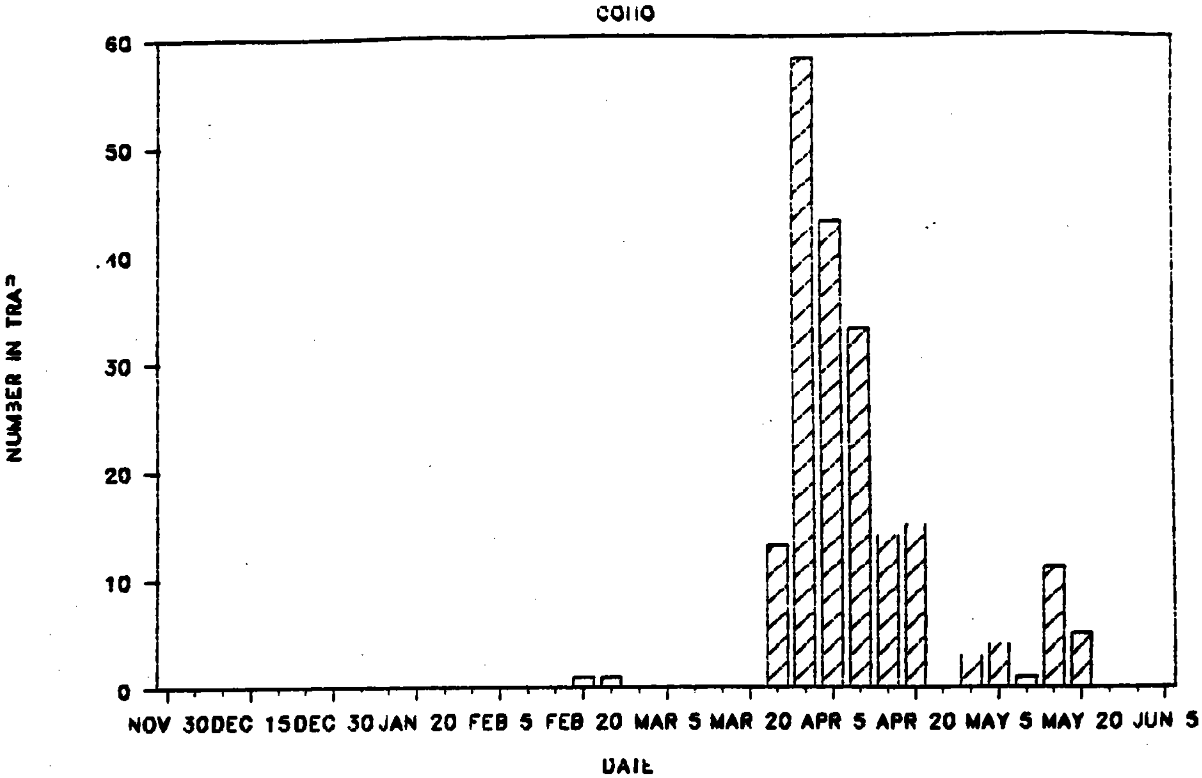



**Figure 66. Number of coho salmon fry trapped in an isolated side channel of the Trinity River, November 1985 to June 1986.**

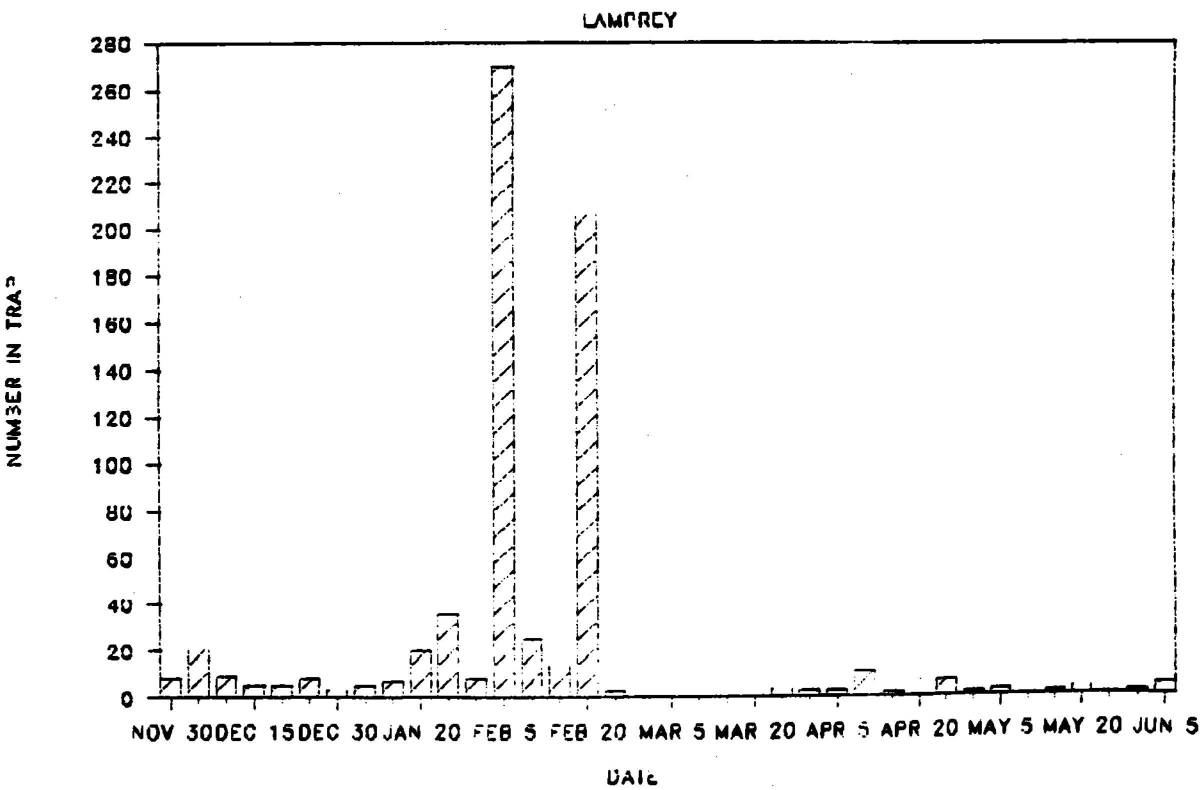



**Figure 67. Number of lamprey ammocetes trapped in an isolated side channel of the Trinity River, November 1985 to June 1986.**

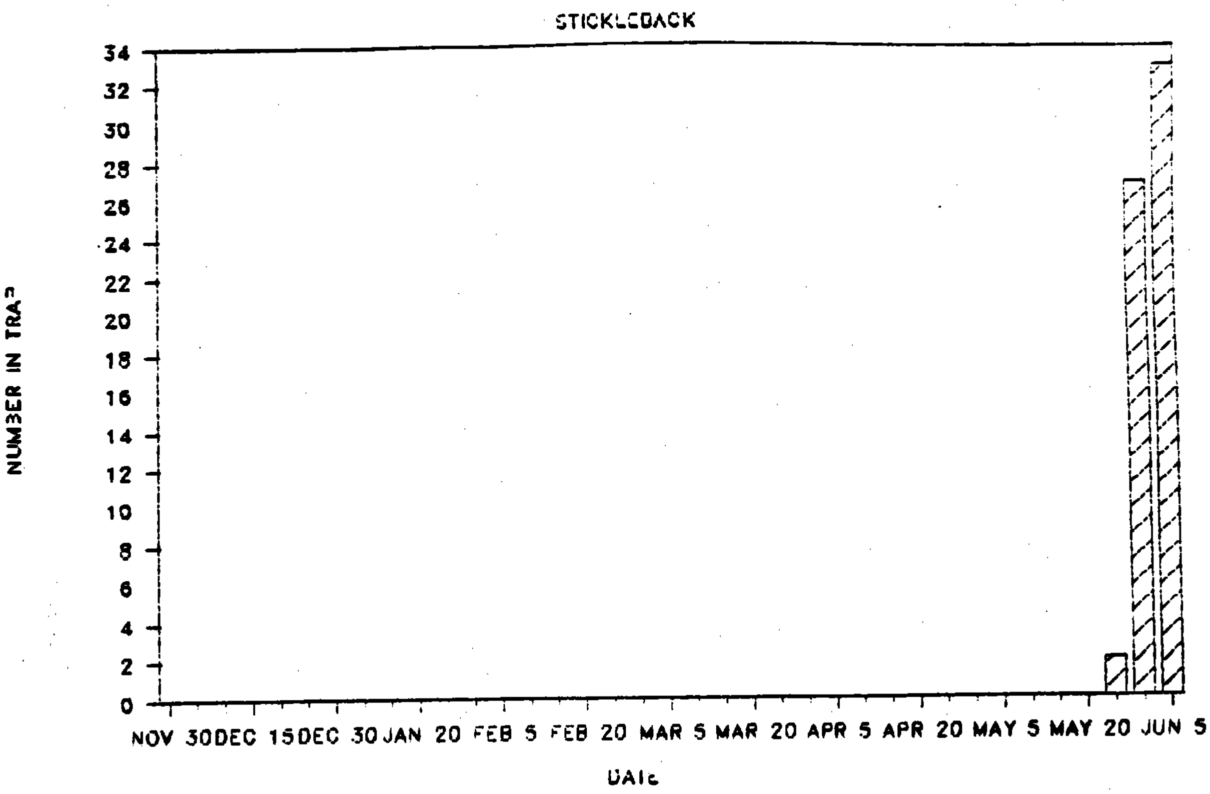



Figure 68. Number of stickleback trapped in an isolated side channel of the Trinity River, November 1985 to June 1986.

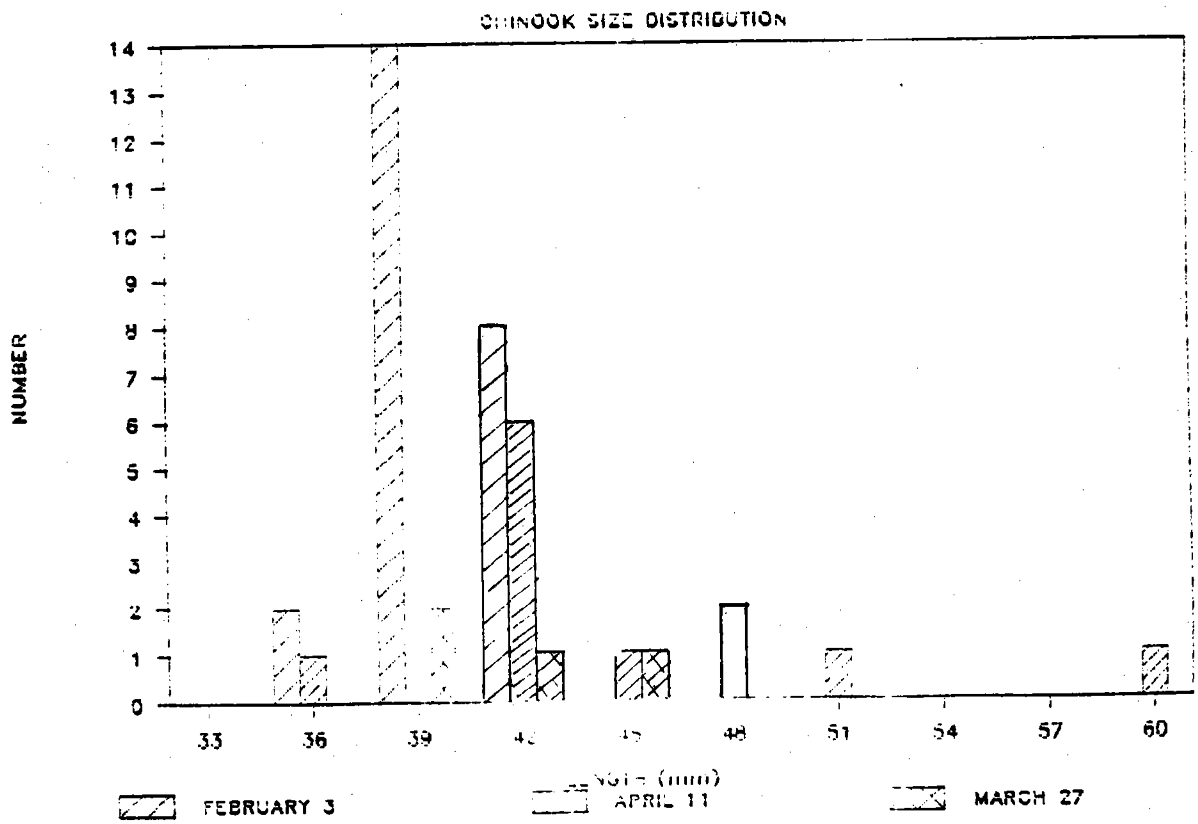



Figure 69. Chinook salmon juvenile size distribution from an isolated side channel for three sample periods, February, April, and March 1986.

## Discussion

A major implication of our observations is that an artificial side channel covering about 5600 square feet, bladed by available equipment to a cost-effective standard, and employing only eight cfs, or 2.67 percent of allotted salmon-spawning discharge, provided spawning habitat for 30 pairs of salmon, a density matched only by two or three mass-spawning areas elsewhere in the river. It is possible that the rearing ponds, though unused during the spawning period, served as an olefactory attraction to spawning salmon. This seems doubtful, however, since qualitative observations showed similar densities at other suitable sites. A major portion of the effort to rehabilitate the Trinity may come as the development of artifical side-channels, and the configuration of the tail-race should be considered in their design.

The appearance of eyed chinook eggs in our early samples underlines the losses incurred by superimposed spawning in the upper Trinity. In 1985 salmon spawning above Douglas City in the mid and late season generally built redds where others had been built previously, moving upstream to an extent but also superimposing on gravel worked earlier. This was most pronounced in the reaches above Bucktail Pool, in the upper 6.5 miles below Lewsiton Dam. Lower areas, such as our study site at Steiner Flat Campground, have potential spawning beds evidently as good as those in the upper reaches, but very few fish spawned on them in 1985. If a means could be found to induce the surplus upper-river spawners to nest in these underutilized sites, as has been suggested in various studies (Moffatt, 1950, VTN, 1979), then overall salmon production could be increased.

Unfortunately, the February flooding made it impossible to accurately gauge the numbers of fry surviving through emeregence to move downstream. However, without the peak movement measured, and assuming that our trap caught 1/3 of the tail-race migrants, at least 2500 chinook and 600 coho juveniles were produced in an area which without habitat manipulation would have produced none. Obtaining an estimate of fry survival from a known spawning area was a major goal of our trapping effort, and we intend to repeat in the tail-race, and elsewhere in river side-channels if possible.

As reported by Moffett and Smith, 1950, ammocetes larvae seem to move downstream throughout the year. It is interesting to note in addition that a peak movement of ammocetes coincided with peaks in emigration of chinook fry. Sticklebacks were caught evidently moving out of the rearing ponds or settling basin in good numbers in late June. These fish, which have only recently appeared in the Trinity River above Gray Falls (Ed Miller, pers. comm. ) were also noted in large numbers schooled with chinook in the main river in late May and June.

## Juvenile Salmonid Growth

Sampling for juvenile salmonid growth began in January of 1986, and is planned to continue throughout the term of the Trinity River Flow Evaluation Study.

### Study Sites

Eight study sites have been selected on the Trinity River from Lewiston downstream to Tish-Tang for monitoring juvenile growth. Two sites, Cemetery and Bucktail, are located on the upper river above Grass Valley Creek. Three sites, Steelbridge, Steiner Flat, and Junction City, represent the middle section of the river from Grass Valley Creek to the North Fork Trinity River confluence. The lower river, below the North Fork Trinity River confluence, is represented by three more sites at Del Loma, Camp Kimtu, and Tish-Tang. See Figure 2 for site locations.

### Methods

Sampling at each site is done in riffle and run habitat types. At each study site fish are collected with a Smith - Root DC backpack electroshocker. Sampling is conducted in an upstream direction. One person operates the electroshocker, while a second person follows behind to capture shocked fish with a dip net. Once captured, the fish are anesthesized with MS-222 (Methyltricaine Sulfate), measured for fork length (mm) and weighed to the nearest gram on a dietetic 500 gm scale. No data is 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 is used to shelter the balance from adverse weather conditions. However, this proved to be ineffective in many cases, and the triple beam balance is used only on a limited basis under ideal conditions.

Approximately five fish per month of each species and age class are sacrificed for stomach analysis at Cemetery, Bucktail, Steelbridge, Steiner Flat , Del Loma , and Tish Tang study sites. All other fish are returned to the river unharmed. Scale samples are taken from selected individual fish that are sacrificed for stomach analysis. Scale samples are also occasionally taken from other fish sampled before they were returned to the river. However, this practice is avoided if possible, in order to prevent unnecessary stress or injury to those fish which are be released. Scales are always taken from the area on the right side between the lateral line and posterior end of the dorsal fin (Figure 70).

Scales are removed by gently scraping a scalpel toward the anterior of the fish. The scales are then placed on wax paper and inserted into coin envelopes for later analysis. The species, forklength, weight, date, time and location of capture are noted on each coin envelope.

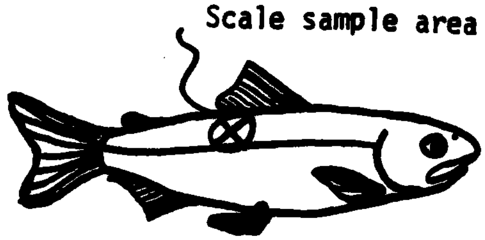



Figure 70. Area where scale samples are taken during growth sampling of juvenile salmonids on the Trinity River, CA. 1986.

Results

After seven months of data collection, from January to July of 1986, a total of 2,265 juvenile salmonids have been collected for data analysis; of these, 896 are chinook salmon, 303 are coho salmon, 798 are rainbow trout, and 268 are brown trout.

Chinook salmon are found throughout the entire river. The number of fish caught at each site generally decreased as sampling progressed downriver, correlating with spawning locations along the river. Although no spawning was observed in the lower river during 1985, some chinook salmon fry have been captured at Tish-Tang. These fry were probably spawned in tributary streams along the lower river.

Juvenile coho salmon were sampled at each site along the river, however, only larger fish (greater than 50mm forklength) were found below Del Loma. The majority of coho salmon were captured above Steiner Flat.

Rainbow trout juveniles were sampled at all study sites. While brown trout juveniles were collected primarily above the confluence of the North Fork Trinity River with the main-stem Trinity.

Bar histograms illustrating mean fork length for each month of sampling are presented in Figures 71 through 74 for chinook and coho salmon and rainbow and brown trout, respectively.

Forklength and weight relationships also have been plotted for all species and are illustrated in Figures 75 through 80.

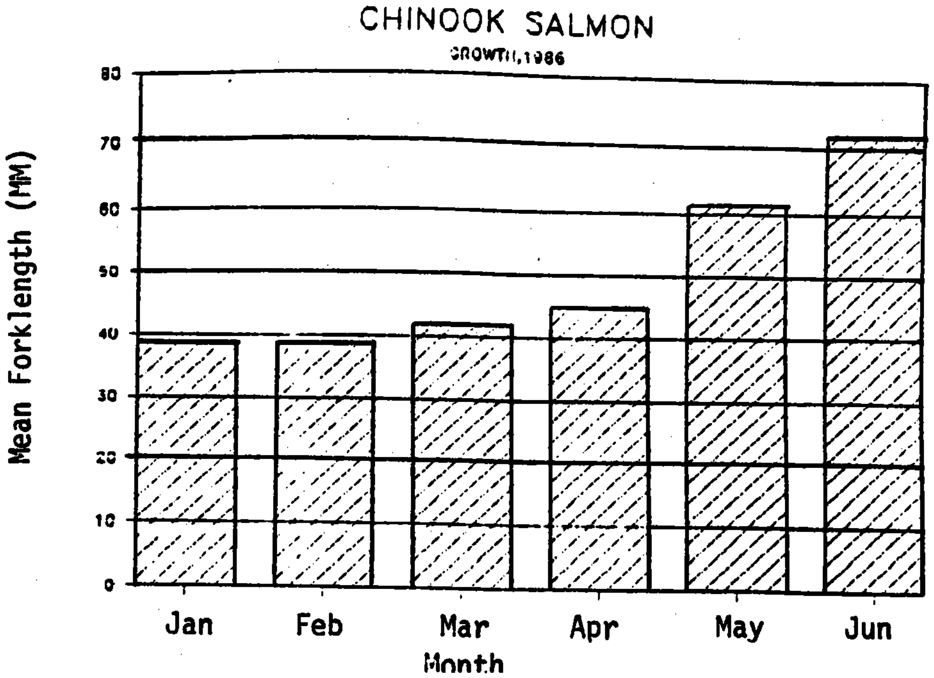



**Figure 71. Mean fork lengths (in mm) of chinook salmon collected from the Trinity River, January through June, 1986.**

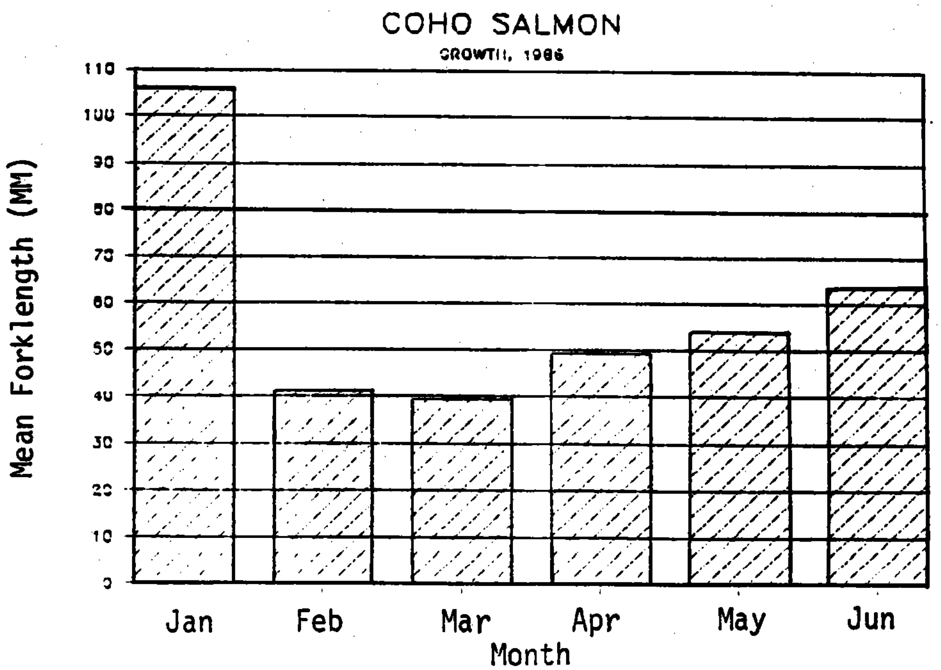



**Figure 72. Mean fork lengths (in mm) of coho salmon collected from the Trinity River, January through June, 1986.**

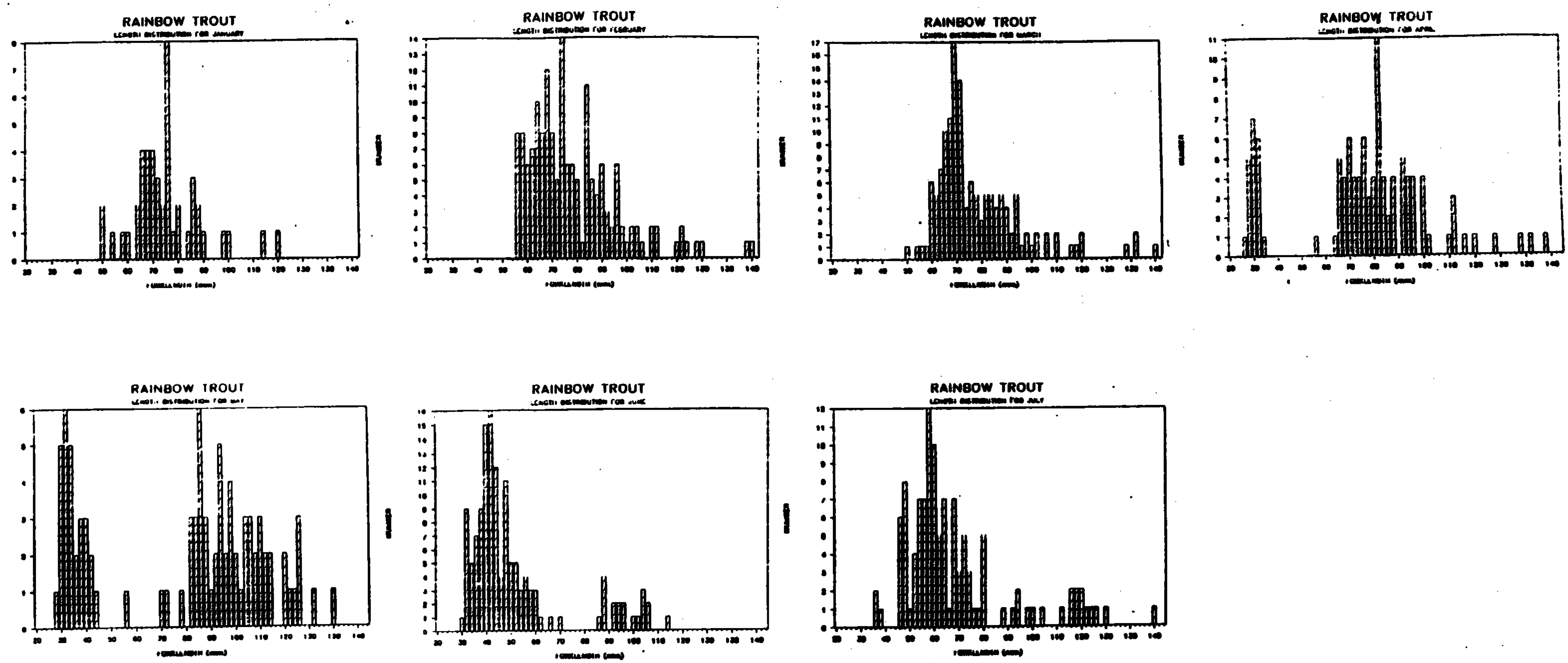



Figure 73. Mean fork lengths (in mm) of Rainbow trout collected from the Trinity River, January through June, 1986.

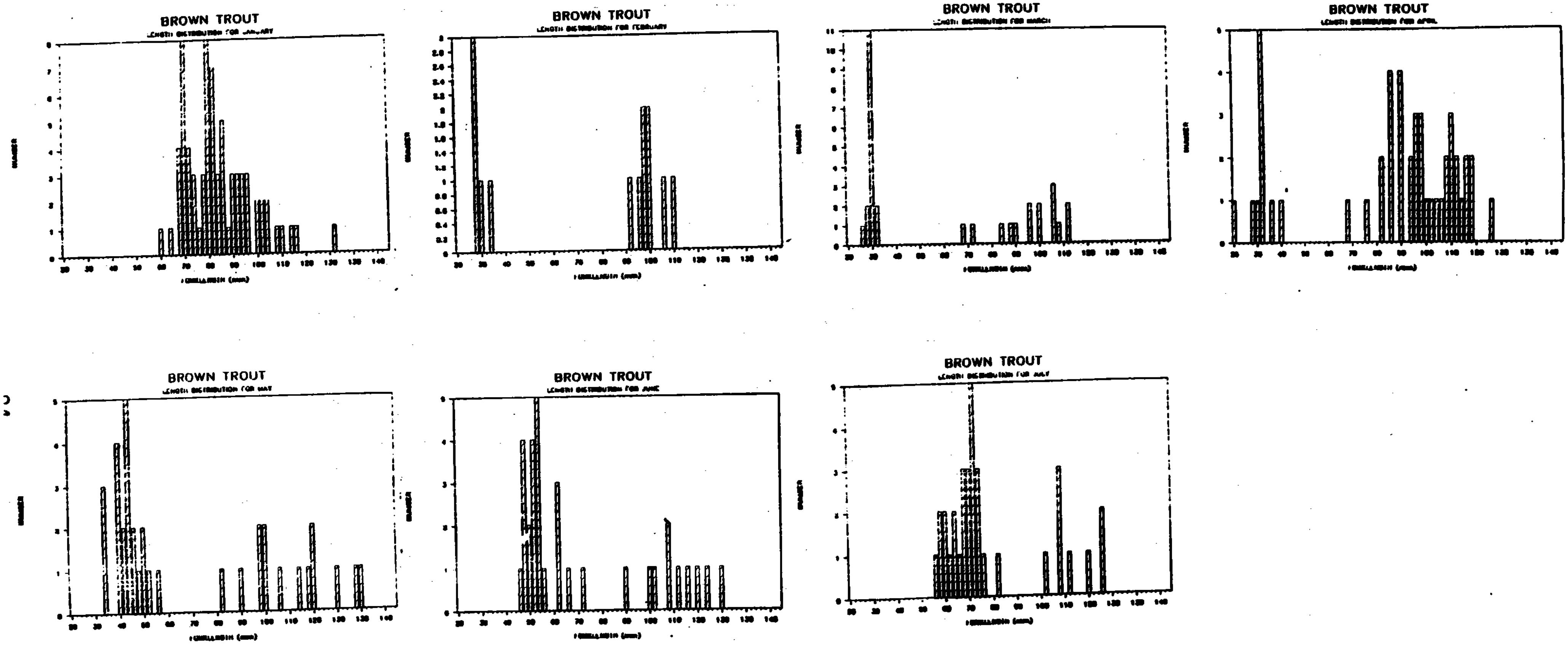



Figure 74. Mean fork lengths (in mm) of Brown trout collected from the Trinity River, January through June, 1986.

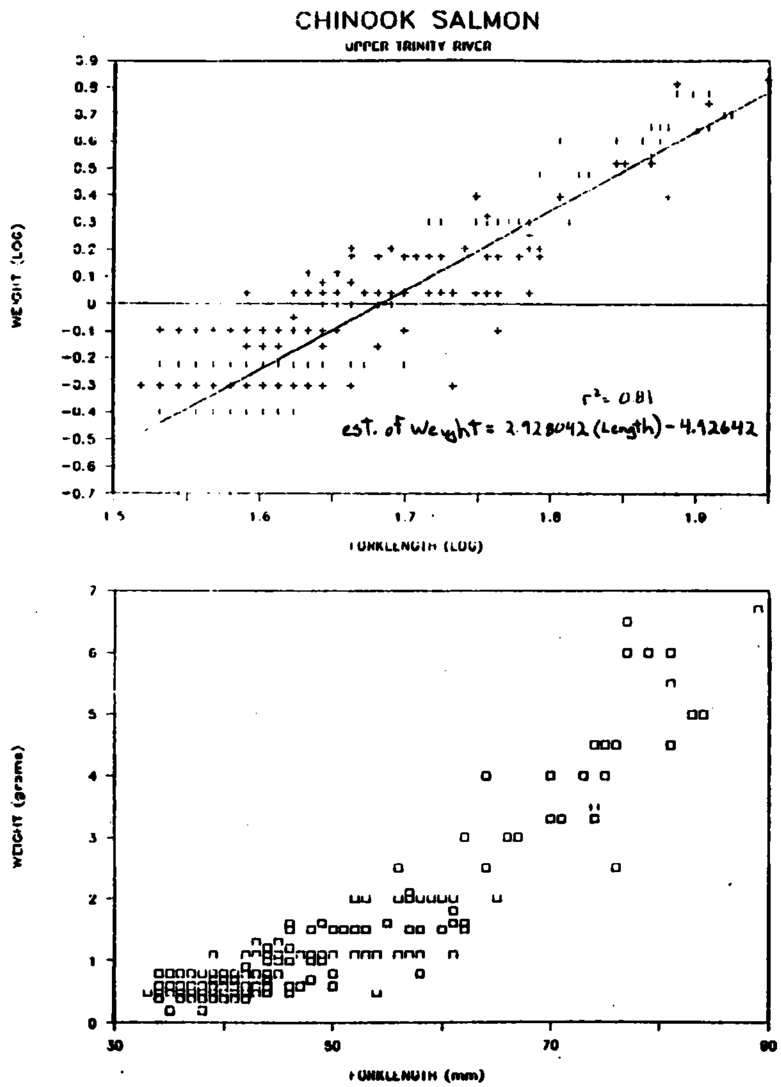



Figure 75. Forklength vs weight distribution and log forklength vs log weight regression analysis for juvenile chinook salmon in the upper Trinity River, 1986.

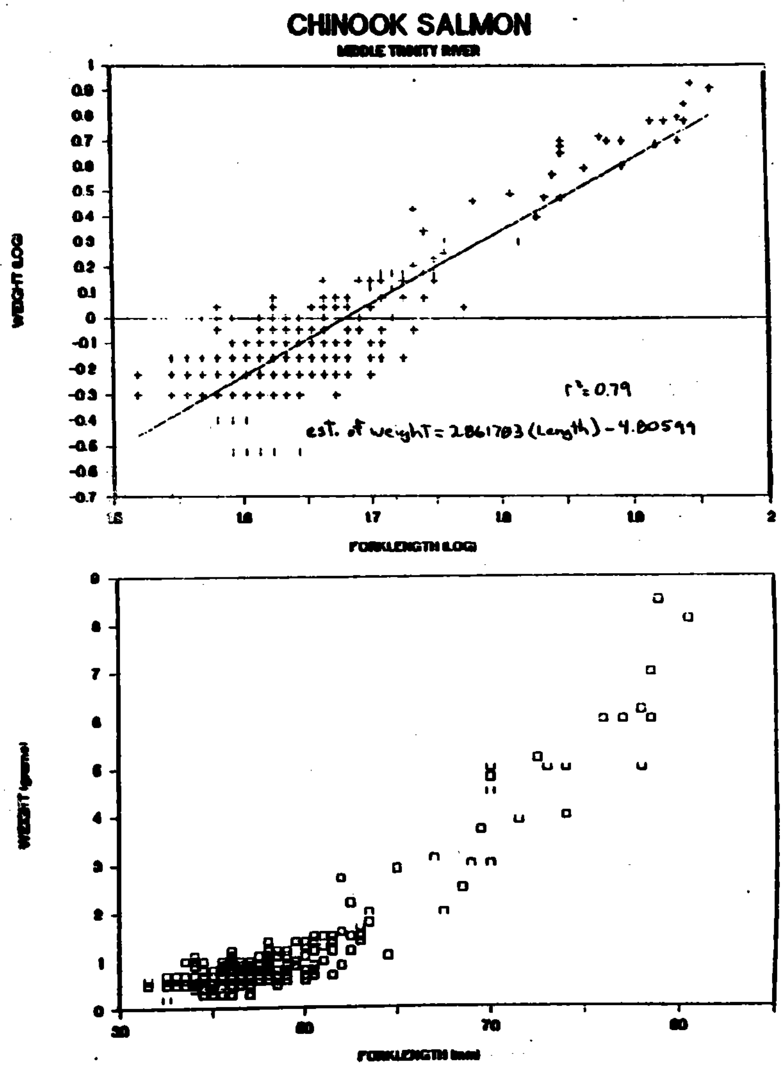



Figure 76. Forklength vs weight distribution and log forklength vs log weight regression analysis for juvenile chinook salmon in the middle Trinity River, 1986.

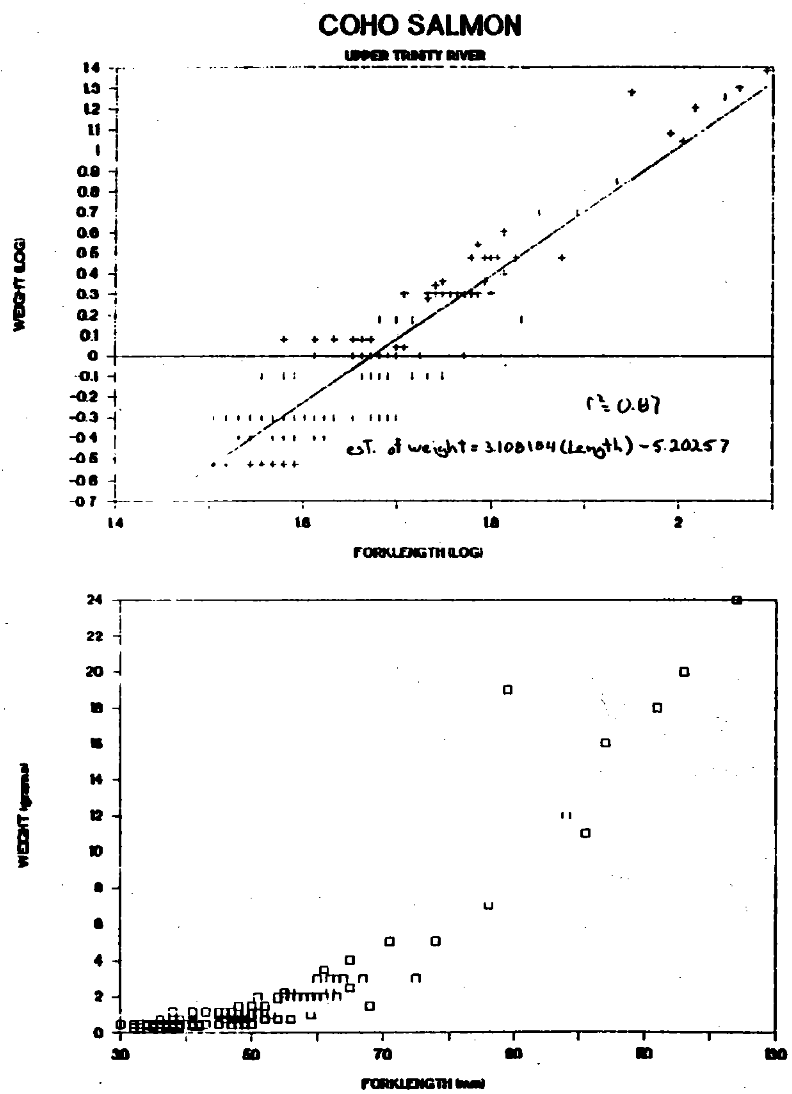



Figure 77. Forklength vs weight distribution and log forklength vs log weight regression analysis for juvenile coho salmon in the upper Trinity River, 1986.

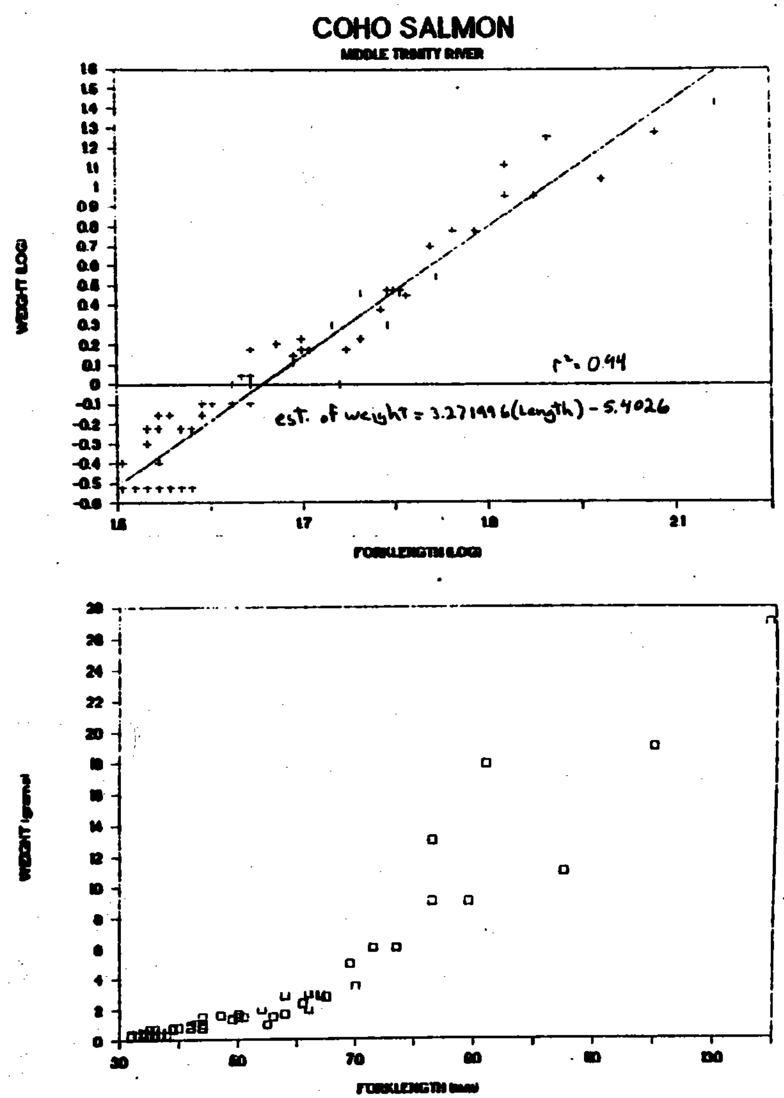



Figure 78. Forklength vs weight distribution and log forklength vs log weight regression analysis for juvenile coho salmon in the middle Trinity River, 1986.

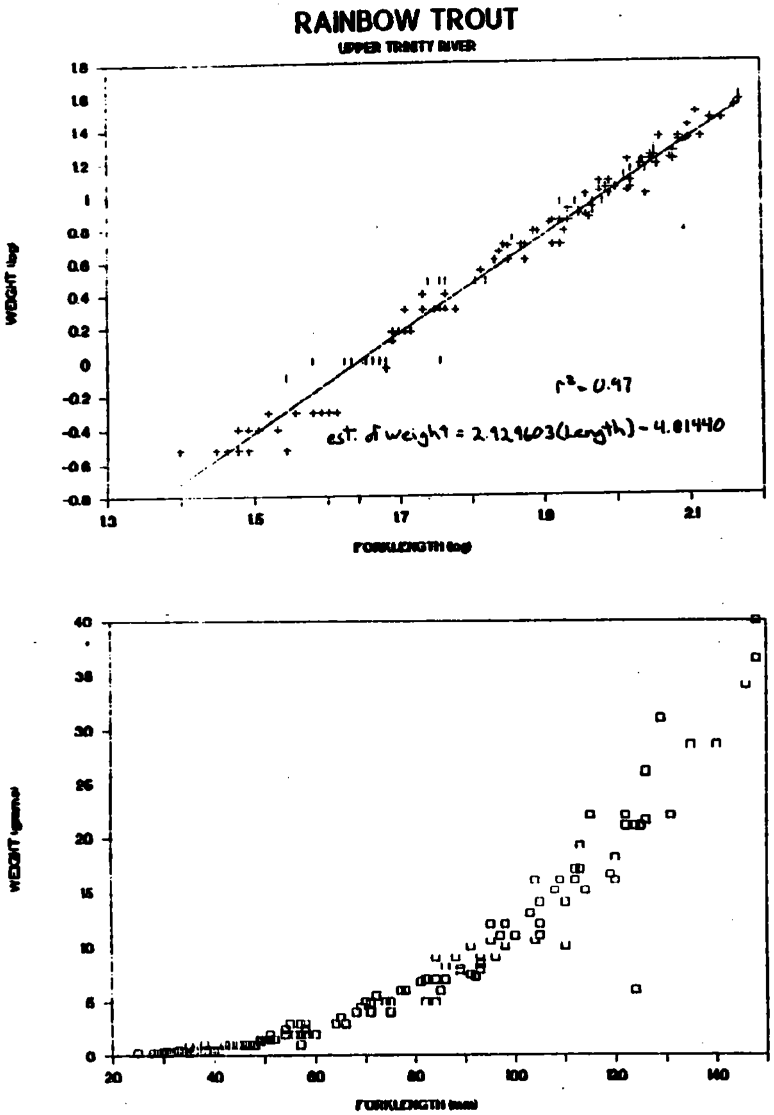



Figure 79. Forklength vs weight distribution and log forklength vs log weight regression analysis for juvenile rainbow trout in the upper Trinity River, 1986.

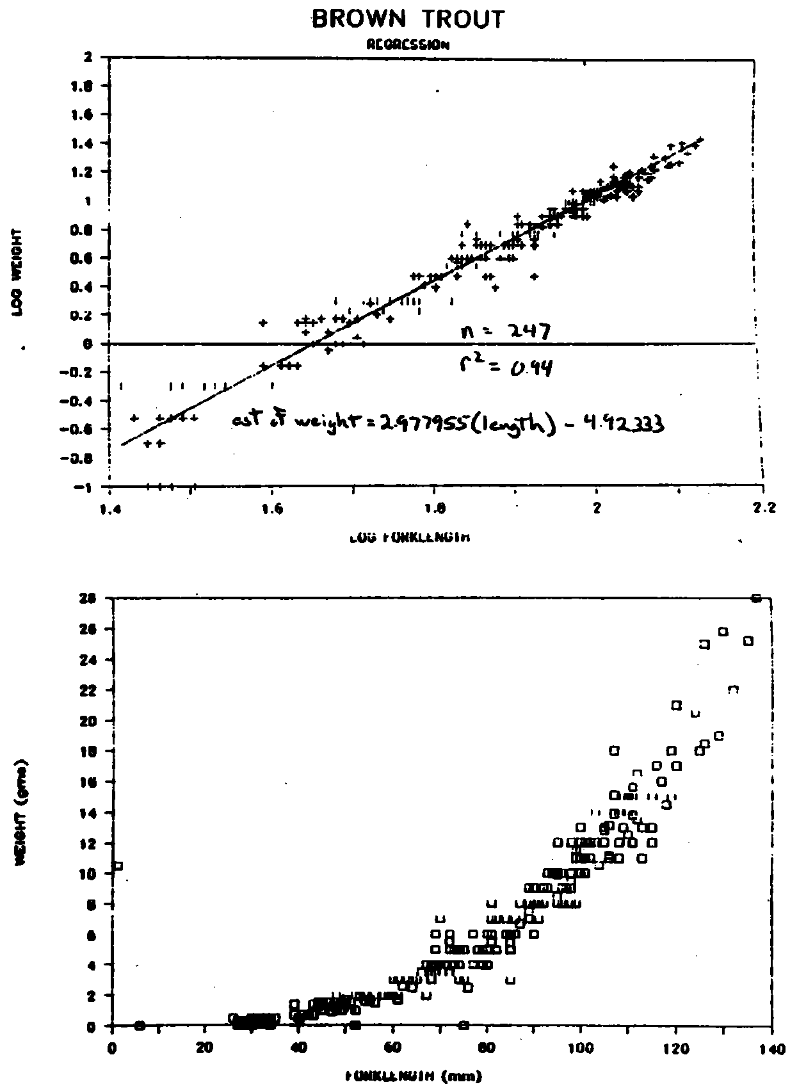



Figure 80. Forklength vs weight distribution and log forklength vs log weight regression analysis for juvenile brown trout in the upper Trinity River, 1986.

Discussion

Chinook salmon were first captured in mid-December at the Cemetery Study Site. Forklength at time of emergence ranged between 32 mm and 38 mm. During May, six months later the majority of these fish are migrating from the river at approximately 72 mm in forklength. As is noticeable in Figure 71, the average forklength of fish collected from April until June shows an increase from approximately 42mm to 72mm. From December until March the mean forklength increased only slightly, from 38 mm to 46 mm. This may in part be due to the continual emergence of late fry and to colder water temperatures present during this time. The increase in forklength during the spring may correlate with warmer water temperatures and increased food availability. An increase in the number of hatchery chinook salmon captured incidentally during the month of June may have also increased the average forklength at this time. However, no fish were measured when they were believed to be of hatchery origin.

A comparison between the regression analysis of length versus weight for chinook salmon captured at the upper river sites (Figure 75) with those captured at the middle river sites (Figure 76) shows that fish at the middle river sites have a slightly greater weight at a given forklength than those in the upper river sites. Rearing habitat and/or food availability may improve as you proceed downstream from Lewiston Dam. This may be confirmed when preliminary data results from the Invertebrate study (Task 4E) and the juvenile food habits study (Task 4F) become available.

Coho salmon emergence from the gravel began in February and continued through March. The forklength of these fish ranged from 29 mm to 36 mm. Coho growth appears to be slightly slower than that observed for chinook salmon during their first months of rearing. While conducting our habitat preference work we have observed that coho salmon fry and juveniles utilize a more defined range of habitat types than do fry and juvenile chinook salmon. Juvenile and fry coho salmon use areas where zero or very slow water velocities are present, usually near the water's edge or in backwater and side channel habitat types. These areas may provide less invertebrate drift as well as different food types entirely, thus possibly explaining their apparent slower growth as compared to chinook salmon.

Migration of age 1+ coho salmon appears to have occurred in February during the high flood waters which coincided with this time. The average forklength at the time of migration was 116 mm.

The regression analysis of length versus weight for coho salmon sampled at the upper site (Figure 77) with those sampled at the mid-river sites (Figure 78) follows the same pattern as that found for chinook salmon. Greater weight for a given forklength is observed for coho salmon at the mid-river sites versus the upper sites.

Rainbow trout fry are first captured during the April sampling period. Button-up fry are caught as late as June in the lower river at Tish Tang. The forklength of emergent fry rainbow trout ranged from 28mm to 35mm. After four months of growth age 0+ rainbow trout doubled in forklength from approximately 30mm to 60mm. This fast growth again seems to correlate with increased water temperatures and a possible increase in food quality which may be present during the Spring months. The mode for age one rainbow trout captured during April is 82mm. A large reduction in the number of age 1+ and 2+ rainbow trout is observed during the June sampling period. This probably correlates with the migration timing of juvenile smolt steelhead trout in the Trinity River. Smoltification in steelhead trout probably begins to occur at some forklength around 80 mm for Trinity River Steelhead stocks.

The majority of brown trout juveniles are collected in the upper river and mid-river study sites above and including Steelbridge. Emergence of brown trout fry occurred in February. Forklengths at time of emergence ranged from 26 mm to 34 mm. Growth during the first three months, from February until April, appears to be very slow, however, from May through July growth rates increased. Again, the cold water temperatures which are present in the winter months may be the reason for the slow growth noticed during the first three months of brown trout rearing, while growth tended to increase in rate during the spring months when water temperature became warmer. Age 1 brown trout captured during February ranged from 92 mm to 110 mm in forklength.

Findings

Further data collection of at least two years will give a much more complete picture of the growth characteristics for juvenile salmonids of the Trinity River. It has been found during preference data collection that once water temperatures fall below about 45 to 50 degrees F juvenile rainbow trout, brown trout, and coho salmon seek refuge by burrowing underneath clean cobble substrates generally in protected areas of the river such as side channels and backwaters. The extent of feeding which occurs at this time is still unknown for the Trinity River salmonids.

# 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.

## Sampling Sites and Procedures

Riffles were chosen 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. Site 2 (Cemetery) was chosen to represent riffle habitat immediately downstream of the reservoir. Sites 3 (Bucktail) and 5 (Steelbridge) represent riffle conditions above and below Grass Valley Creek, respectively. Sites 7 (Steiner Flat) and 10 (Del Loma) represent riffles with increasing distance (and probably, decreasing influence) downstream from the reservoir.

Macroinvertebrates are collected with a modified Hess sampler (dimensions of 27" height and 14" diameter) with a sampling area of 1.07 square feet. Net mesh size used in the sampler is 500 microns.

Five replicate samples are collected 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. Samples will be collected in January and March of 1987. Sampling locations on the study riffle are selected at random, and microhabitat measurements of depth, mean velocity, bottom velocity, and substrate type (refer to description of the modified Brusven size classification in Task 2) are recorded. The modified Hess sampler can operate in depths ranging from 0.6 to 1.5 feet, and velocities up to 5.8 ft/sec (with an assistant breaking current and stabilizing the sampler). The modified Hess sampler can be used in substrate ranging from sand to 9" to 12" cobble. Hess samples are condensed on a 500 micron sieve and stored in 70 % ethanol for laboratory processing.

Rose Bengal solution is used to stain the chitinous and soft tissue of invertebrates pink, which are thus contrasted from detritus. After Hess samples are stained, they are floated in saturated salt solution to separate invertebrates from sediment collected. The stained invertebrates are then hand picked from the supernatant, and the sediment fraction checked for remaining organisms.

Macroinvertebrates are keyed with a dissecting scope to the lowest identifiable taxa. Lengths and widths for each taxa and size class of invertebrates are estimated using an ocular micrometer. Volume is 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 will be converted to dry weight by $1 mm^3 = 0.1$ mg (Cummins and Wuycheck 1971). Shannon - Weaver diversity index (Wilhm and Dorris 1968) will be used to determine diversity per sampler. Diversity (H') is calculated as:

$$H' = - \sum_{i=1}^{s} \left[ \frac{Ni}{N} \right]^2 \times \log 2 \left[ \frac{Ni}{N} \right]$$

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 taxa "i" in sample

Annual macroinvertebrate production will be estimated using the size - frequency method (Hynes and Coleman 1968) as modified by Hamilton (1969) and Benke (1979). Biomass estimates will be generated from dry weight calculated using ocular micrometer measurements.

Preliminary Results

To date, 11 samples have been keyed and 46 have been sorted, out of a total of 250 samples to be collected. A preliminary taxa list of invertebrates collected with the Hess sampler from samples keyed to date is presented in Table 9. This table also includes aquatic invertebrate adults that were collected incidentally while working on other tasks.

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 (i.e. Grass Valley Creek) on downstream invertebrate populations; 3) downstream and seasonal changes in macroinvertebrate populations.

Table 9. Macroinvertebrates collected in the Trinity River by Area and Season, current through spring 1986.

| Taxa | Location[a] | | | Season[b] | | | |
|---|---|---|---|---|---|---|---|
| | Low | Mid | up | su | f | w | sp |
| ANNELIDA | | | | | | | |
| Hirudinea | | cc | | | | ad | |
| Oligochaeta | | | | | | | |
| Lumbriculidae | | | a | | | a | |
| ARTHROPODA | | | | | | | |
| Arachnida | | | | | | | |
| Hydracarina | | | r | | | | a |
| Coleoptera | | | | | | | |
| Dytiscidae | | | | | | | |
| Dytiscus | | | r | | | | l |
| Hygrotus | | | r | | | | a |
| Elmidae | | | | | | | |
| Ampumixis sp. | | | o | | | | l |
| Cleptelmis sp. | | o | | | | | a |
| Dubiraphia giulianii | | o | | | | | a |
| Narpus sp. | | c | c | | | l | l |
| Zaitzevia parvula | | o | | | | | l |
| Diptera | | | | | | | |
| Athericidae | | | | | | | |
| Atherix sp. | | | o | | | l | |
| Ceratopogonidae | | | | | | | |
| Ceratopogoninae | | o | | | | | l |
| Chironomidae | | | | | | | |
| Tanytarsini | | | a | | | | l |
| Tanytarsus sp.(not verified) | | | a | | | l | |
| Empididae | | c | | | | l | |
| Chelifera sp | | | c | | | | l |
| Heterodromia sp. | | c | | | | | l |
| Simuliidae | | | | | | | |
| Simulium sp. | | | a | | | l | |
| Tipulidae | | | | | | | |
| Antocha sp. | | | o | | | | l |
| Dicranota sp. | | c | | | | l | l |
| Hexatoma sp. | | | o | | | | l |
| Ephemeroptera | | | | | | | |
| Ametropodidae | | | | | | | |
| Ametropus sp. | | o | | | | n | |
| Baetidae | | | | | | | |
| Baetis sp. | | a | a | | | n | n |
| Ephemerellidae | | | | | | | |
| Drunella coloradensis | | c | c | | | | n |
| D. doddsi | | | o | | | | n |

Table 9. (continued) Macroinvertebrates collected in the Trinity River by Area and Season, current through spring 1986.

| Taxa | Location[a] | | | Season[b] | | | |
|---|---|---|---|---|---|---|---|
| | Low | Mid | up | su | f | w | sp |
| Drunella spinifera | | | o | | | n | |
| Ephemerella inermis | | c | c | | | n | n |
| Heptageniidae | | | | | | | |
| Cinygmula sp. | | o | | | | | n |
| Epeorus (Ironopsis) sp. | | c | | | | n | n |
| (Iron) | | c | | | | | n |
| Rhithrogena sp. | | a | a | | | n | n |
| Leptophlebiidae | | | | | | | |
| Paraleptophlebia sp. | | o | o | | | n | n |
| Siphlonuridae | | | | | | | |
| Ameletus sp. | | o | | | | n | |
| Tricorythidae | | | | | | | |
| Tricorythodes sp. | | r | | | | | n |
| Lepidoptera | | | | | | | |
| Pyralidae | | | | | | | |
| Petrophila sp. | | r | | | | | l |
| Odonata | | | | | | | |
| Anisoptera | | | | | | | |
| Gomphidae | | | | | | | |
| Ophiogomphus sp. | o | o | | | | n | n |
| Plecoptera | | | | | | | |
| Capniidae | | | | | | | |
| Capnia sp. | | o | o | | | b | |
| Chloroperlidae | | | | | | | |
| Alloperla sp. | | r | | | | | n |
| Perlidae | | | | | | | |
| Calineuria californica | | | a | | | n | |
| Claassenia sabulosa | | a | a | | | | n |
| Hesperoperla pacifica | | | o | | | | b |
| Perlodidae | | c | c | | | | n |
| Chernokrilus sp. | o | | | | | a | |
| Cultus sp. | | o | | | | n | |
| Isoperla sp. | | o | | | | | n |
| Perlinodes aurea | | | o | | | a | |
| Skwala curvata | | | o | | | a | a |
| Skwala parallela | | | o | | | a | |
| Pteronarcyidae | | | | | | | |
| Pteronarcys californicus | | | c | | | n | |
| Trichoptera | | | | | | | |
| Brachycentridae | | | | | | | |
| Brachycentrus sp | | a | | | | | l |
| Micrasema sp. | | c | | | | | l |

Table 9. (continued) Macroinvertebrates collected in the Trinity River by Area and Season, current through spring 1986.

| | Location[a] | | | Season[b] | | | |
|---|---|---|---|---|---|---|---|
| Taxa | Low | Mid | up | su | f | w | sp |
| Glossosomatidae | | | | | | | |
| Glossosoma sp. | | | a | | | l | |
| Protoptila sp. | | r | | | | | l |
| Hydropsychidae | | | | | | | |
| Cheumatopsyche sp. | | c | | | | | l |
| Hydropsyche sp. | | a | | | | l | l |
| Lepidostomatidae | | | | | | | |
| Lepidostoma sp. | | o | | | | l | l |
| Limnephilidae | | | | | | | |
| Dicosmoecus sp. | | | o | | | | l |
| Hydatophylax hesperus | | | r | | | | l |
| Onocosmoecus sp. | | | o | | | l | l |
| Philopotamidae | | | | | | | |
| Wormaldia sp. | | o | | | | | l |
| Rhyacophilidae | | | | | | | |
| Rhyacophila sp. | | | a | | | a | |
| Sericostomatidae | | | | | | | |
| Gumaga sp. | | r | | | | | l |
| MOLLUSCA | | | | | | | |
| Pelecypoda | | | | | | | |
| Sphaeriidae | | | | | | | |
| Pisidium sp. | | | r | | | | a |
| NEMATOMORPHA | | | | | | | |
| Gordiidae | | | | | | | |
| Gordius sp. | r | | | | | a | |
| NEMATODA | | a | | | | | a |

[a] Locations: Low = Weitchpec to South Fork; Mid = South Fork to North Fork; Up = North fork to Lewiston Dam

[b] Seasons: Su = Summer; F = Fall; W = Winter; Sp = Spring

[c] Rough Abundance per Location (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

# EVALUATION OF CONSTRUCTED SPAWNING RIFFLES

## Introduction

In 1976 and 1977, fourteen spawning riffles were constructed in an effort to provide better salmon spawning habitat in the upper Trinity River. Periodic surveys of these riffles indicate that many were not being used at all while others were crowded with spawners. Reasons for these apparent differences in distribution of spawning fish not readily apparent. Therefore, in an effort to answer these questions we undertook an evaluation of several selected constructed riffles. This effort was accomplished in cooperation with the California Cooperative Fishery Research Unit, Humboldt State University, through the efforts of Mary Buck and Roger Barnhart. The following paragraphs summarize their final report (Appendix I).

The objectives of the study were to: 1) evaluate six of the artificial riffles based on quantity and quality of spawning gravels, water velocity, depth and available cover; 2) to characterize redd sites of chinook ans coho salmon as to depth, velocity, substrate, and cover; and, 3) to determine preference criteria for salmon using these riffles.

## Study Sites

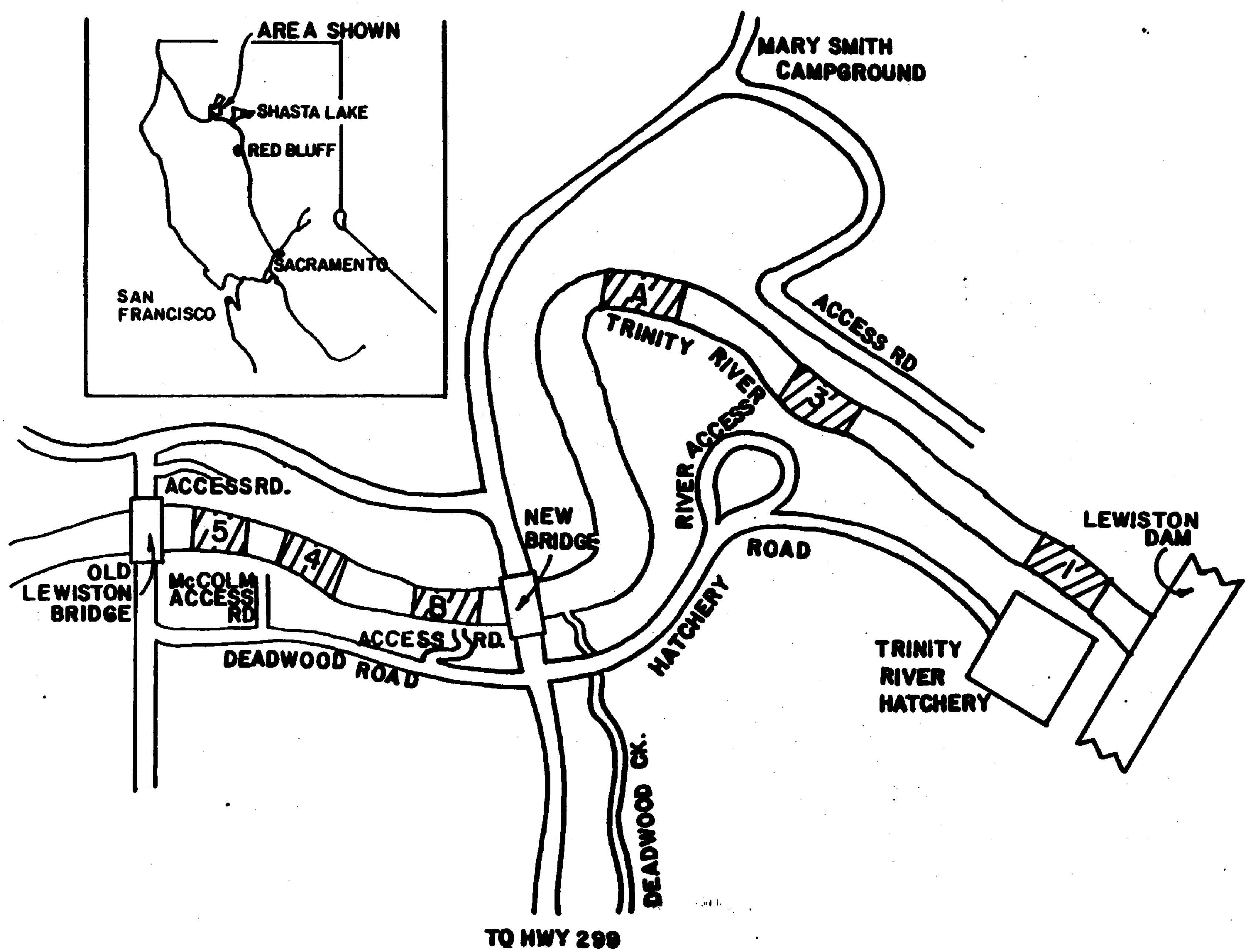
The six spawning riffles evaluated are all located above the Old Lewiston Bridge in Lewiston, California (Figure 81). They were chosen primarily on the basis of accessability, the availability of past records on spawning use, and whether the riffle boundaries are still reasonably distinct.

Generally, the six riffles range from 213 ft to 656 ft (65 to 200 meters) in length and 72 to 125 ft (22 to 38 meters) in width. Mean depths range from 1.4 to 2.3 ft (.44 to .70 meters) and mean water velocities from 1.5 to 1.9 ft/sec (.45 to .59 meters/second). Table 10 summarizes the general characteristics of each riffle.

## Methods

Weekly spawning surveys were conducted at each of the six study riffles from early October, 1985 through mid-January, 1986. Permanent transects were established at 30 meter intervals through each riffle. During each survey the total number of salmon were counted, redds located and water temperature recorded. Species was determined by one of both of the following: 1) the presence of chinook or coho actively building redds of in close proximity, and 2) the time of year. Since the chinook run was completed by mid-November, all new redds found after that were considered coho redds.

Once redds were located they were marked to facilitate additional measurements after all spawning was completed. Data gathered at each redd included: 1) its location relative to the nearest bank and transect; 2)




Figu

Figure 81. Location of constructed (artificial) spawning riffles in the upper Trinity River, Trinity County, California.

Table 10. General characteristics of the six artificial riffles evaluated.

| Riffle | Length (feet) | Width (feet) | Mean Depth (feet) | Mean Water Velocity (ft/sec) |
|---|---|---|---|---|
| 1 | 394 | 125 | 1.4 | 1.7 |
| 3 | 394 | 82 | 1.7 | 1.9 |
| A | 262 | 98 | 2.3 | 1.7 |
| B | 213 | 72 | 2.0 | 1.6 |
| 4 | 394 | 115 | 2.1 | 1.5 |
| 5 | 656 | 98 | 2.0 | 1.7 |

the total length of the redd and width measurements at the head, across the pot, and at the tailspill; 3) water velocity at mean column and .4 ft from the bottom at the head, across the pot and at the tailspill; 4) water depth at the head, across the pot and at the tailspill; 5) surface substrate using codes and the Brusven index system used in Task 2 and 3 of the Flow Evaluation Study; and 6) distance to nearest cover, escape or resting, and type of cover as overhead vegetation, aquatic vegetation, boulder groups or depth.

Lateral distribution and graduation of depth, velocity and surface substrate composition of each riffle was determined by taking a minimum of ten mean velocity and depth measurements across each established transect.

After completion of spawning, surface and intergravel dissolved oxygen and water temperatures were measured at a number of randomly selected redds and at three locations (.25, .50, and .75) across each transect. To accomplish this a perforated standpipe with plastic liner was used into which a polargraphic probe and thermister were lowered. Within each redd intragravel readings were taken at at the approximate location of egg deposition.

Results

A total of 74 salmon spawning redds (42 chinook and 32 coho) were located and measured. The average area used for spawning was 58.6 sq. ft. for chinook and 31.0 sq. ft. for coho salmon. The average velocity found at the head of the redd was 1.3 ft/sec for both species and the average depth was 1.4 ft.

During the collection period, streamflow remained constant at 300 cfs. Water temperatures ranged from 42.8 degrees F to 46.8 degrees F.

Table 1 in Appendix I lists the mean redd characteristics found for each of the six spawning riffles evaluated.

A summary and frequency analysis of these data, including probability of use curves, are included within Appendix I. In addition, isohyetal maps of velocities across each riffle and the locations of salmon redds on the riffles are included in Figures 6 through 11 of Appendix I.

The majority of chinook salmon redds were found with surface substrate compositions in the undisturbed area above the redds of small cobble (75-150 mm) as dominant type and large gravel (50-75 mm) as subdominant, with less than 20 % embeddedness. The coho observations were found to show a similar distribution although a fair number of observations (8) were found with dominant substrate of large gravel and subdominant substrate made up of medium gravel (25 - 50 mm).

Ranges and means of the interchange percentages, surface and intragravel DO and percent saturation found at each riffle are also listed in Table 2 of Appendix I.

Discussion

The spawning velocity use curves developed from data gathered on the six artificial spawning riffles for both chinook and coho salmon are similar, but skewed toward slightly lower water velocities and depths, than those curves developed in TASK 2. This may be in part due to several factors. First, the sample size in this evaluation is much smaller, only 74 observations, while that used to develop the curves in TASK 2 number in the hundreds. Secondly the artificial riffles provide only limited available habitat. And, finally, the artificial spawning riffles are all at the upstream limit to salmon migration on the Trinity River.

The depth use curves developed in the evaluation of the artificial riffles are also similar, but skewed, when compared to curves developed in TASK 2. Again the reasoning may be the same. Sample size is substantially smaller, habitat variation is not available, and the riffles are the last available areas for salmon to spawn in the river below Lewiston Dam.

Analysis of surface substrate shows a definite preference by both chinook and coho for substrates in the range of 75 to 150 mm and an embededness of less than 10 percent. This is almost identical to the findings elsewhere in the river as seen in TASK 2, with the exception that larger cobbles (150 to 225 mm in size) were more frequently used outside of the artificial riffles. Whether this is a function of selection of simply availability is a question which still needs to be addressed. An interesting note is that on constructed riffle 5, the compacted gravel area downstream of the 495 foot (150 meter) transect line was unused by salmon.

Proximity to cover also seems to be an important factor in redd location for both chinook and coho salmon. Seventy (70) percent of the redds for both species were found within 33 feet (10 meters) of cover and 50 percent were found wihtin 16 feet (5 meters). This was not entirely unexpected, however, since other studies have observed the importance of cover to both trout and salmon (Bousu, 1954; Hourston and MacKinnon, 1957; Johnson et. al., 1966; Butler and Hawthorne, 1968; and Reiser and Wesche, 1977).

In all six artificial riffles intergravel owygen levels were found to be within acceptable ranges for egg development and did not appear to have a bearing on spawning use.

Of the six riffles evaluated, riffles 4 and 5 had the most spawner use. These riffles seemed to have the most spawning gravel available at preferred velocities and depths and in close proximity to cover. Riffle 1 had comparatively fewer redds and although adequate spawning gravel was available it was not as close to cover as similar gravel on the more heavily used riffles. Riffles 3 and B seemed to provide sufficient habitat , in terms of depths, velocities, substrate, and cover, but still were not used as extensively. At this time there seems to be no explanation for this apparent avoidance.

Generally, activities associated with the Trinity River Flow Evaluation Study for 1987 will continue to focus on: 1) the development of fish habitat preference criteria for the Trinity River (TASK 2); 2) the determination of habitat availability at various streamflows; and, 3) the determination of habitat and population characteristics which are influenced by streamflows.

Habitat Preference Criteria Development (TASK 2)

Efforts at Habitat Preference Criteria Development (TASK 2) will be directed at the completion of field data gathering and a final report. Priority will be placed on obtaining additional data points for holding chinook and coho salmon, fry and adult steelhead trout, and all life-stages of brown trout during the coming year. Low priority data collection will continue for the nongame species present, as the opportunity arises.

The final report on salmonid habitat preference for the Trinity River is currently scheduled for completion by September 30, 1987 and will combine the elements of fish habitat use and habitat availability into preference criteria. Subsequently, it is planned that annual monitoring of habitat use and availability will be conducted and periodic updates of these criteria will be published throughout the term of the Flow Evaluation Study.

Determination of Habitat Availability and Needs (TASK 3)

During the upcoming year it is planned that efforts associated with this task will be directed at reviewing and refining the instream flow modeling procedures used during 1985 and 1986. This effort will be necessary due to the refinement of fish habitat use data and eventually the development of preference criteria. As these criteria are completed we plan to rerun previously completed instream flow models for the Trinity River (e.g. the 1985 and 1986 IFG-4 models and the 1978 model completed by Hoffman). It is hoped that through this effort we will be able to establish "baseline" conditions of habitat availability upon which future changes can be gaged. This is one of the primary objectives of the task in the 12-year study.

In addition, we are planning to complete detailed habitat maps of all study sites during 1987, using field techniques and aerial photos. This effort is designed to provide: 1) a verification of available habitat as predicted by the instream flow models; and 2) a clear description of Trinity River habitat characteristics within our study reaches, prior to any major instream enhancement efforts by the Trinity River Basin Fish and Wildlife Management Program Field Office.

Another element, which has been addressed in the initial study plan objectives and was to be considered under TASK 3, is the effects of water temperature on the amount of available habitat within the Trinity River. During 1987 we plan to initiate efforts at conducting an instream water temperature model for the upper Trinity (i.e. above the Nort Fork). Field data collection and analysis will be accomplished using procedures outlined in Instream Flow Information Paper No. 16 (Theurer, Voos and Miller, 1984). It is hoped that this effort will complement the habitat criteria developed as part of TASK 2, since water temperature is not a variable considered in preference criteria development and is generally recognized as a major controlling factor in the survival and fitness of juvenile salmonids.

## Fish Population Characteristics and Life History Relationships (TASK 4)

During 1986 we initiated a number of elememts aimed at providing insite into these relationships on the Trinity River. The initial plan of study for the Flow Evaluation Study describes this information as necessary due to our limited knowledge about the total distribution of fish between Lewiston Dam and Weitchpec, their spawning success, and the subsequent survival and growth of salmonid juveniles. As you have read in this report, initial efforts have been aimed at gaining some information on: 1) the distribution and habitat use by 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. Generally, we are planning to continue these efforts through 1987.

Efforts will be initiated to gain additional information on the use of side-channels by juvenile salmonids and the importance of these habitat types to the salmonid population as a whole. We will also attempt to monitor the juvenile production of several selected natural side-channels and, where these habitats have been used for spawning, the emigration of juveniles from them.

Efforts aimed at the determination of juvenile growth within the river, especially of "wild" or naturally produced fish will continue but at a slightly lower level, designed to monitor and to build upon the "baseline data" obtained in 1986. Also, during 1986, selected specimens were preserved for future food habits analysis. It is planned that these samples will be sorted and analysed during 1987. In addition, scale analysis, on collected samples have not begun at this time. Thus far, 156 scale samples have been collected. Analysis of this data is expected to be completed in 1988.

Finally, studies designed to determine and monitor the health and production of benthic aquatic invertebrates within the Trinity have only just begun. We plan to continue these efforts through 1987. It is planned that, by the time of the next annual report, we will have completed initial analysis, by study site, of macroinvertebrate populations within the mainstem of the Trinity and have some bases for a comparative analysis.

Study Coordination

During 1986, the Trinity River Basin Fish and Wildlife Management Program Field Office was established, and has 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 it may need to monitor changes in available habitat or habitat use brought about by the implementation of the Management Program. Such an effort is necessary if it is expected that habitat changes due to increases in downstream releases are to be accurately separated from those brought about through implementation of the Management Program. Therefore, we plan to maintain close coordination with the Trinity Management Program Field Office.

Along these lines, efforts were initiated during 1986 to monitor habitat changes and subsequent salmonid use and macroinvrtebrate population of spawning riffles ripped during September, 1986 in an effort to improve spawning habitat on the river. Comparisons will also be made with similar riffles selected as controls.

In addition, coordination efforts will be directed to the Bureau of Reclamation, specifically with regards to Trinity River releases from Lewiston Dam, and the California Department of Fish and Game, with regards to the operation of the Trinity River hatchery (e.g. salmon smolt releases) and the fish counting facilities planned for 1987.

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## APPENDIX

# TRINITY RIVER FISH HABITAT STUDIES - AN ASSESSMENT OF ANADROMOUS FISH HABITAT AND RELATED ANADROMOUS FISH POPULATIONS BELOW LEWISTON DAM IN NORTHWESTERN CALIFORNIA

## TASK I

## EVALUATION OF CONSTRUCTED ANADROMOUS SALMONID SPAWNING RIFFLES, TRINITY RIVER CALIFORNIA

Final Report

by


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Contract 91547 W.O. #10


July 15, 1986

# EVALUATION OF CONSTRUCTED ANADROMOUS SALMONID SPAWNING RIFFLES, TRINITY RIVER CALIFORNIA

## Introduction

In 1963, as part of the Central Valley Project, Trinity and Lewiston Dams were constructed to divert approximately 85% of the natural flow of the upper Trinity River to California's Central Valley (U.S. Fish and Wildlife 1980). Prior to construction of the dams, peak winter flows on the Trinity River exceeded 16,990 $m^3$/minute (10,000 cfs) compared to the present periodic high flow of 3,398 $m^3$/minute (2,000 cfs) and normal flow of 510 $m^3$/minute (300 cfs) released from Lewiston Dam (Bodin 1982). Reduced sediment carrying capacity of the Trinity, caused by low flows, combined with the sediment discharge from tributaries have resulted in sedimentation of pools and spawning areas downstream of the dam (Bodin 1982). The numbers of adult salmon and steelhead returning to the upper Trinity have declined markedly due to this sediment covering spawning gravel (Meacham 1973). Sediment accumulation, compacted riverbed gravels, and encroaching vegetation have caused a loss of 44% of the previously existing habitat (Hubbell 1973).

Trinity River Hatchery was built in 1972 to mitigate the loss of the fishery. In 1976 and 1977, fourteen spawning riffles were constructed to provide better spawning habitat in the upper Trinity River (U.S. Fish and Wildlife 1980). Spawning riffles possess gravel beds and sufficient gradient to provide necessary water velocities and depths. These parameters are defined within certain limits from previous spawning habitat studies. A good spawning habitat has a mixture of chemical, physical and hydraulic factors which promote spawning and allow development and hatching of eggs (Reiser and Wesche 1977).

The fourteen riffles were constructed in the following manner: 1) The riffle bed was scarified and oversized cobbles and boulders removed; 2) barriers were constructed at the top and bottom of the riffle section to establish necessary riffle gradients; 3) berms were placed where needed along the sides of the river; 4) gravel, graded from 3/4 inch up to 4 inches, was then placed between the barriers and smoothed out (U.S. Dept. of Interior 1977).

In 1983 and 1985, more gravel was placed on the riffles where needed and damaged riffles repaired. Also, spawning and escape areas were created by placing boulder groups or piles of gravel in various locations on the riffles (Dept. of Water Resources 1983, 1985).

Periodic surveys of the fourteen artificial spawning riffles on the Trinity River indicate that many of the riffles are not being used for spawning and others are crowded with spawners. Reasons for such a skewed distribution of fish are not readily apparent. In order to answer these questions this study was developed. The purpose of this study is to: 1) Evaluate six of these artificial riffles based on quantity and quality of spawning gravels, water velocity, depth and availability of cover; 2) to characterize redd sites of chinook and coho salmon as to depth, velocity, substrate and cover; and 3) to determine preferences criteria curves for Trinity River chinook and coho salmon.

## Location and Description of Study Sites

The six spawning riffles evaluated are located above the Old Lewiston Bridge in Lewiston, California (Figure 1). The spawning riffles 1, 3, A, B, 4

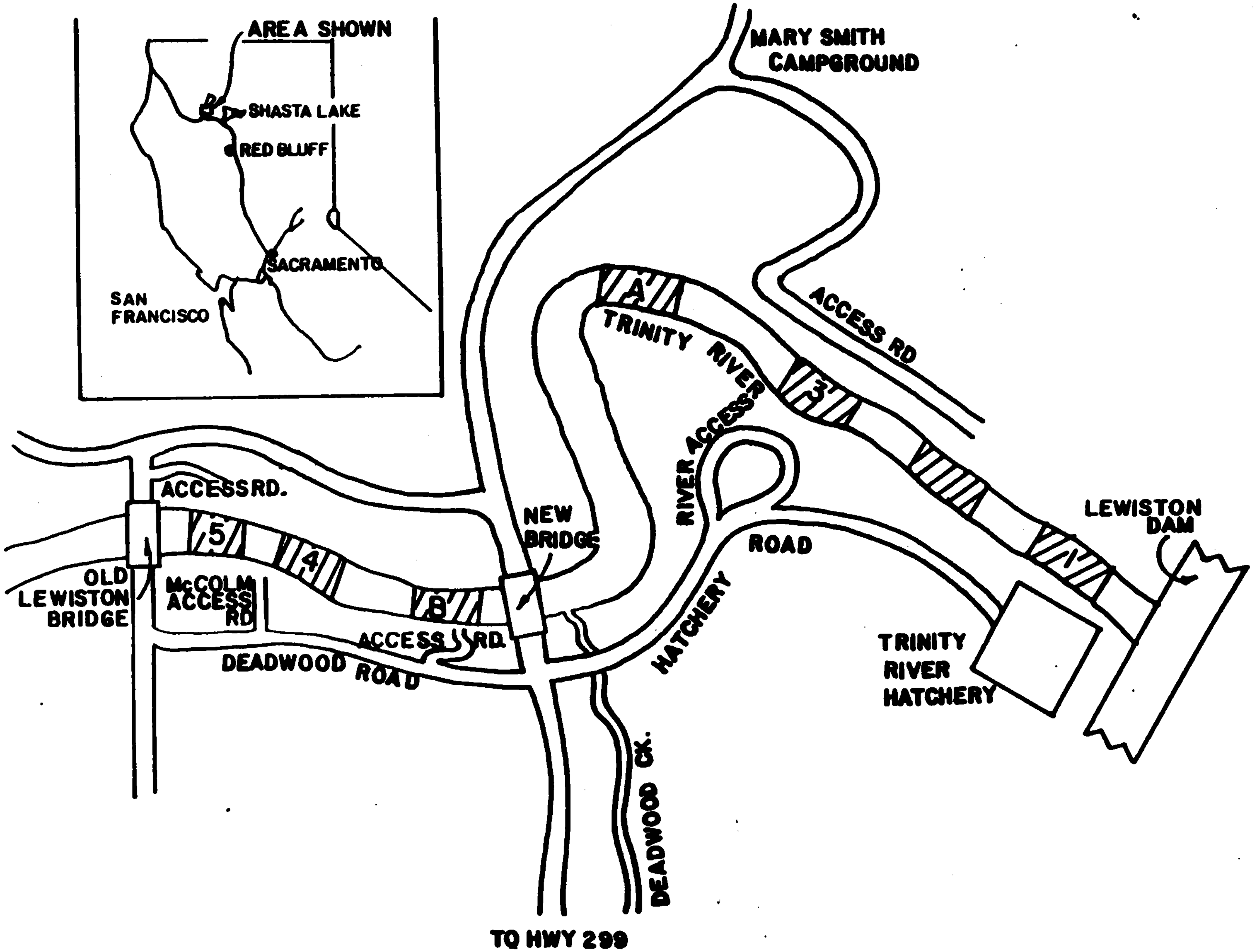


Figure 1. Location of constructed spawning riffles, upper Trinity River, Trinity County, California.

and 5 were chosen for this study. They were selected on the basis of accessability, past records of spawner use, and whether the riffle boundaries were still reasonably discrete.

The following is a general description of the six riffles:

Riffle 1 - Spawning Riffle 1 is located directly downstream from the Lewiston Dam. It is 120 m long and 38 m wide. The average water depth is 0.44 m and average water velocity is 0.52 m/sec. It is accessable by two roads, the Mary Smith Campground road or the Lewiston Hatchery road.

Riffle 3 - Riffle 3 is located approximately 360 m downstream from Riffle 1. It is 120 m long and 25 m wide. The average water depth is 0.53 m and the average water velocity is 0.59 m/sec. The upper and lower boundaries have deteriorated somewhat but were approximated with the help of Fish and Game personnel (Ed Miller, personal communication). It is accessable by the Mary Smith Campground dirt road.

Riffle A - Riffle A is located approximately 200 m downstream from Riffle 3. It is accessable by a short dirt road off of the Lewiston Hatchery road. The upper and lower boundaries of the riffle are well established. It is 80 m long and 30 m wide. The average water depth is 0.70 m and average water velocity was 0.53 m/sec.

Riffle B - Riffle B is located directly downstream from the New Lewiston Bridge. It is accessable by a short dirt road off Deadwood road. The upstream boundary of Riffle B was not distinguishable but Fish and Game personnel helped to approximate the upper boundary. The lower boundary is still well established. Riffle B is 65 m long and 22 m wide. The average water depth is 0.60 m and the average water velocity is 0.50 m/sec.

Riffle 4 - Riffle 4 is located approximately 300 m downstream from Riffle B. Riffle 4 is accessable by the McColm access road off Deadwood road.

The upstream and downstream boundaries are well established. Riffle 4 is 120 m long and 35 m wide. The average water depth is 0.63 m and the average water velocity is 0.45 m/sec.

Riffle 5 - Riffle 5 is located 120 m downstream from Riffle 4, right above the Old Lewiston Bridge. Riffle 5 is accessable by the McColm access road. Riffle 5 is 200 m long and 30 m wide. The average water depth is 0.60 m and average water velocity is 0.52 m/sec. We decided to shorten the Riffle 5 study area to the 150 m transect line. Downstream from the 150 m transect line, riffle 5 is badly deteriorated. Spawning gravel has been carried out which has resulted in a deep run. The spawning gravel that is present along the riffle margins is compacted with sediment and unsuitable for spawning. No salmon were observed spawning in this area.

## Procedures

From early October, 1985 to January 11, 1986 weekly spawning surveys were conducted on each of the six spawning riffles. Permanent transects were established every 30 m on each of the riffles. Spawning surveys were conducted by wading upstream through the riffle. The total number of salmon were counted, redds located and water temperature was taken at each survey site.

Because both chinook Oncorhynchus tshawytscha and coho salmon O. kisutch were spawning on these riffles, it was necessary to determine which species had constructed each redd. This was determined by one or both of the following: 1) The presence of chinook or coho actively building the redd or in the near vicinity, 2) the time of the year. The chinook run was completed about the middle of November. Beyond that date, all new redds found were labeled "coho". Redds were located and marked with large painted rocks placed in the pot of the redd and by flagging the tailspill area with red taped stakes. Redds were marked so that intergravel dissolved oxygen readings and other measurements could be taken after the completion of spawning.

The following measurements were made at each redd site:

1. The location of the redd was determined by measuring the distance from the nearest bank and nearest transect line with a tape measure.

2. The total length of the redd and three widths (at the head, pot, and tailspill) were measured with a tape measure. The total redd length did not include the downslope portion of the tailspill.

3. Mean velocity and water depths were measured using a Price current meter which was attached to a four foot top adjusting rod. Mean velocity and nose velocity taken at 0.4 ft depth, were measured at the head of the redd. The mean velocity and water depth at the pot and tailspill of the redd were also determined.

4. Surface substrate composition was determined by visually examining the undisturbed area right above the redd. The visual analysis was made here because this area represents substrate present before spawning activity. A substrate index developed by Brusven (1977) and revised by the Instream Flow Group (Bovee 1982) was used to characterize the substrate. The Brusven index is composed of a three digit code. The first digit represents a code for the dominant particle size present. The second digit represents the size range of the subdominant material surrounding the dominant particle size. The third digit is used to describe the percent embeddedness, or the degree that fine sediment surrounds the larger particles. The criteria codes used to describe the substrate are:

| I Substrate | II Percent Embedded |
|---|---|
| 0 Fines less than 4 mm | 0 less than 10 |
| 1 Small gravel 4-25 mm | 1 10-20 |
| 2 Medium gravel 25-50 mm | 2 20-30 |
| 3 Large gravel 50-75 mm | 3 30-40 |
| 4 Small cobble 75-150 mm | 4 40-50 |
| 5 Medium cobble 150-225 mm | 5 50-60 |
| 6 Large cobble 225-300 mm | 6 60-70 |
| 7 Small boulder 300-600 mm | 7 70-80 |
| 8 Large boulder 600+ mm | 8 80-90 |
| 9 Bedrock | 9 90-100 |

For example, an index 430 would signify that the dominant particle size was small cobble, surrounded by subdominant large gravel and that the small cobbles were less than 10 percent embedded by fine sediment.

5. The distance to nearest cover, escape or resting, was measured with a tape measure. The type of cover was also noted: Overhead vegetation, aquatic vegetation, boulder groups or depth.

Cross channel transects were established and used to compare areas chosen for spawning with those not selected. Temporary transects every 15 m were established between the permanent 30 m transect lines. We determined lateral distribution and graduation of depth and velocity of the riffle by taking a minimum of ten mean velocity and water depth readings across the channel. Depths and mean velocities were measured every 2-4 meters depending on width of channel:

| Stream width | Interval used |
|---|---|
| 40 meters | 4 meters |
| 30 meters | 3 meters |
| 20 meters | 2 meters |

Surface substrate composition using the Brusven index (1977), was also determined in conjunction with the depth and velocity measurements.

The week of December 16, 1985, the intergravel dissolved oxygen distribution was determined for each riffle. Intergravel oxygen was measured using a dissolved oxygen meter with a polargraphic probe and thermister. A perforated steel standpipe with a plastic inner jacket was pounded into the streambed to a depth of 25-30 cm. The probe was then lowered into the standpipe to take the reading. Readings were taken at three locations, 0.25, 0.5, and 0.75 of the distance across each 25 m transect line. We measured both surface and intergravel oxygen and temperatures. Intergravel oxygen was also determined at a random number of redd sites. The oxygen reading was taken at the approximate area of egg deposition downstream from the pot.

## Data Analysis

The spawning preference curves were developed according to the guidelines of the U.S. Fish and Wildlife Service's Cooperative Instream Flow Service Group (IFG) (Bovee and Cochnauer 1977).

Intergravel dissolved oxygen readings were used to compare and contrast differences in oxygen levels at each riffle site. Percentage saturation was determined using a nomagraph, for each dissolved oxygen value, to reduce effects of water temperature differences among the six riffle sites. Interchange was expressed as a percent (Woods 1980) using the equation:

P = I/S x 100 where P = interchange percent, I = mean intragravel dissolved oxygen concentration and S = surface dissolved oxygen concentration.

## Results

During the data collection period stream temperatures ranged from 6.0 - 8.2°C. Streamflow released from the Lewiston Dam during the study period was approximately 300 cfs. During the period October 1985 - January 1986, 42 chinook and 32 coho redds were located and measured. The average area used in spawning was 5.33 $m^2$ for chinook salmon and 2.82 $m^2$ for coho salmon. The average velocity found at the upper edge (head) of the redd was 0.44 m/sec for chinook salmon and 0.43 m/sec for coho salmon. The average depth at the upper edge of the redd was 0.43 m for chinook and 0.42 m for coho. Table 1 lists the mean of the redd characteristics for the six spawning riffles.

A summary of the surface substrate composition found in the undisturbed area above the redds is as follows:

| Modified Brusven Index | Number of Observations (Chinook) | Number of Observations (Coho) |
|---|---|---|
| 320 | 1 | 8 |
| 321 | 1 | 1 |
| 322 | | 1 |
| 420 | 3 | 1 |
| 422 | 1 | |
| 430 | 21 | 7 |
| 431 | 11 | 10 |
| 432 | 3 | 2 |
| 433 | 1 | |
| 434 | 1 | 2 |

Table 1. Means of physical and hydraulic redd characteristics of six constructed riffles, Trinity River, California.

| | Riffle 1 | | Riffle 3 | | Riffle A | | Riffle B | | Riffle 4 | | Riffle 5 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Chinook | Coho | Chinook | Coho | Chinook | Coho | Chinook | Coho | Chinook | Coho | Chinook | Coho |
| Length (m) | 3.60 | 2.56 | 3.20 | 1.93 | 4.13 | 2.65 | 3.53 | 2.45 | 3.11 | 2.37 | 3.17 | 1.95 |
| Upper width (m) | 2.12 | 1.54 | 1.50 | 1.03 | 1.82 | 1.37 | 1.63 | 1.30 | 1.71 | 1.49 | 1.84 | 1.08 |
| Middle width (m) | 1.74 | 1.48 | 1.20 | 0.73 | 1.65 | 1.18 | 1.38 | 1.03 | 1.55 | 1.22 | 1.79 | 0.76 |
| Tailspill width (m) | 0.91 | 1.36 | 1.10 | 0.67 | 0.94 | 0.88 | 1.00 | 0.85 | 1.42 | 1.07 | 1.51 | 0.72 |
| Area ($m^2$) | 6.83 | 5.21 | 5.01 | 1.70 | 5.57 | 3.31 | 5.28 | 2.67 | 4.92 | 3.08 | 5.68 | 1.73 |
| Depth (m) upper edge | 0.23 | 0.40 | 0.53 | 0.24 | 0.46 | 0.33 | 0.56 | 0.31 | 0.48 | 0.54 | 0.38 | 0.48 |
| V (m/s) upper edge | 0.28 | 0.34 | 0.33 | 0.45 | 0.25 | 0.31 | 0.45 | 0.18 | 0.57 | 0.46 | 0.49 | 0.63 |
| Depth (m) pit | 0.34 | 0.41 | 0.62 | 0.37 | 0.48 | 0.41 | 0.58 | 0.35 | 0.59 | 0.65 | 0.45 | 0.57 |
| V (m/s) pit | 0.29 | 0.35 | 0.29 | 0.34 | 0.24 | 0.86 | 0.43 | 0.14 | 0.47 | 0.40 | 0.41 | 0.56 |
| Depth (m) tailspill | 0.14 | 0.16 | 0.35 | 0.17 | 0.22 | 0.22 | 0.29 | 0.21 | 0.35 | 0.63 | 0.27 | 0.35 |
| V (m/s) tailspill | 0.38 | 0.53 | 0.45 | 0.49 | 0.43 | 0.48 | 0.51 | 0.25 | 0.62 | 0.81 | 0.55 | 0.71 |

Seventy-four measurements of spawning velocities and depths were obtained. Summarization and frequency analysis of these data are given in Appendix Tables 1-4. The resulting probability of use curves for spawning velocities and depths are shown in Figures 2-5.

Isohyetal maps of the velocities found across each riffle are depicted in Figures 6A-11A. The locations of chinook and coho redds in the different riffle sites and their proximity to cover and spawning gravel and relation to depth are depicted in Figures 6B-11B.

The ranges and means of the interchange percentages, surface and intragravel dissolved oxygen concentration and percent saturation found at each riffle site are listed in Table 2.

## Discussion

The spawning velocity preference curves for Trinity River chinook and coho salmon are similar to those developed by Bovee (1978). Bovee developed two separate curves for fall and spring chinook salmon. We combined the redd information for spring and fall chinook because of small sample size which could explain some of the differences in optimum and range of velocities. Trinity River chinook salmon seem to prefer a lower range of velocities than Bovee (1978) observed. A higher percentage used 1.0-1.5 ft/sec range and none used 3.0 ft/sec and above velocities (Figure 2). This could be due to the unavailability of such velocities on the riffles or more likely the lack of spawning gravel in these high velocity areas. The coho velocity curve is very similar to the Bovee curve (Figure 4).

The preference curves generated for depth had a similar optimum to the Bovee (1978) curves, but shallower depths were utilized by Trinity River

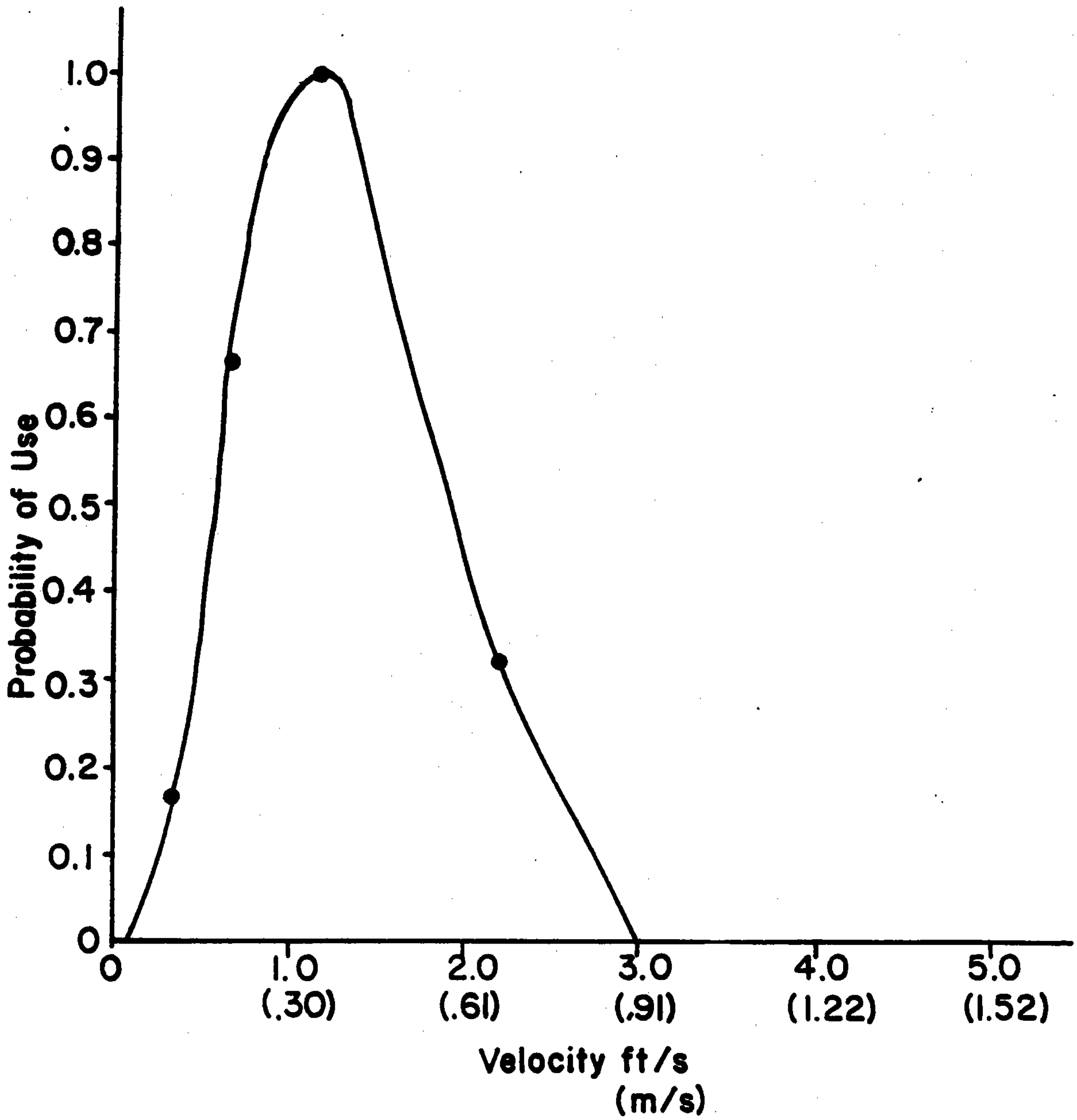


Figure 2. Trinity River chinook salmon spawning velocity preference curve.

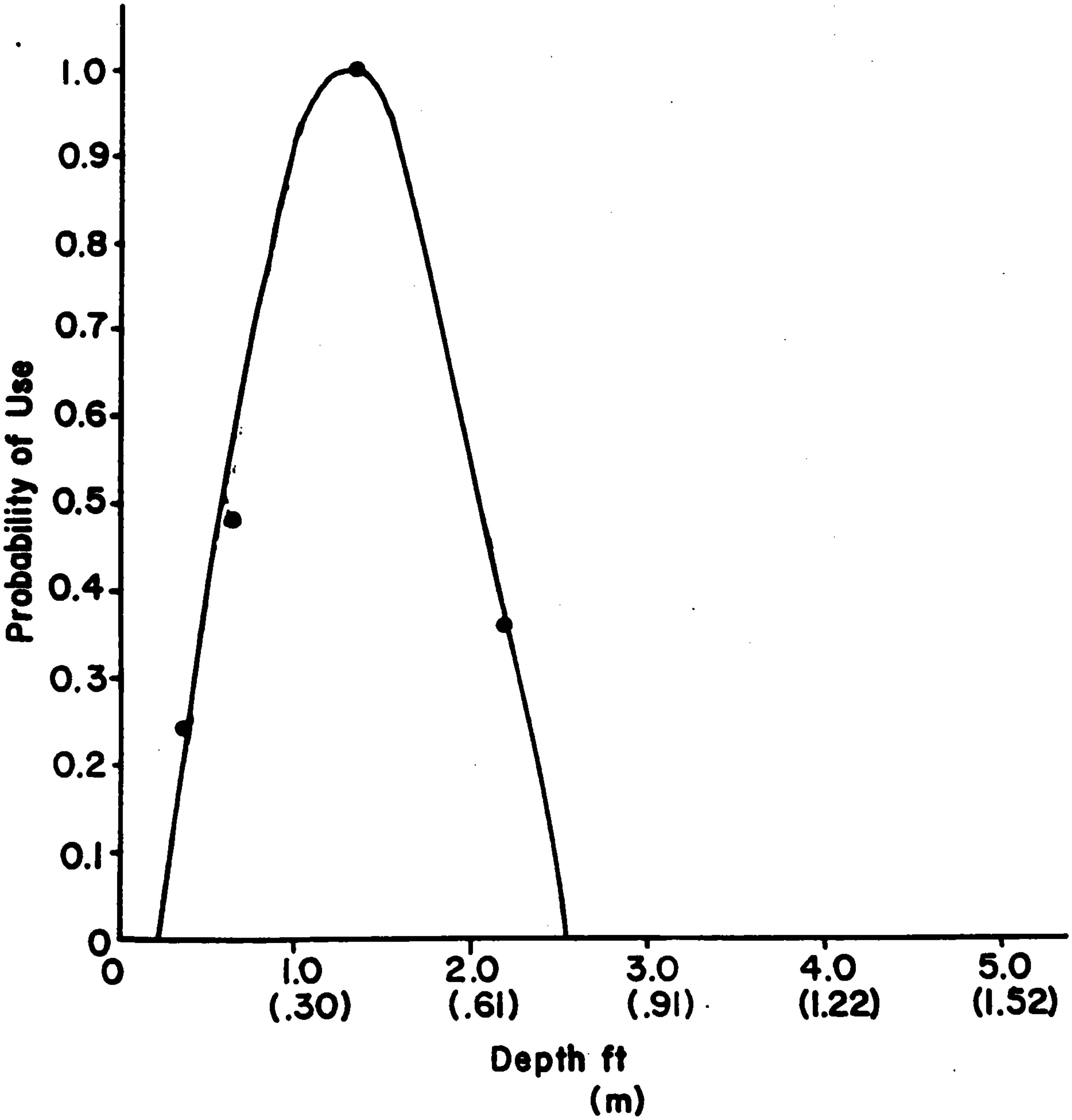


Figure 3. Trinity River chinook salmon spawning depth preference curve.

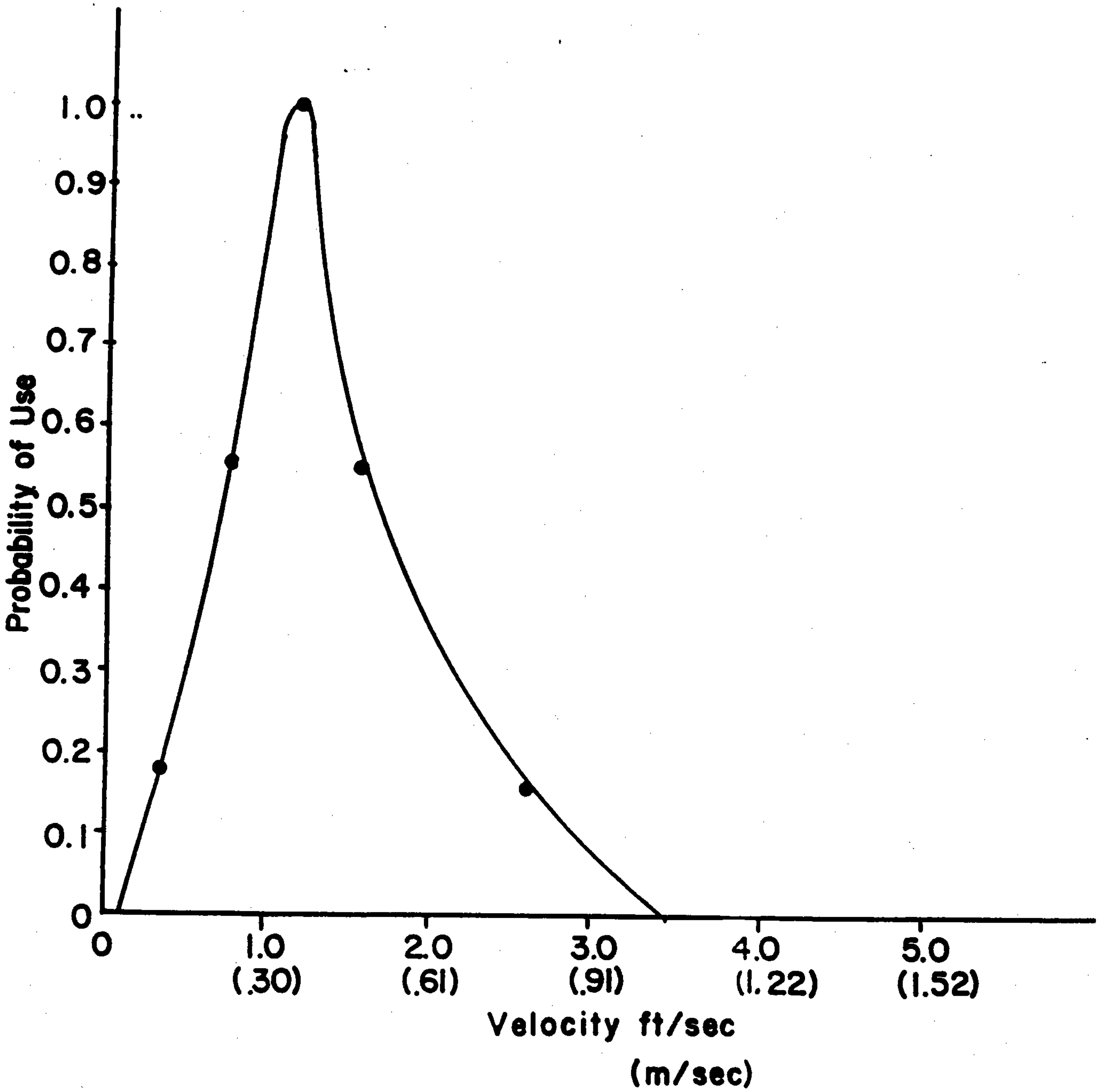


Figure 4. Trinity River coho salmon spawning velocity preference curve.

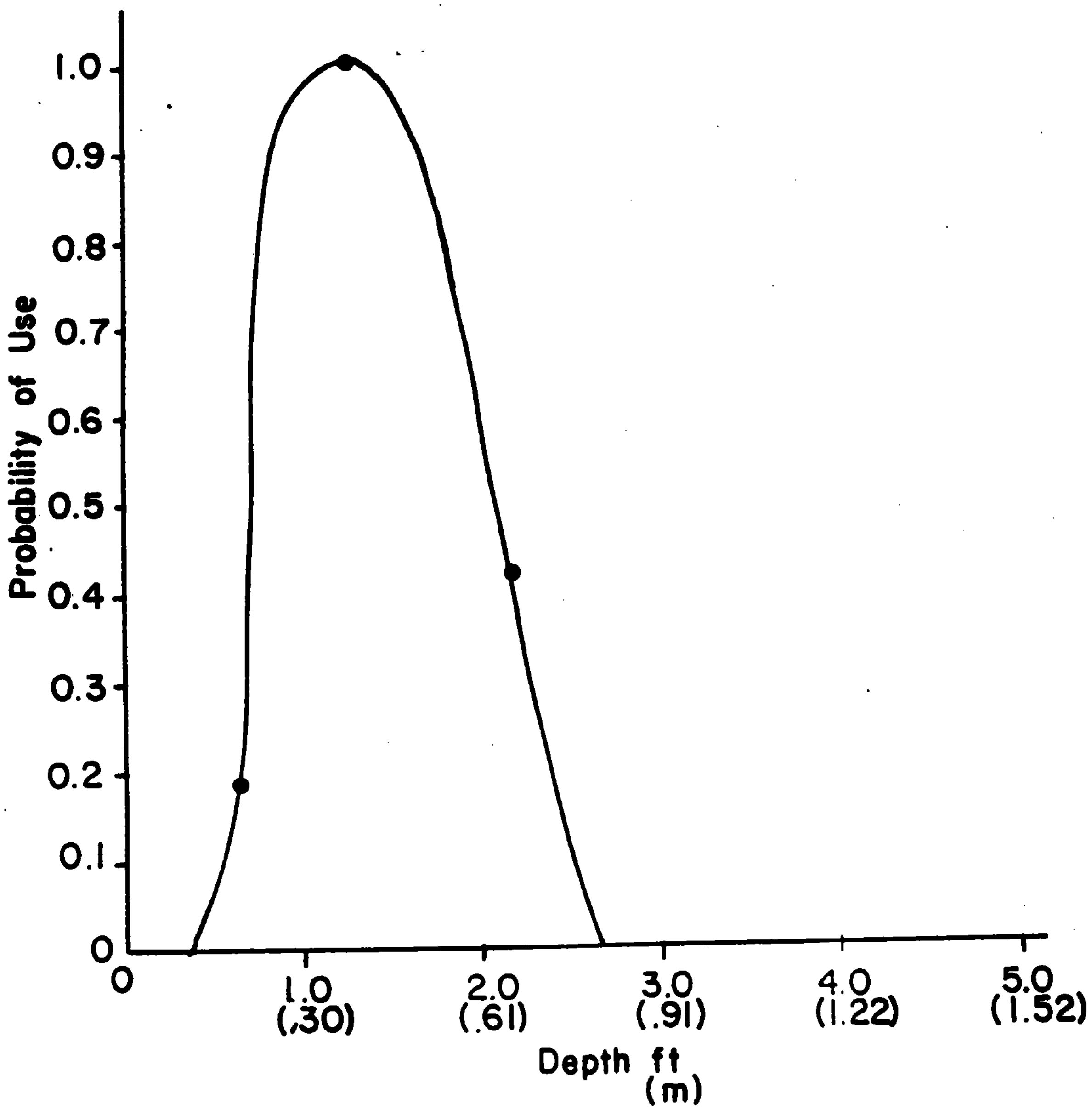


Figure 5. Trinity River coho salmon spawning depth preference curve.

Table 2. Dissolved oxygen surface and intragravel concentrations, interchange percentages and percent saturation measured at constructed riffle sites, Trinity River, California (December 16-20, 1985).

| Riffle (No. of readings) | Interchange (%) | Surface D.O. concentration (mg/l) | Intragravel concentration (mg/l) | Percent saturation |
|---|---|---|---|---|
| A<br>n = 20 | 96.0[a]<br>(73.2-103.0)[b] | 11.60<br>(11.30-11.80) | 10.94<br>(8.20-11.60) | 90.8<br>(68-95) |
| B<br>n = 17 | 92.8<br>(73.2-99.2) | 12.0<br>(11.80-12.30) | 11.21<br>(9.0-12.10) | 93.2<br>(75-100) |
| 1<br>n = 25 | 99.70<br>(97.2-102.0) | 11.0<br>(10.50-11.30) | 10.82<br>(10.2-11.30) | 90.0<br>(85-94) |
| 3<br>n = 20 | 93.36<br>(2.0-101.0) | 11.40<br>(11.20-11.60) | 10.70<br>(0.2-11.70) | 90.0<br>(3-97) |
| 4<br>n = 33 | 98.16<br>(79.6-101.0) | 11.60<br>(11.10-12.00) | 11.18<br>(9.0-11.80) | 93.2<br>(77-98) |
| 5<br>n = 37 | 97.35<br>(93.1-101.0) | 11.80<br>(11.50-12.00) | 11.34<br>(10.80-12.00) | 93.9<br>(89-100) |

[a]Average

[b]Range

salmon. Again the reason for this could be that deeper areas on the riffles generally lacked sufficient spawning gravel (Figures 6B-11B).

The intragravel oxygen readings showed that there is sufficient oxygen available in the spawning gravel for development of eggs. The minimum level is 4 mg/l (Wickett 1954). Wickett (1954) found that dissolved oxygen averaged from 56-88% saturation in spawning gravel. The percent saturation found across the Trinity River riffles was well within or above this range. The interchange percentage found for each riffle was above 90% and this is usually a good indicator of high permeability of the streambed (Woods 1980). Woods (1980) found significantly lower interchange percentages in creeks where large amounts of fine sediment from logging had decreased the permeability of the streambed by inhibiting water exchange.

Analysis of the surface substrate composition data shows a definite preference by chinook and coho for the 4-3-0, 4-3-1 size and embeddedness combinations (7.5 cm - 15 cm, 0-10% embeddedness). Briggs (1953) and Burner (1951) found chinook and coho salmon prefer spawning gravel ranging from 4 - 15 cm also. Burner (1951) also noted that salmon avoided firmly impacted gravel for spawning. Trinity River salmon chose spawning gravels with low embeddedness. On constructed riffle 5, the compacted gravel area downstream of the 150 transect line (Figures 11A-B) was unused by salmon.

Close proximity to cover seemed to be important to both chinook and coho salmon when building redds. Seventy percent of the redds of both coho and chinook were found within 10 meters of cover and 50% were found within 5 meters (Figures 6B-11B). Deep water holding areas seemed to be suitable cover as well as overhanging branches from riparian vegetation, underwater vegetation (riffle 3) and boulder groups. Riffle 4, the most used riffle, had a mixture of depth and vegetative cover that was apparently attractive to the

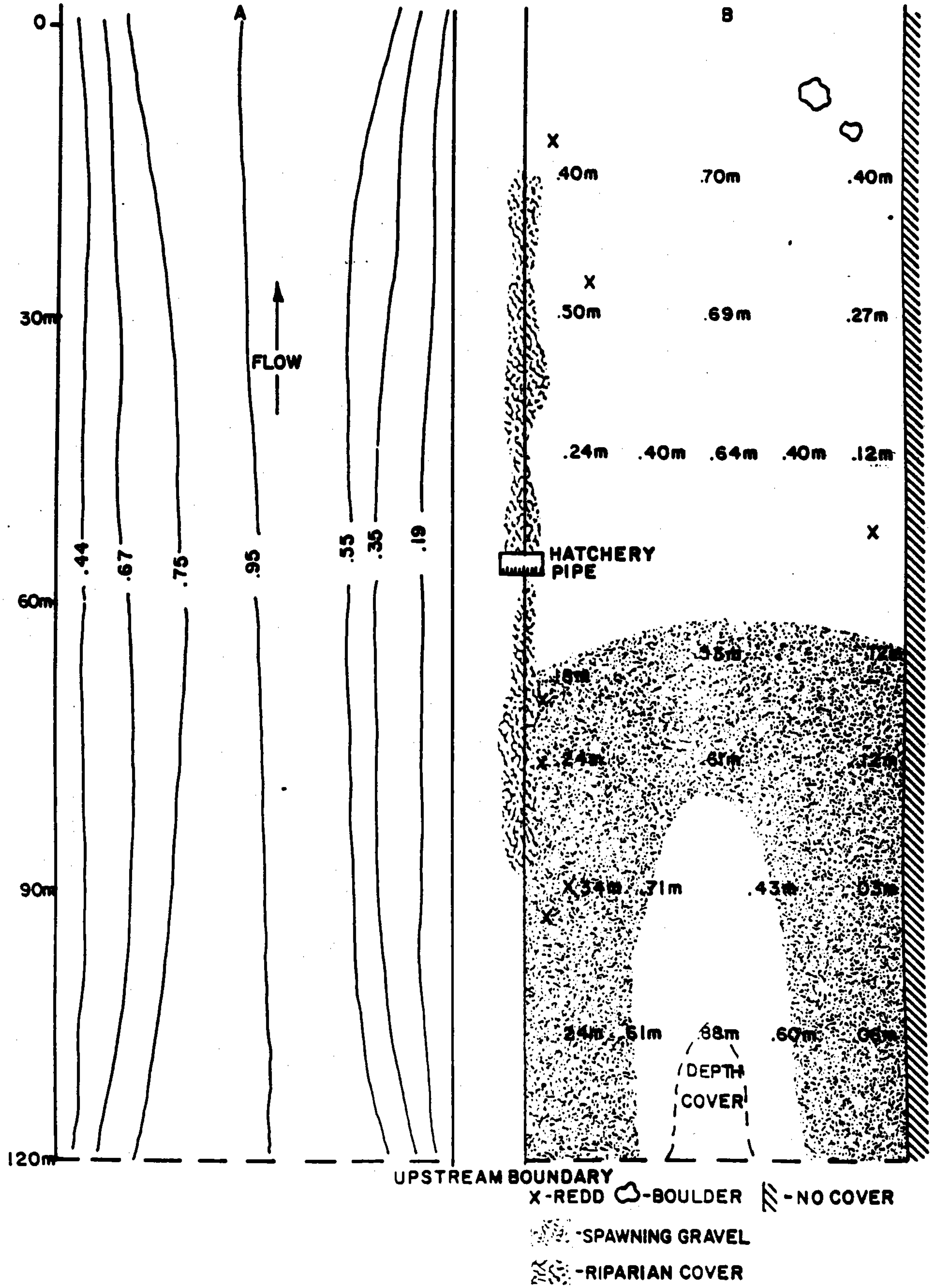


Figure 6A,B. Riffle 1, Trinity River, California. A) Velocity (m/sec) distribution isohyetal map. B) Depth (m) transects, cover, spawning gravel and redd locations.

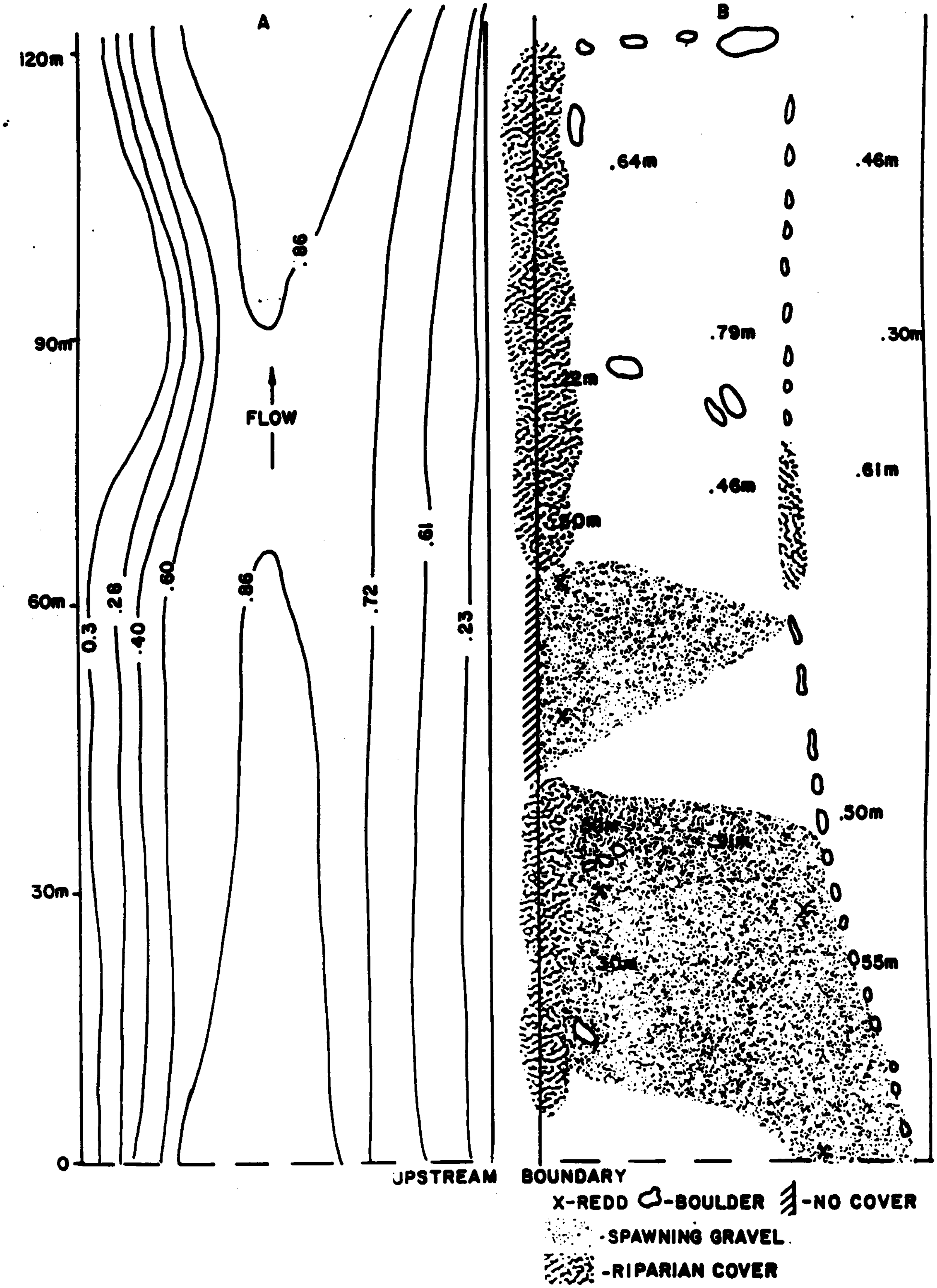


Figure 7A,B. Riffle 3, Trinity River, California. A) Velocity (m/sec) distribution isohyetal map. B) Depth (m) transects, cover, spawning gravel and redd locations.

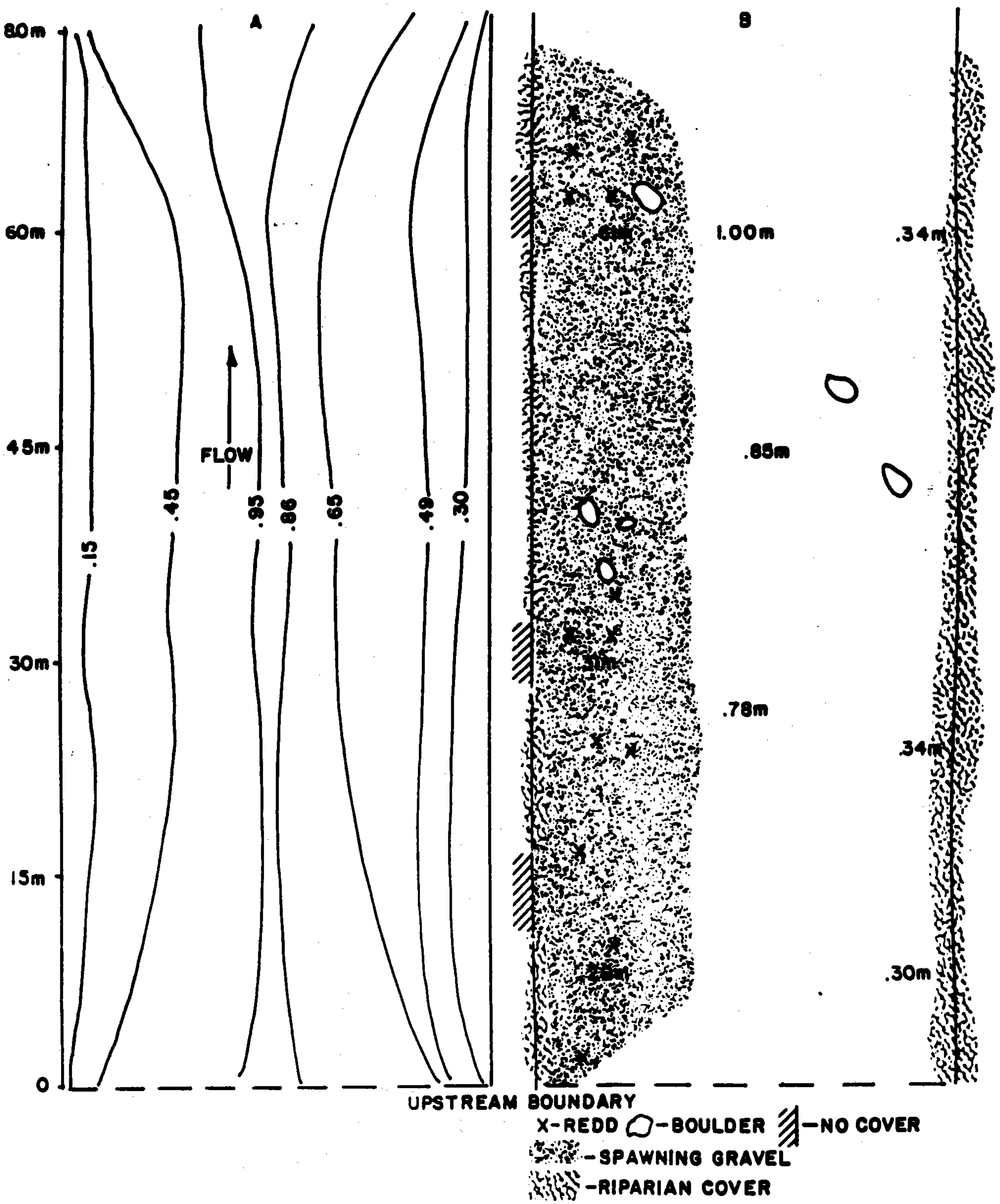


Figure 8A,B. Riffle A, Trinity River, California. A) Velocity (m/sec) distribution isohyetal map. B) Depth (m) transects, cover, spawning gravel and redd locations.

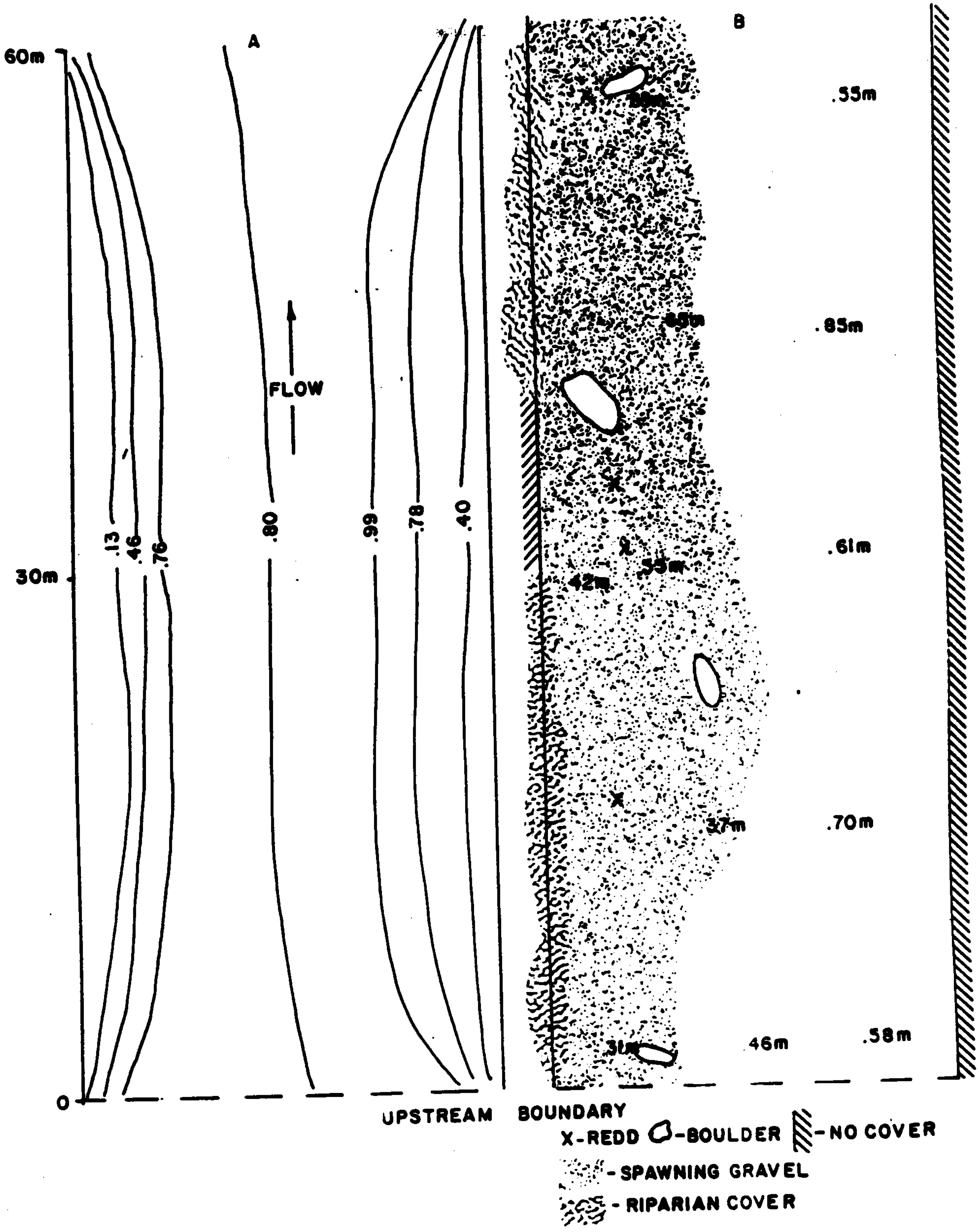


Figure 9A,B. Riffle B, Trinity River, California. A) Velocity (m/sec) distribution isohyetal map. B) Depth (m) transects, cover, spawning gravel and redd locations.

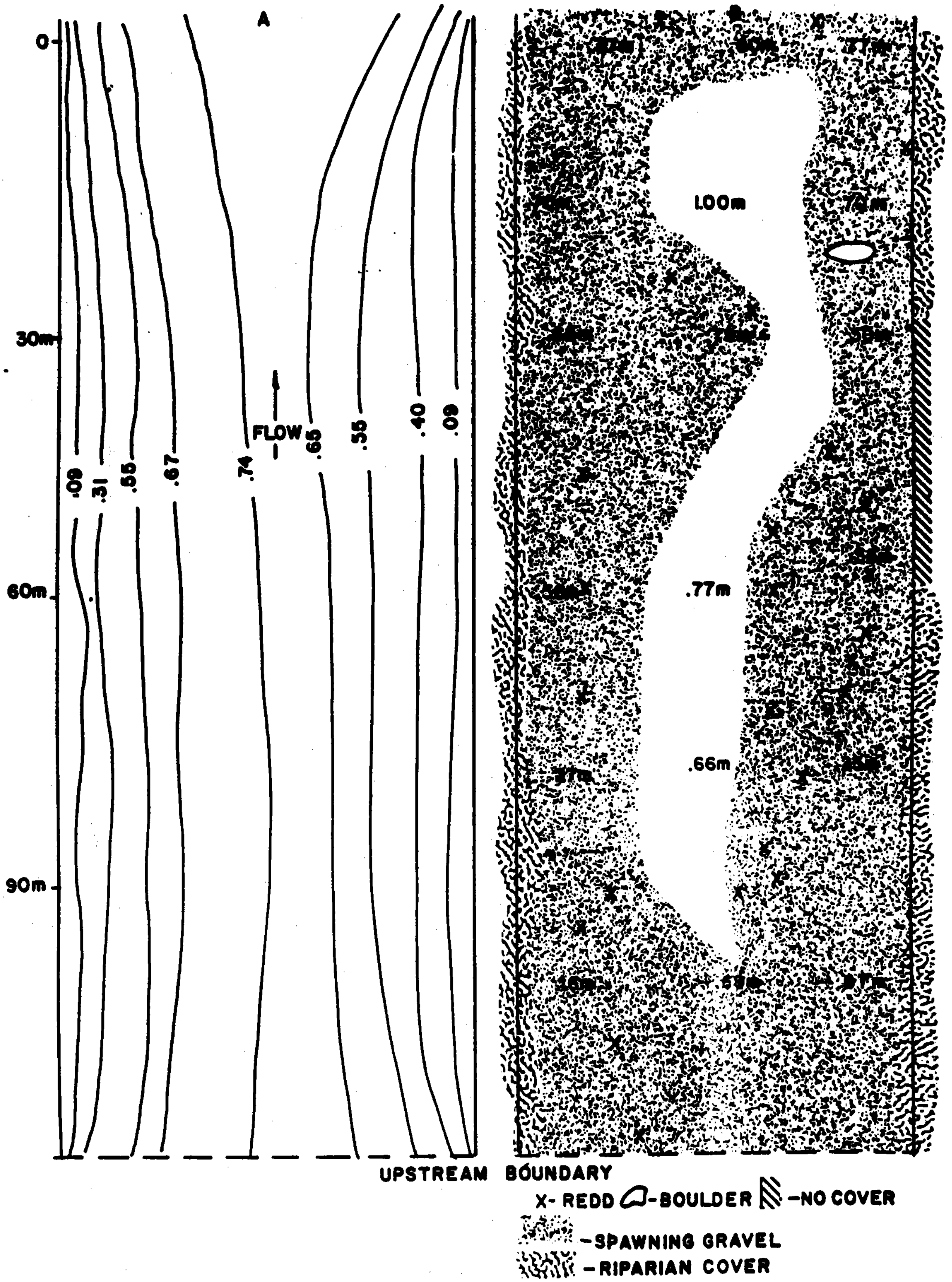


Figure 10A,B. Riffle 4, Trinity River, California. A) Velocity (m/sec) distribution isohyetal map. B) Depth (m) transects, cover, spawning gravel and redd locations.

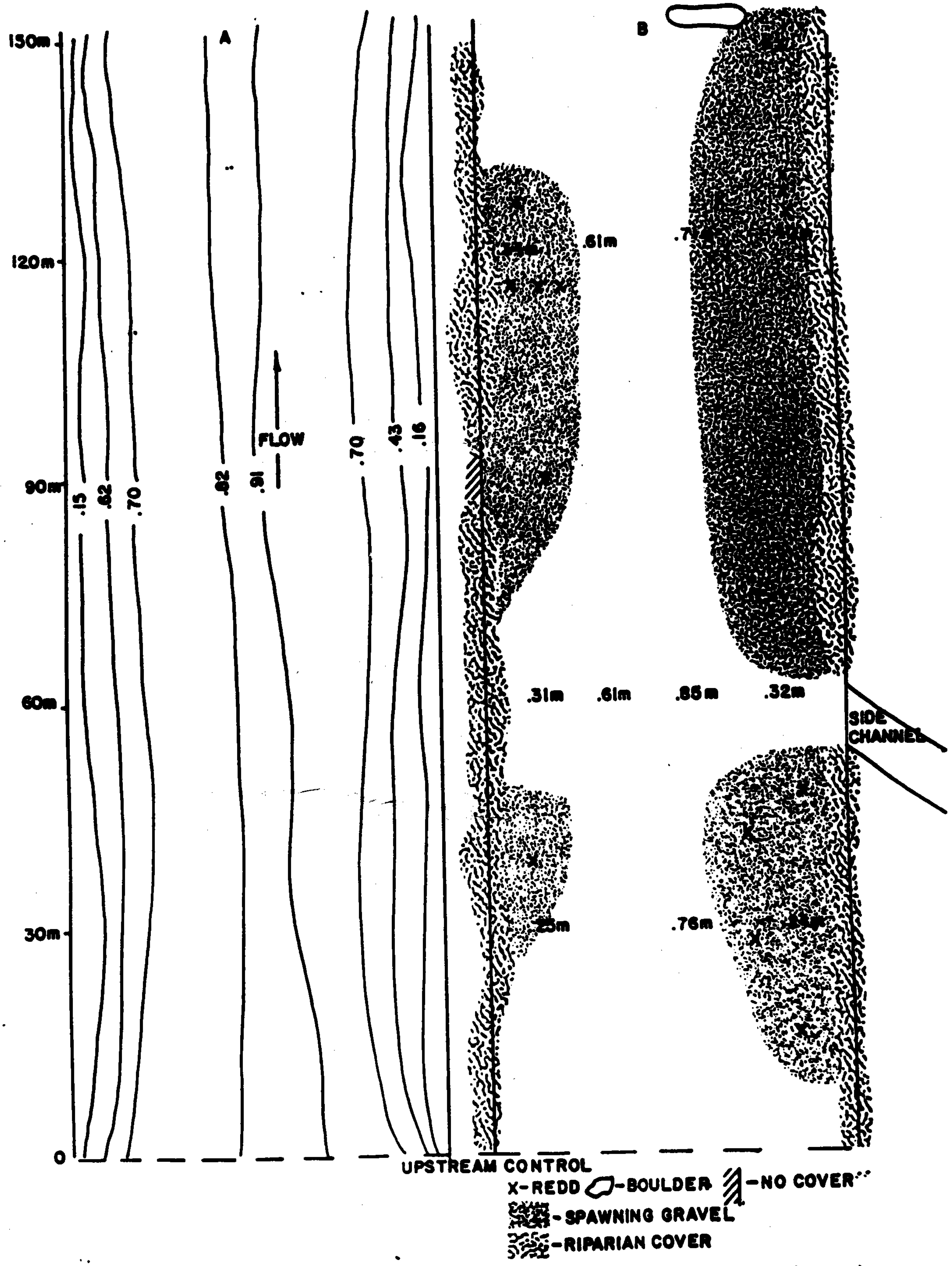


Figure 11A,B. Riffle 5, Trinity River, California. A) Velocity (m/sec) distribution isohyetal map. B) Depth (m) transects, cover, spawning gravel and redd locations.

salmon. Other studies have observed the importance of cover to both trout and salmon (Boussu 1954; Hourston and MacKinnon 1957; Johnson et al. 1966; Butler and Hawthorne 1968; Reiser and Wesche 1977).

## Conclusions and Recommendations

One purpose of this investigation was to determine the reason why some constructed riffles were being used and others not. Of the six riffles evaluated, Riffles A, 4 and 5 had the most spawner use. These three riffles seemed to have the most spawning gravel available at preferred velocities and depths in close proximity to cover. Riffle 1 was used extensively for a holding and rest area, but we detected comparatively few redds. There was adequate spawning gravel available, but not as many areas were close to cover as on riffles A, 4 and 5. Riffle 3 and B had sufficient spawning gravel which was not compacted, the depths and velocities seemed to be in the preferred range and cover was available near spawning areas. However, neither chinook nor coho salmon used these riffles significantly. A more in depth analysis of substrate, using the McNeil subsurface sampler, may help to determine why these riffles are not used. The placement of more gravel, boulder groups, and creating deeper areas on riffles 3, B and 1 should increase salmon utilization.

Another season of monitoring and evaluation of these riffles is recommended. With more spawning depth and velocity data, preference curves generated from a larger sample size would be more accurate. It is also recommended that McNeil subsurface substrate samples be collected at each riffle site to determine percent of fines and corresponding quality with the Fredle Index (Everest et al. 1982).

Appendix Table 1. Data summarization and frequency analysis for Trinity River chinook spawning velocities (n = 42).

| Velocity (ft./sec.) | Tally | Left Cluster* | Frequency | Right Cluster | Probability | Velocity (ft./sec.) |
|---|---|---|---|---|---|---|
| 0.1 | | | 0 | 0 | 0.0 | |
| 0.2 | | 1 | 0 | | | |
| 0.3 | 1 | | 1 | 1 | 0.17 | 0.35 |
| 0.4 | | 0 | 0 | | | |
| 0.5 | | | 0 | 2 | | |
| 0.6 | 11 | 4 | 2 | | | |
| 0.7 | 11 | | 2 | 5 | 0.67 | 0.65 |
| 0.8 | 111 | 7 | 3 | | | |
| 0.9 | 1111 | | 4 | 7 | | |
| 1.0 | 111 | 6 | 3 | | 1.0 | 1.15 |
| 1.1 | 111 | | 3 | 4 | | |
| 1.2 | 1 | 4 | 1 | | | |
| 1.3 | 111 | | 3 | 6 | | |
| 1.4 | 111 | 7 | 3 | | | |
| 1.5 | 1111 | | 4 | 5 | | |
| 1.6 | 1 | 1 | 1 | | | |
| 1.7 | | | 0 | 1 | | |
| 1.8 | 1 | 2 | 1 | | | |
| 1.9 | 1 | | 1 | 3 | | |
| 2.0 | 11 | 2 | 2 | | | |
| 2.1 | | | 0 | 0 | | |
| 2.2 | | 3 | 0 | | | |
| 2.3 | 111 | | 3 | 3 | 0.32 | 2.2 |
| 2.4 | | 2 | 0 | | | |
| 2.5 | 11 | | 2 | 3 | | |
| 2.6 | 1 | 2 | 1 | | | |
| 2.7 | 1 | | 1 | 2 | | |
| 2.8 | | 1 | 1 | | | |
| 2.9 | | | | | | |

*The left cluster was chosen for curve construction.

Appendix Table 2. Data summarization and frequency analysis for Trinity River chinook spawning depths (n = 42).

| Velocity (ft./sec.) | Tally | Left Cluster* | Frequency | Right Cluster | Probability | Velocity (ft./sec.) |
|---|---|---|---|---|---|---|
| 0.4 | | | 0 | 0 | | |
| 0.5 | | 1 | 0 | | | |
| 0.6 | 1 | | 1 | 3 | | |
| 0.7 | 11 | 6 | 2 | | 0.19 | 0.65 |
| 0.8 | 1111 | | 4 | 9 | | |
| 0.9 | ~~1111~~ | 0 | 5 | | | |
| 1.0 | | | 0 | 4 | | |
| 1.1 | 1111 | 6 | 4 | | | |
| 1.2 | 11 | | 2 | 6 | | |
| 1.3 | 1111 | 6 | 4 | | 1.0 | |
| 1.4 | 11 | | 2 | 3 | | 1.30 |
| 1.5 | 1 | 3 | 1 | | | |
| 1.6 | 11 | | 2 | 4 | | |
| 1.7 | 11 | 6 | 2 | | | |
| 1.8 | 1111 | | 4 | 5 | | |
| 1.9 | 1 | 4 | 1 | | | |
| 2.0 | 111 | | 3 | 6 | | |
| 2.1 | 111 | 3 | 3 | | | |
| 2.2 | | | 0 | 0 | | |
| 2.3 | | 0 | 0 | | 0.42 | 2.20 |
| 2.4 | | | 0 | 2 | | |
| 2.5 | 11 | 2 | 2 | | | |

*The left cluster was chosen for curve construction.

Appendix Table 3. Data summarization and frequency analysis for Trinity River coho spawning velocities (n = 32).

| Velocity (ft./sec.) | Tally | Left Cluster* | Frequency | Right Cluster | Probability | Velocity (ft./sec.) |
|---|---|---|---|---|---|---|
| 0.1 | | | 0 | 0 | | |
| 0.2 | | 1 | 0 | | | |
| 0.3 | 1 | | 1 | 2 | | |
| 0.4 | 1 | 1 | 1 | | 0.18 | 0.35 |
| 0.5 | | | 0 | 2 | | |
| 0.6 | 11 | 3 | 2 | | | |
| 0.7 | 1 | | 1 | 2 | | |
| 0.8 | 1 | 3 | 1 | | 0.55 | 0.75 |
| 0.9 | 11 | | 2 | 4 | | |
| 1.0 | 11 | 7 | 2 | | | |
| 1.1 | ~~1111~~ | | 5 | 8 | 1.0 | 1.15 |
| 1.2 | 111 | 4 | 3 | | | |
| 1.3 | 1 | | 1 | 2 | | |
| 1.4 | 1 | 3 | 1 | | | |
| 1.5 | 11 | | 2 | 3 | 0.55 | 1.55 |
| 1.6 | 1 | 3 | 1 | | | |
| 1.7 | 11 | | 2 | 2 | | |
| 1.8 | | 0 | 0 | | | |
| 1.9 | | | 0 | 0 | | |
| 2.0 | | 0 | 0 | | | |
| 2.1 | | | 0 | 1 | | |
| 2.2 | 1 | 2 | 1 | | | |
| 2.3 | 1 | | 1 | 3 | | |
| 2.4 | 11 | 3 | 2 | | | |
| 2.5 | 1 | | 1 | 1 | | |
| 2.6 | | 0 | 0 | | | |
| 2.7 | | | 0 | 0 | 0.16 | 2.55 |
| 2.8 | | 0 | 0 | | | |
| 2.9 | | | 0 | 1 | | |
| 3.0 | 1 | 1 | 1 | | | |
| 3.1 | | | 0 | 0 | | |
| 3.2 | | 1 | 0 | | | |
| 3.3 | 1 | | 1 | 1 | | |

*The left cluster was chosen for curve construction.

Appendix Table 4. Data summarization and frequency analysis for Trinity River coho spawning depths (n = 32).

| Velocity (ft./sec.) | Tally | Left Cluster* | Frequency | Right Cluster | Probability | Velocity (ft./sec.) |
|---|---|---|---|---|---|---|
| 0.2 | | | 0 | | | |
| 0.3 | | | 0 | 0 | | |
| 0.4 | 1 | 1 | 1 | | 0.24 | 0.35 |
| 0.5 | 1 | | 1 | 2 | | |
| 0.6 | 1 | 2 | 1 | | | |
| 0.7 | | | 0 | 1 | 0.48 | 0.65 |
| 0.8 | 11 | 2 | 2 | | | |
| 0.9 | 1 | | 1 | 3 | | |
| 1.0 | 111 | 4 | 3 | | | |
| 1.1 | 111 | 5 | 3 | 6 | | |
| 1.2 | 11 | | 2 | | | |
| 1.3 | 1 | 3 | 1 | 3 | 1.0 | 1.35 |
| 1.4 | 11 | | 2 | | | |
| 1.5 | 1 | 3 | 1 | 3 | | |
| 1.6 | 11 | | 2 | | | |
| 1.7 | 1111 | 6 | 4 | 6 | | |
| 1.8 | 11 | | 2 | | | |
| 1.9 | 11 | | 2 | 4 | | |
| 2.0 | 1 | 3 | 1 | | | |
| 2.1 | 1 | | 1 | 2 | | |
| 2.2 | | 1 | 0 | | 0.36 | 2.2 |
| 2.3 | | | 0 | 0 | | |
| 2.4 | | 0 | 0 | | | |
| 2.5 | 11 | 2 | 2 | 2 | | |
| 2.6 | | | | | | |
| 2.7 | | | | | | |
| 2.8 | | | | | | |

*The left cluster was chosen for curve construction.

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