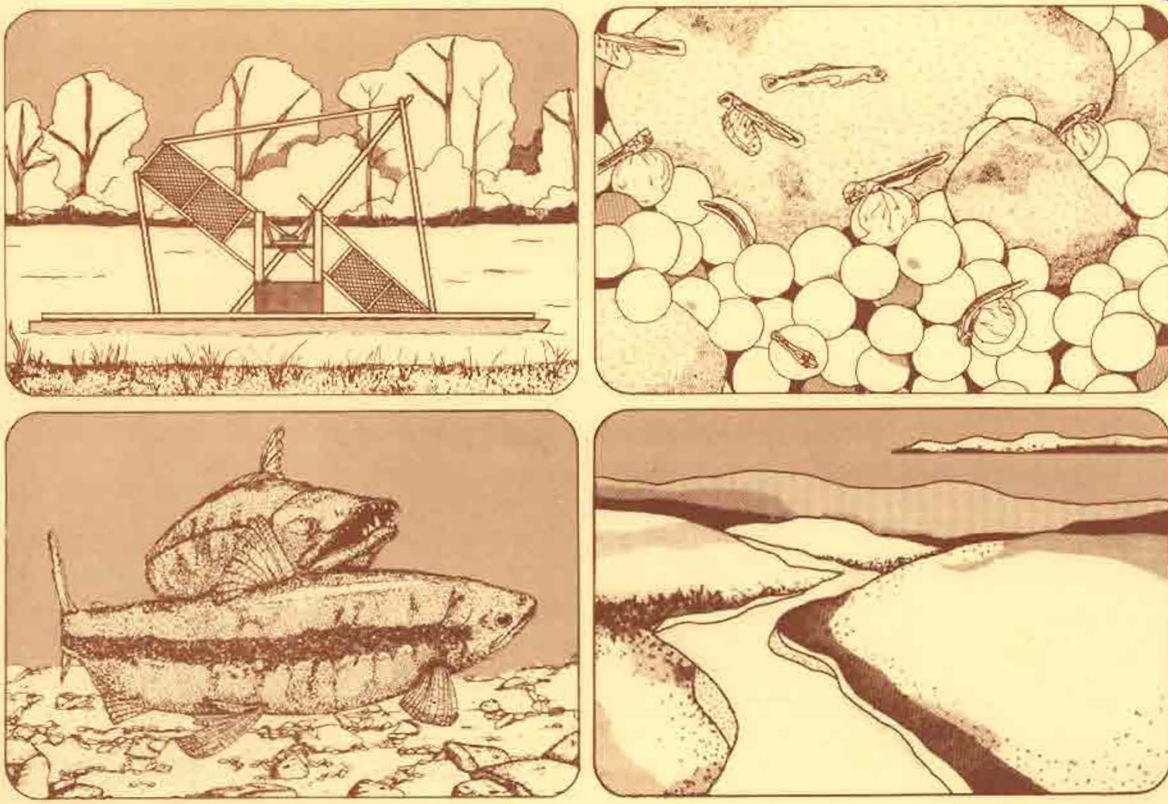

ALASKA DEPARTMENT OF FISH AND GAME
SUSITNA HYDRO AQUATIC STUDIES REPORT SERIES

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ALASKA DEPARTMENT OF FISH AND GAME
SUSITNA HYDRO AQUATIC STUDIES

REPORT NO. 2

RESIDENT AND JUVENILE ANADROMOUS FISH INVESTIGATIONS (MAY - OCTOBER 1983)

Edited by:

Dana C. Schmidt
Stephen S. Hale
Drew L. Crawford
Paul M. Suchanek

Prepared for:

Alaska Power Authority
334 W. Fifth Avenue, Second Floor
Anchorage, Alaska 99501

July 1984

NOTICE

ANY QUESTIONS OR COMMENTS CONCERNING THIS REPORT SHOULD BE DIRECTED TO THE ALASKA POWER AUTHORITY SUSITNA PROJECT OFFICE

PREFACE

This report is one of a series of reports prepared for the Alaska Power Authority (APA) by the Alaska Department of Fish and Game (ADF&G) to provide information to be used in evaluating the feasibility of the proposed Susitna Hydroelectric Project. The ADF&G Susitna Hydro Aquatic Studies program was initiated in November 1980. Beginning with the reports for the 1983 open water season, all reports will be sequentially numbered as part of the Alaska Department of Fish and Game Susitna Hydro Aquatic Studies Report Series.

TITLES IN THIS SERIES

Report Number	Title	Publication Date
1	Adult Anadromous Fish Investigations: May - October 1983	April 1984
2	Resident and Juvenile Anadromous Fish Investigations: May - October 1983	July 1984
3	Aquatic Habitat and Instream Flow Investigations: May - October 1983	1984
4	Access and Transmission Corridor Aquatic Investigations: May - October 1983	1984

Questions concerning this report should be directed to:

Alaska Power Authority
334 W. 5th Avenue
Anchorage, Alaska 99501
Telephone (907) 276-0001

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INTRODUCTION

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Part 2. The Distribution and Relative Abundance of Juvenile Salmon in the Susitna River Drainage Above the Chulitna River Confluence.

Part 3. Juvenile Salmon Rearing Suitability Criteria.

Part 4. Juvenile Salmon Rearing Habitat Models.

Part 5. Resident Fish Distribution and Population Dynamics in the Susitna River Below Devil Canyon.

Part 6. Resident Fish Habitat Studies.

Part 7. Modelling of Juvenile Salmon and Resident Fish Habitat.

INTRODUCTION TO REPORT NO. 2

This volume of the series includes juvenile salmon and resident species studies conducted during the period May to October, 1983. The majority of these studies took place in the Susitna River reach between the Chulitna River confluence and Devil Canyon, but a small amount of sampling (primarily for resident species) was conducted below the Chulitna River confluence.

We have used a format for presenting the 1983 data which is different from that of previous years. The studies are organized into individual papers (Parts 1 to 7) which are essentially complete reports by themselves. The papers contain summary tables and figures; no long appendices of raw field data are included. Printouts of the raw data or access to computer files of raw data are available upon request.

There are four general categories of studies included in this volume. The first category covers basic distribution and relative abundance information on each species, similar to the studies from previous years. This information is contained in Part 2 for juvenile salmon species and in Part 5 for resident species. However, the emphasis this year is on distribution by macrohabitat type. This frequency of use data may be coupled with the total surface areas of these macrohabitat types at different levels of discharge (which is being compiled by Trihey and Associates) to provide an estimate of the habitat potential of the reach. Another difference is that the apparent causes of the observed distributions are analyzed in greater detail than in reports from previous years.

The second category of studies includes movement and migration data. Information on the outmigration of juvenile salmon is contained in Part 1 and data on movement and migration of resident species can be found in Part 5. With an eye toward new technology, we used a battery-powered portable microcomputer to store data on outmigrating salmon. This eliminated several steps in the process of transferring field data to the final computer data base and also reduced the number of data processing errors. Radio-tagging of selected resident species made it possible to determine the amount of time these fish spend in each macrohabitat type; this information can be used in determining the relative value of each macrohabitat type for the species. Radiotelemetry also made it possible to track resident species to their spawning areas and then obtain data on spawning habitat.

The third category of studies included in this volume covers population dynamics, including population estimates. A new technique which yielded interesting results was used this year to obtain population estimates and percent survival information for chum and sockeye salmon juveniles. We captured newly-emergent chum and sockeye salmon at their natal areas and tagged them with coded wire tags. A sample of the fish were subsequently recaptured in two downstream migrant traps. This work is described in Part 1. Population estimates for several species of resident fishes were attempted using a capture-recapture technique.

These data were analyzed by the CAPTURE computer program which calculated capture probabilities and maximum likelihood estimates of population size (Part 5). A version of this model was implemented on a portable microcomputer so that biologists would have on-site verification that the juvenile salmon sampling techniques were providing appropriate capture probabilities (Part 2).

The fourth and most emphasized category of studies includes the habitat relationships of each species. The primary factors examined in these studies are discharge and the relation of species/life stages to discharge-influenced variables such as depth and velocity. However, other variables, especially cover, are also examined. The influences of habitat parameters on juvenile salmon outmigration is examined in Part 1 and the effect of habitat variables on the distribution and relative abundance of juvenile salmon is covered in Part 2. Habitat data for spawning resident species are presented in Part 6. Suitability criteria curves for several variables are developed for juvenile salmon in Part 3 and for resident species in Part 6.

These suitability criteria are used in habitat models described in Part 4 and Part 7. Results of the Instream Flow Group (IFG) hydraulic models in simulating habitat (weighted useable area) are presented in Part 7. In Part 4, we develop a new kind of habitat model which requires significantly less field data collection than the IFG models and which runs on a microcomputer rather than the mainframe. These two kinds of models are evaluated and compared in Part 7. Finally, Part 7 discusses the implications of the models and all the other data in determining the instream flow requirements of juvenile salmon and resident species.

PART 1

The Outmigration of Juvenile Salmon from the Susitna River Above the Chulitna River Confluence

THE OUTMIGRATION OF JUVENILE SALMON FROM THE SUSITNA RIVER ABOVE THE CHULITNA RIVER CONFLUENCE

1984 Report No. 2, Part 1

by Kent J. Roth, Daniel C. Gray, and Dana C. Schmidt

Alaska Department of Fish and Game
Susitna Hydro Aquatic Studies
2207 Spenard Road
Anchorage, Alaska 99503

ABSTRACT

Population estimates of juvenile salmon were obtained by mark-recapture using a unique application of the coded wire tagging technique during 1983. One-half length coded wire tags were used to mark 24,287 post-emergent chum and 17,963 post-emergent sockeye salmon fry at four sloughs and one tributary of the Susitna River between the Chulitna River confluence and Devil Canyon. Tag retention rates averaged 96% and total mortalities caused by the capture and tagging procedure were 1%. Sixty-two coded wire tagged chum salmon fry and 394 tagged sockeye salmon fry were recovered in two downstream migrant traps located in the Susitna River five miles above the Chulitna River confluence. The mark-recapture estimates indicated that 3,322,000 chum salmon fry and 560,000 sockeye salmon fry migrated downstream past the outmigrant traps during 1983. Estimated survival rates between potential egg deposition and outmigration for chum and sockeye salmon fry were 14% and 41%, respectively. The downstream migrant traps collected all five species of Pacific salmon during the open water period. Pink salmon trap catches were highest in early June, and peak outmigration of chum salmon occurred in mid June. Chinook, coho, and sockeye salmon juveniles were collected at the traps throughout the sampling season, with peaks occurring during high mainstem discharge levels in early June, early July, and mid August. The rate of outmigration of chum salmon showed a higher correlation with discharge than that of other species.

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1.0 INTRODUCTION

Since November 1980, studies of the distribution, relative abundance and timing of outmigration of juvenile salmon in the Susitna River have been part of the Susitna Hydro Aquatic Studies program. A portion of these studies have been directed towards determining the interactions of outmigrating juvenile salmon with their habitat to provide the data necessary to predict their response to environmental changes associated with hydroelectric development. This report presents the results of the juvenile salmon outmigration studies conducted on the Susitna River between the Chulitna River confluence and Devil Canyon during the open water period of 1983. Five Pacific salmon species are addressed in this report: sockeye (Oncorhynchus nerka), chum (O. keta), chinook (O. tshawytscha), coho (O. kisutch), and pink (O. gorbuscha).

Previous distribution and abundance studies of juvenile salmon in the Susitna River were conducted by Barrett (1974), Friese (1975), and Riis and Friese (1978) as part of preliminary environmental assessments of the proposed hydroelectric development. Juvenile salmon life histories including outmigration timing have also been studied on the Susitna River (ADF&G 1981, 1983b, 1983c) and its major tributary streams including the Deshka River (Delaney et al. 1981), Willow Creek (Engel and Watsjold 1978) and Montana and Rabideux creeks (Kubik and Wadman 1978).

The effects of discharge fluctuations on juvenile salmon during the periods of incubation, emergence and outmigration have been reported by White (1939), Neave (1953), Gangmark and Broad (1956), Wickett (1958), Andrew and Geen (1960), and McNeil (1966). Other factors affecting survival and timing of outmigration include the size of smolts (Foerster 1937 and Barnaby 1944), predation (Neave 1953; Roos 1958; Hunter 1959; and Thompson 1964), and water temperature (Foerster 1968 and McCart et al. 1980). Changes in photoperiod have also been reported to influence the timing of juvenile salmon outmigration (Hunter 1959; McDonald 1960; Burgner 1962; Heard 1964; and Hartman et al. 1967).

To provide a clearer understanding of the relationship between present production and natural changes in habitat conditions of the Susitna River, a portion of the 1983 aquatic studies were directed toward quantifying the rates of survival and the rates and timing of outmigration of juvenile salmon in the Susitna River between the Chulitna River confluence and Devil Canyon.

Specific objectives of this portion of the 1983 program were as follows:

A. Estimate the current numbers of chum and sockeye salmon juveniles outmigrating from the study reach.

B. Estimate the egg-to-outmigrant survival for chum and sockeye salmon for the period spent in the study area under present environmental conditions.

C. Determine the periods of freshwater residence and the timing of outmigration for all species of juvenile salmon in the study area and the relationship of outmigration and habitat parameters.

D. Continue the collection of biological data including species, age class and length frequency distribution to determine the condition and stage of development for each species during outmigration.

E. Provide descriptions of the variability of biological development and outmigration behavior among the different species and within a given species.

Data were collected at downstream migrant traps in 1983 to determine the outmigration timing windows and periods of freshwater residence for juvenile salmon (objectives C, D and E). Information was also collected on the migration and redistribution of juvenile resident fish species within the study reach (See Part 5 of this Report).

A coded wire tag, mark-recovery program was initiated during 1983 to estimate the population size and survival rate of juvenile sockeye and chum salmon during the period they spend above the outmigrant traps (Objectives A and B). These population estimates may be compared with estimates of egg production in order to calculate survival rates for sockeye and chum salmon during the period of freshwater residence in the study area. By correlating survival rates with habitat conditions at the individual study sites, it is possible to evaluate the contribution that these sites make to the overall production of chum and sockeye salmon outmigrants from this reach.

The coded wire tagging program will also assist in determining the viability and importance of sockeye salmon stocks between the Chulitna River confluence and Devil Canyon. Although not an integral part of this study, the future recovery of tagged adult salmon will provide definitive evidence concerning the contribution of sockeye salmon spawning in this reach of river to the number of returning adults.

Through the continued monitoring of the survival and distribution of existing stocks as a function of natural environmental changes, more accurate predictions can be made on the subsequent effects of habitat changes on juvenile salmon production in this reach of river. Continued monitoring will also provide weighted values for the different species during certain critical periods of their freshwater residence. This data coupled with data collected by other portions of the Susitna Hydro Aquatic Studies program will assist in developing mitigation requirements necessary to maintain existing salmon stocks.

2.0 METHODS

2.1 Study Locations

The coded wire tag deployment sites and tag recovery sites are shown in Figure 1. Coded wire tagging sites were selected from locations which had previous high density spawning history (ADF&G 1983a), and from surveys of the availability of sufficient numbers of post-emergent chum and sockeye salmon for collection and tagging. The tagging sites were Sloughs 8A (RM 125.3), 9 (RM 129.2), 11 (RM 135.3), and 21 (RM 142.0), and one tributary site at the mouth of Indian River (RM 138.6). Tag recovery efforts were conducted at two downstream migrant traps located on opposite banks of the mainstem Susitna River at RM 103.0. Dye marking and data collection on outmigrant rates were conducted at Slough 11 and Slough 21.

2.2 Field Data Collection

2.2.1 Coded wire tagging

The sample sizes required to provide valid population estimates for each species were calculated prior to the tagging program using the estimator provided by Robson and Regier (1964). The actual numbers of fish tagged for each species was ultimately determined by the availability of fish at the collection sites and the time constraints of the field program.

The coded wire tagging program was conducted by five fisheries personnel based at the Gold Creek camp (RM 136.8) from May 16 through June 19, 1983. Tagging operations were conducted mainly at the individual collection sites, and the primary tagging equipment and personnel were staged in a six-man portable wall tent. However, if logistical or equipment problems occurred, the fish to be tagged were transported from the collection area to the base camp and then returned to the collection site for release following tagging.

The primary fisheries collection techniques were beach seines, dipnets, and backpack electrofishing units. Beach seines were used to weir off the downstream end of the study site and were checked periodically to collect fish and remove debris (Plate 1). Beach seining, dipnetting, and backpack electrofishing supplemented the weir catches at sites where weiring did not provide enough fish for the tagging operation or at those sites where the weirs were not deployable.

The coded wire tagging equipment was leased from Northwest Marine Technology, Inc. of Shaw Island, Washington, and operated in accordance with the manufacturer's instructions and operation manuals. The leased equipment was the NMT MK2A tagging unit and included the following:

- Coded wire tag injector with 1/2 length tag capability
- Quality Control Device (QCD)
- Water pump
- Portable power supply

The equipment was field portable and included a more compact prototype of the standard quality control device.

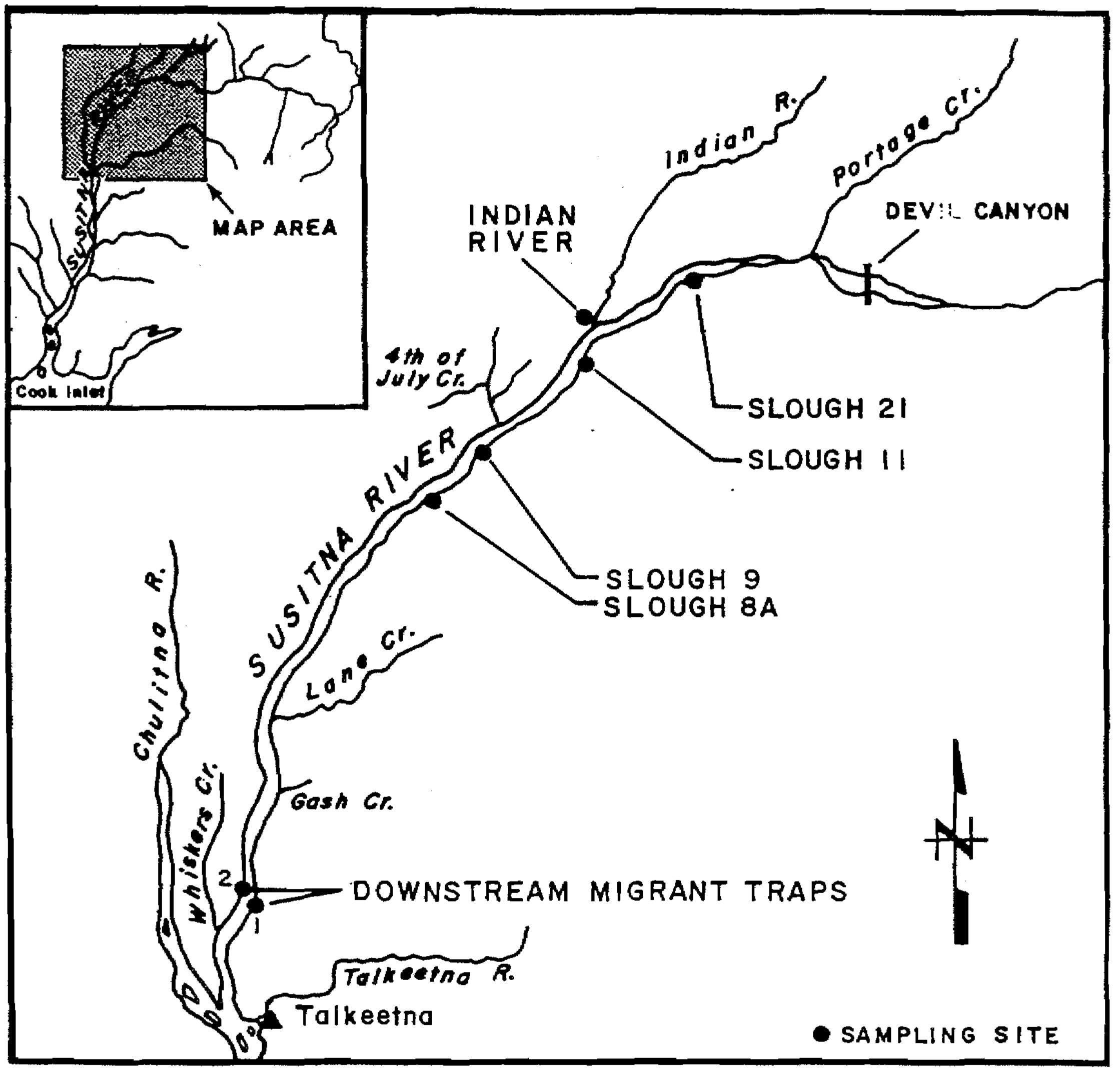

Figure 1. Map of the Susitna River from Talkeetna upstream to Devil Canyon showing the coded wire tag deployment and recovery sites.

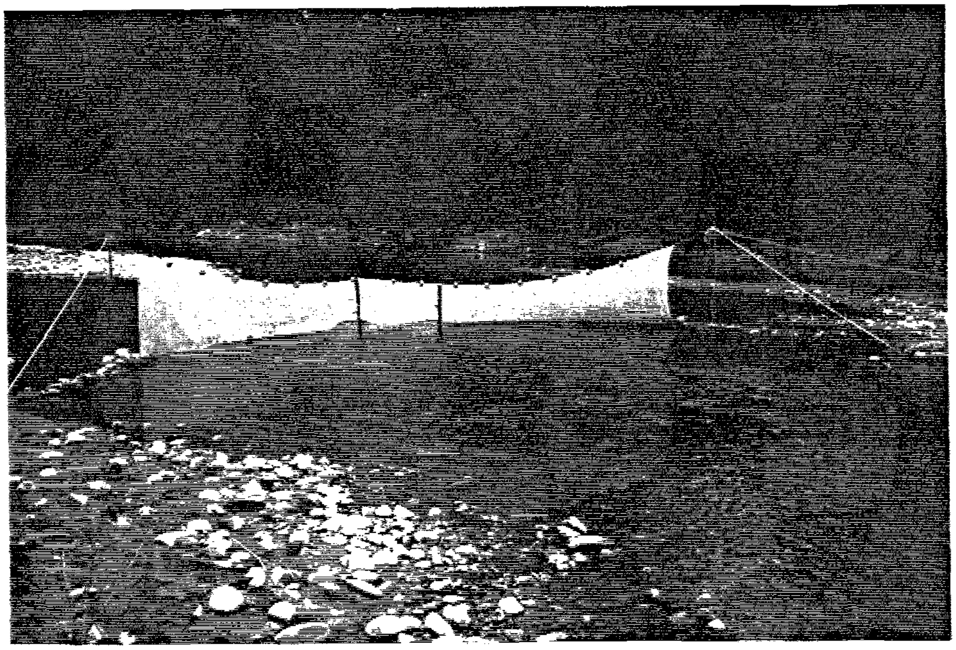

Plate 1. A weir set near the mouth of Slough 8A (RM 125.3) to collect outmigrating chum and sockeye salmon fry for coded wire tagging, 1983.

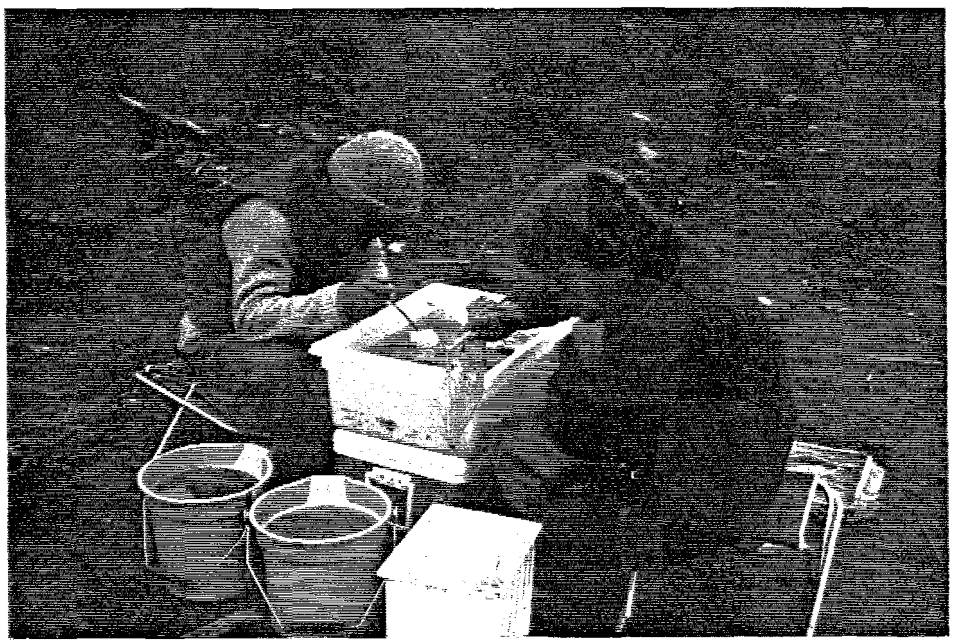

Plate 2. Separation of salmon fry by species and length prior to the implantation of coded wire tags, 1983.

One-half length binary coded wire tags measuring 0.02 inches (0.533 mm) long and 0.01 inches (0.254 mm) in diameter were obtained from Northwest Marine Technologies, Inc. The one-half length tags were used due to the small size of the fish to be tagged. The total length of post emergent chum salmon averaged 40 mm (1,500 fry/lb) and the total length of sockeye fry averaged 32 mm (3,000 fry/lb). Tag injector head molds were constructed by the manufacturer from samples of fish of the species and size ranges to be tagged.

The coded wire tag implantation procedures were similar to those outlined by Moberly et al. (1977) and Koerner (1977). The captured fish were separated by species and length prior to tagging (Plate 2), as physical differences between fish required the use of separate head molds for each species and length class. A sample of 50 fish of each group was measured for total length to determine the proper headmolds for the tagging procedure. The adipose fin was clipped from each fish prior to tagging to provide a visual indicator to the presence of a coded wire tag during recovery efforts. At the end of each tagging day, a subsample of 100 tagged fish were anesthetized and passed through the quality control device to determine the tag retention rate. Mortalities were recorded the following day. All tagged fish were released at the sites of collection. The number of valid tagged fish was determined daily by subtracting the number of mortalities from the number of total tagged fish and then multiplying this by the tag retention rate.

Only one tag code was used for a given site during a single tagging period, which ranged from one to six days. The same tag code was used for both sockeye and chum salmon fry at a site during each tagging period, but physical differences between fish required the use of separate head molds for each species and length class. Up to three different code groups were used at a single collection site during the entire program with a minimum of ten days separating the releases of different tag codes at the same site.

2.2.2 Downstream migrant traps

A two to three person crew recovered coded wire tagged fish using two downstream migrant traps (Plate 3) operated at Talkeetna Station on the mainstem Susitna River (RM 103.0), 23 miles downstream from the nearest coded wire tagging site (Figure 1). The traps were operated off the east bank (Trap 1) and the west bank (Trap 2) of the river on a continuous 24 hour schedule from May 18 through August 30, with short periods of down time due to high water and debris, manpower limitations, and trap repair. The traps were checked from two to nine times daily, depending on the capture rate and the debris load. The traps were operated on an abbreviated schedule during September. A description of the inclined plane traps is presented in the FY84 procedures manual (ADF&G 1984).

Trap fishing depths and distances from shore were adjusted to maximize catches and minimize mortalities. All juvenile fish captured were anesthetized using MS-222 (Tricaine methanesulfonate). Field specimens were identified using the guidelines set forth by Trautman (1973),

Plate 3. The east bank downstream migrant trap at its fishing location on the mainstem Susitna River at River Mile 103.0, 1982.

McConnell and Snyder (1972) and Morrow (1980). Chum and sockeye salmon juveniles having an adipose fin clip were passed through a Northwest Marine Technologies FSD-1 field sampling detector to verify the presence of a coded wire tag. The detector sensed the magnetic field emitted by the tag and provided an auditory cue when a tagged fish was passed through. All coded wire tagged fish recovered at the traps were preserved in 10% formalin for later tag removal and decoding. All other fish were retained until anesthetic recovery was complete and then released downstream of the traps.

Daily habitat data measured at the downstream migrant traps were air and surface water temperatures (°C), turbidity (NTU), pH, dissolved oxygen (ppm), specific conductance (umho/cm), water velocity (ft/sec), and mainstem stage data. The equipment and methods used to collect and measure the habitat data are contained in the FY84 procedures manual (ADF&G 1984).

Scales were collected from a sample of juvenile fish captured in the traps for comparison with length frequency data for final age determinations. Scales were placed between two microscope slides, and age determination from the collected scale samples was conducted at the end of the field season with a Micron 780 portable microfiche reader using the guidelines provided by Mosher (1969) and Lux (1971).

2.2.3 Dye marking

Bismark Brown dye was used to mark a portion of the juvenile salmon collected at the coded wire tagging sites to determine the dye retention rates and the ability to observe the dye mark on recovered fish. The fish were soaked for 30 minutes in a solution of one gram of dye for each 30 liters of water.

The dye was also used in conjunction with coded wire tagging on chum salmon fry in a pilot study to determine the feasibility of providing population estimates of outmigrating fry from individual sites. The mark and recovery experiment was conducted over a three day period using the guidelines set forth by Ricker (1975).

Fish were collected in a beach seine set across the lower portion of Slough 11. On the first day, captured chum fry were coded wire tagged and then dyed and released. Marked fish were randomly distributed in the study site above the collection net. All chum collected on the second day were checked for marks. Unmarked fish were dyed and then released with the previously marked fish. On the third day, captured chum fry were separated into the following groups and totaled: coded wire tagged and dyed fish, dyed fish with no coded wire tag, and unmarked fish. All fish were released at the end of the experiment. Outmigration rates were also monitored during six 24-hour periods at sloughs 11 and 21 using beach seines set across the lower portions of each site.

2.3 Data Recording

2.3.1 Coded wire tagging

Coded wire tagging data recorded at each site included species, mean total length, numbers of fish tagged, percent tag retention, and mortality. Date, tag code, and time of release were also recorded. Total numbers of fish tagged by species, collection site, and release date as well as final tag retention and mortality were tabulated for each code group. Total valid tagged fish were determined by subtracting the mortalities for each days tagging from the total number of fish tagged and then multiplying this by the tag retention rate.

2.3.2 Downstream migrant traps

Biological data collected at the downstream migrant traps included catch by species, age class, total length, presence of a coded wire tag, fate, and scale sampling. Up to 50 fish of each species and age class were measured for total length (tip of snout to tip of tail) in millimeters (mm) daily and all remaining fish were tallied for total catch. Trap depth and distance from shore were recorded for each trap at every check. All other habitat parameters (Section 2.2.2) were measured once daily. Refer to Appendix A for a discussion of the sampling selectivity of the traps.

Biological and habitat data were entered in the field directly into an Epson HX-20 microcomputer which provided a magnetic tape and paper printout of the data. Operational procedures for the microcomputer and the associated data form program are presented in the FY84 procedures manual (ADF&G 1984). Computer entries were made for each trap check throughout the field season. Printouts and cassettes were periodically transferred to Data Processing. These data were then transferred to a mainframe computer for later data retrieval and analysis.

Coded wire tags were dissected from preserved fish at the end of the field season and were decoded using a reading jig and an American Optical binocular microscope (Plates 4 and 5).

2.3.3 Dye Marking

Total numbers of dyed fish, date of release, date of recapture, and periods of dye retention were recorded.

2.4 Data Analysis

2.4.1 Population and survival estimates

Potential egg deposition refers to the total number of eggs carried upstream by a given spawning run and is determined by multiplying the average fecundity by the number of female spawners. The estimated number of young fish emigrating from the study reach is expressed as a percentage of the potential egg deposition and represents the percentage survival between these points in the life cycle.

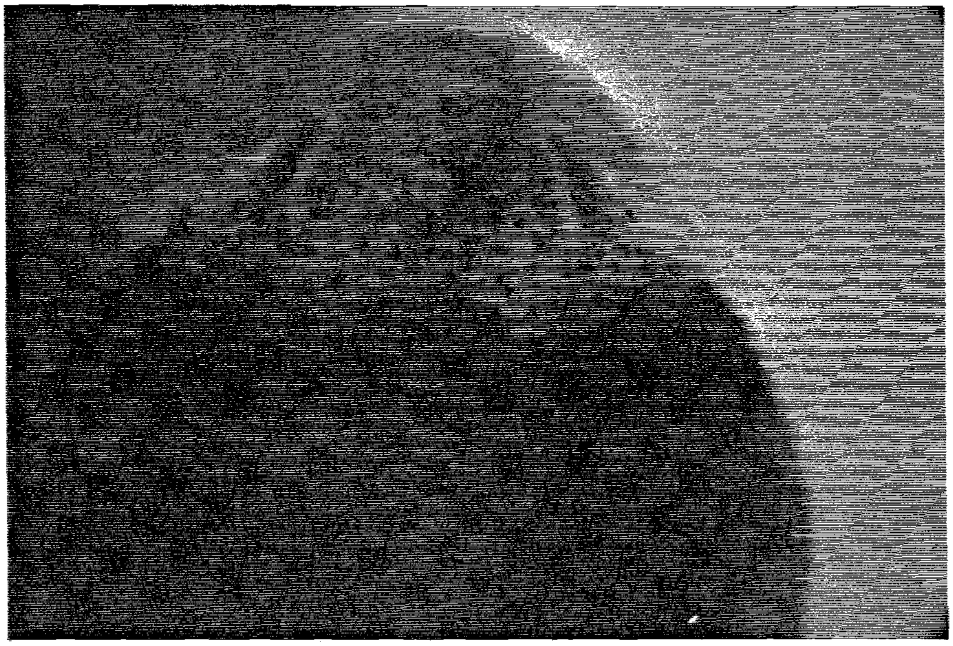

Plate 4. A dorsal view of a one-half length coded wire tag (arrow) in the snout of a sockeye salmon fry recovered in the downstream migrant traps, 1983.

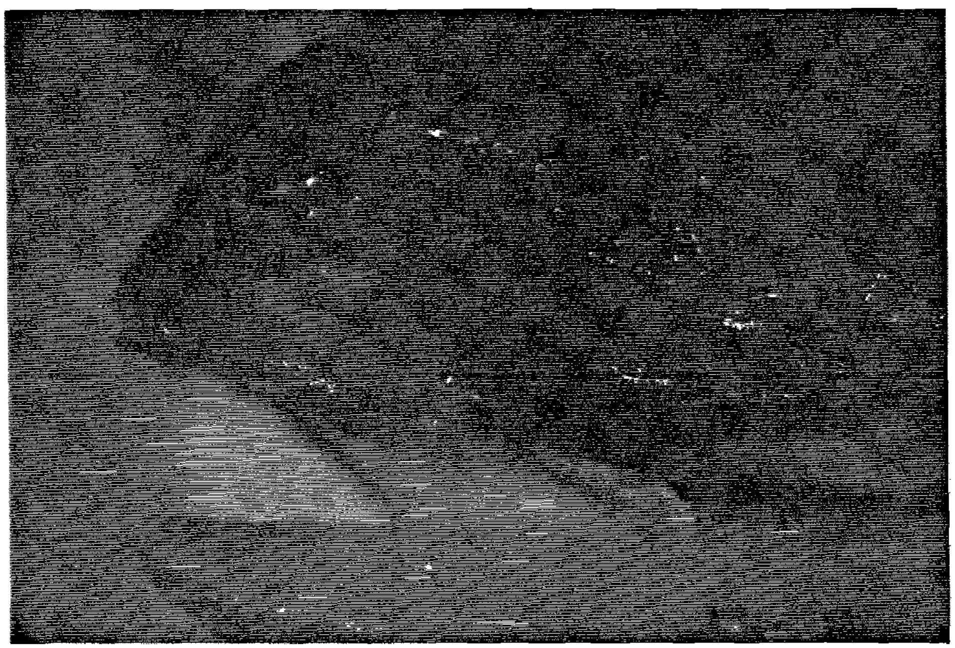

Plate 5. A side view of a one-half length coded wire tag (arrow) in the dissected snout of a sockeye salmon fry recovered in the downstream migrant traps, 1983.

Potential egg deposition for chum and sockeye salmon in the Susitna River between the Chulitna River confluence and Devil Canyon was generated from the 1982 adult population data collected at Curry Station (RM 120). One hundred percent of the sockeye and over 99% of the chum salmon spawning in the study reach used the habitats located above this survey site during 1982 (ADF&G 1983a). The chum salmon population estimates of adults at Curry Station were reduced by 40% to account for milling fish which eventually spawned below the Chulitna River confluence; no milling factor was suggested for sockeye spawning in 1982 (Bruce Barrett, personal communication). The number of female spawners was determined from sex ratios recorded at Curry Station during 1982 (ADF&G 1983a). Fecundities of Susitna River chum and sockeye salmon were determined from egg counts conducted in 1983 (Barrett et al. 1984).

Population estimates for chum and sockeye salmon outmigrants were calculated using the adjusted Petersen estimate outlined by Chapman (1951) and the marking experiments provided by Schaefer (1951). Final survival estimates for both species were determined by taking the population estimates and dividing by the calculated potential egg deposition for each species. Only the numbers of valid tagged fish (as described in Section 2.2.1) were used in the calculations. Total tag recoveries at the traps include only those fish which had a coded wire tag. Clipped fish with no tag were not considered in the estimates.

Population and recruitment estimates for the dye marking experiment were calculated using the multiple mark-recapture technique outlined by Bailey (1951), as discussed by Ricker (1975). Mortalities were low during the experiment and were not factored in the estimates.

2.4.2 Juvenile salmon catch per unit effort

The catch per unit effort (CPUE) data collected on juvenile salmon at the downstream migrant traps are presented as the combined trap catch per hour for each calendar date of sampling effort. The number of fish of a given species and age class which were caught on a particular day was divided by the number of hours the trap fished that day.

The catch per hour rates plotted for each species and age class of juvenile salmon collected at the traps during 1983 were smoothed using the von Hann linear filter (Dixon et al. 1981). The equation is:

$$Z_{(t)} = \tfrac{1}{4}Y_{(t-1)} + \tfrac{1}{2}Y_{(t)} + \tfrac{1}{4}Y_{(t+1)}$$

where: $Z_{(t)}$ = smoothed catch per hour for day (t) and
$Y_{(t)}$ = observed catch per hour for day (t)

This is similar to a three day moving average except that the current day is weighted twice as heavily as the preceding and subsequent days.

The cumulative catch totals for each species are for both traps combined and were adjusted to 24 hour intervals for the sampling conducted from May 18 through August 30. The totals were adjusted for the periods not sampled (six days in all) by tabulating the mean of the total catches recorded for the three days preceding and the three days following each unsampled period.

2.4.3 Relation of outmigration to habitat variables

Correlation analysis of the relationships between outmigration timing of juvenile salmon and environmental variables recorded for the Susitna River at the downstream migrant traps was conducted using the 1983 data. Turbidity and water temperature were recorded daily at the traps through the sampling period. Discharge levels are provisional data collected by the U. S. Geological Survey at the Gold Creek gaging station (RM 136.6). Temperature values for days the traps were not fished were provided by a thermograph located at Talkeetna Station (RM 103.0).

Correlation analysis for chinook, coho, and sockeye salmon included the 106 days of trap fishing effort which occurred between May 18 and September 25. Correlation analysis on chum and pink salmon catch data was performed only for the period from May 18 through July 15 as 98.4% of the chum and 100% of the pink salmon were captured during this period. Discharge and catch per hour data were smoothed by the linear filter described above. The significance test for all correlations was to determine whether the correlation coefficient was significantly greater or less than zero.

Because some of the variables appeared to lag behind discharge, discharge correlations were included with one day ($discharge_{t-1}$) and two day ($discharge_{t-2}$) lags. The season was separated into three periods early (May 18 to June 15), middle (June 16 to August 31), and late (September 1 to 25) because of different climatological and hydrological processes occurring during these periods. The early period follows break-up and is a time of melting ice and snow and increasing solar insulation. Glacial melting occurs mainly during the middle period. Also, there often are large amounts of rainfall during this period. September is a time of rapidly declining water temperature and turbidity.

Autocorrelation coefficients were calculated for each variable on both raw and transformed (log (X+1)) data for the period May 18 through August 30. Catch per hour for the six days with no sampling data during this period were interpolated to provide a continuous time series. September data were not included in this portion of the analysis because of the limited sampling conducted during this period.

3.0 RESULTS

3.1 Coded Wire Tagging and Recovery

A total of eight distinct tag code groups were implanted in chum salmon fry at five study sites during 1983. Table 1 presents the total chum salmon fry tagged by site and tag code and includes tag retention and mortality rates. A total of 24,287 valid tagged chum fry averaging 40 mm total length were released between May 24 and June 19. Tag retention rates ranged from 91.7 to 100% and averaged 97.7%. Mortality rates between tagging and release averaged 1.1% and ranged from 0.1 to 2.4%.

A total of 17,963 valid tagged sockeye salmon fry averaging 32 mm total length were released between May 24 and June 20. Six tag codes were distributed at three study sites (Table 2). Tag retention rates for sockeye fry averaged 96.3% and ranged from 92.6 to 100%. Tagging mortality averaged 1.2% for sockeye salmon fry and ranged from 0.3 to 6.3%.

Of the 8,616 chum salmon fry captured and examined for tags at the downstream migrant traps during 1983, 62 tagged chum salmon fry (0.3% of the total tagged chum released) were recovered (Table 3). Trap recoveries of tagged chum fry were made from 0 to 28 days following their release at the tagging sites. In addition, two chum fry with clipped adipose fins but no coded wire tags were recovered in the traps. When compared to the total tagged chum salmon fry recovered, this provides a tag retention rate at the traps of 96.9%.

A total of 394 tagged sockeye salmon fry (2.2% of the total tagged sockeye released) were recovered from the 12,312 age 0+ sockeye captured and examined for tags at the outmigrant traps (Table 4). Tag recoveries occurred within zero to 113 days following the release of sockeye at the tagging sites. Nineteen sockeye salmon fry with clipped adipose fins but no coded wire tags were also captured, providing a tag retention rate of 95.4% for sockeye fry at the traps.

A test of adipose fin clip efficiency conducted at the traps during a 48-hour period of recovery efforts showed no captures of tagged fish that did not also have an adipose fin clip. No partial fin clips or regeneration of the adipose fin were observed during the recovery efforts. Also, no sockeye or chum salmon fry were observed to have naturally missing adipose fins during the fin clipping operation.

A t-test comparison of daily recoveries of coded wire tagged chum and sockeye salmon to the total daily captures of each species showed no significant difference ($p < 0.05$) in recovery rates between the two downstream migrant traps.

3.2 Population Estimates and Survival Rates of Outmigrants

The total potential egg deposition for chum and sockeye salmon in the study area during 1982 was calculated using the following formula:

Table 1. Coded wire tag release data for chum salmon fry on the Susitna River by site and date, 1983.

Tagging Site (River Mile)	Dates of Tagging	Number of Fish Tagged	Dates of Release	Percent Tag Retention	Percent Mortality
Slough 21 (RM 142.0)	5/25-29	8,555	5/27-30	99.5	0.1
	6/15-16	2,149	6/19	99.5	1.2
Indian River (RM 138.6)	6/4-5	1,131	6/5	91.7	2.4[a]
	6/18	2,541	6/19	93.0	2.0[a]
Slough 11 (RM 135.3)	5/21-22	2,579	5/24	93.9	2.2[a]
	6/4-9	2,409	6/5-10	99.8	0.3
Slough 9 (RM 128.3)	5/30	13	6/5	100.0	0.0
Slough 8A (RM 125.3)	6/10-14	4,910	6/13-15	99.1	1.7[a]
TOTAL - ALL SITES	5/21-6/18	24,287	5/24-6/19	97.7	1.1

[a] Mortalities were due to oxygen loss, thermal stress, or anesthetic.

Table 2. Coded wire tag release data for sockeye salmon fry on the Susitna River by site and date, 1983.

Tagging Site (River Mile)	Dates of Tagging	Number of Fish Tagged	Dates of Release	Percent Tag Retention	Percent Mortality
Slough 21 (RM 142.0)	5/27-29	288	5/29-30	100.0	0.3
	6/15-16	884	6/19	100.0	1.0
Slough 11 (RM 135.3)	5/23-24	4,264	5/24-25	92.9	0.3
	6/5-9	8,491	6/6-10	96.7	0.5
	6/19	1,928	6/20	99.0	0.9
Slough 8A (RM 125.3)	6/10-14	2,108	6/13-15	98.0	6.3[a]
TOTAL - ALL SITES	5/23-6/19	17,963	5/24-6/20	96.3	1.2

[a] Mortalities were due primarily to oxygen loss during transfer.

Table 3. Comparison of release and recovery data for coded wire tagged chum salmon fry on the Susitna Riv by site and date, 1983.

Tagging Site (River Mile)	Dates of Release	Number of Fish Tagged	Dates of Recovery[a/]	Number Recovered	Percent of Tags Recovered	Days Bet Release Recove
Slough 21	5/27-30	8,555	5/30-6/24	12	0.1	0 to
(RM 142.0)	6/19	2,149	6/20-7/8	12	0.6	0 to
Indian River	6/5	1,131	6/20-21	2	0.2	15 to
(RM 138.6)	6/19	2,451	6/20-26	12	0.5	1 to
Slough 11	5/24	2,579	5/25-6/18	9	0.3	1 to
(RM 135.3	6/5-10	2,409	6/10-15	3	0.1	0 to
Slough 9 (RM 128.3)	6/5	13	--	0	0.0	--
Slough 8A (RM 125.3)	6/13-15	4,910	6/15-7/2	12	0.2	0 to
TOTAL - ALL SITES	5/24-6/19	24,287	5/25-7/8	62	0.3	0 to

a/ Recoveries were made at the two downstream migrant traps (RM 103.0).

Table 4. Comparison of release and recovery data for coded wire tagged sockeye salmon fry on the Susit River by site and date, 1983.

Tagging Site (River Mile)	Dates of Release	Number of Fish Tagged	Dates of Recovery[a/]	Number Recovered	Percent of Tags Recovered	Days Betw Release Recover
Slough 21	5/29-30	288	5/31-7/29	4	1.4	1 to 6
(RM 142.0)	6/19	884	6/21-8/12	7	0.8	2 to 5
Slough 11	5/24-25	4,264	5/25-9/14	93	2.2	0 to 11
(RM 135.3)	6/6-10	8,491	6/6-8/25	181	2.1	0 to 8
	6/20	1,928	6/22-8/30	22	1.1	2 to 7
Slough 8A (RM 125.3)	6/13-15	2,108	6/16-8/23	87	4.1	1 to 6
TOTAL - ALL SITES	5/24-6/20	17,963	5/25-9/14	394	2.2	0 to 11

a/ Recoveries were made at the two downstream migrant traps (RM 103.0).

$$\text{Total potential egg deposition} = \frac{(E) \times (M) \times (P) \times (F)}{100}$$

where:

E = Adult population estimate at Curry Station
P = Percent females
F = Average fecundity
M = Percent milling

Adult population estimates at Curry Station during 1982 were 17,648 chum salmon (adjusted for 40% milling) and 1,261 sockeye salmon (ADF&G 1983a). Females comprised 46.7% of the chum salmon and 32.4% of the sockeye salmon at the survey site. Fecundities of Susitna River fish were determined during 1983 to be 2,850 for chum salmon and 3,350 for sockeye salmon (Barrett et al. 1984). Total potential egg deposition was calculated to be 23,490,000 eggs for chum salmon and 1,370,000 eggs for sockeye salmon.

Adjusted Petersen population estimates were generated for outmigrant chum and sockeye salmon fry from the mark-recapture data using the formula by Chapman (1951):

$$N = \frac{(M+1)(C+1)}{(R+1)} - 1$$

where:

N = Estimate of population
M = Number of fish marked
C = Number of fish captured and examined for marks
R = Number of marked fish recaptured

For chum salmon, this formula provided an outmigrant population estimate of 3,322,000 fish with a 95% confidence interval (Ricker 1975) of 2,633,000 to 4,327,000 fish. The age 0+ sockeye salmon outmigrant population was estimated to be 559,976 fish with a 95% confidence interval of 508,632 to 619,641 fish.

Since tag releases and trap recoveries were extended over a period of time, the method outlined by Schaefer (1951) was also used to estimate the outmigrant populations. The calculations to determine the Schaefer estimate are provided in Appendix B. This method provided population estimates of 3,037,000 chum salmon and 575,000 sockeye salmon outmigrants.

Using the above data, calculations of survival were made for both species. An egg-to-outmigrant survival rate of 14.1% was calculated for chum salmon with the adjusted Petersen estimate and a rate of 12.9% was determined using the Schaefer estimate. Sockeye salmon survival rates were calculated to be 40.9% with the Petersen estimate and 42.0% with the Schaefer estimate.

3.3 Outmigrant Rates From Selected Sloughs

A mark-recapture experiment based on Bailey's Deterministic Model (Ricker 1975) was conducted at Slough 11 to estimate the population and the rates of emergence and emigration of chum salmon fry at the study site. The results of the pilot study are presented in Table 5. A population of 2,068 chum fry was determined for Day 2 and the daily emigration rate was estimated to be 32.7% of the population. The daily recruitment or emergence rate of chum salmon fry during the survey was estimated at 1.84.

Outmigrant rates for chum and sockeye salmon fry at Sloughs 11 and 21 determined by fyke net catches are presented in Table 6.

3.4 Juvenile Salmon Catch Per Unit Effort

Length frequency distribution and scale analysis data were used to determine the age class composition for chinook, coho and sockeye salmon juveniles. The points of length separation of age classes for each species by two week periods are presented in Table 7. The graphs presented in this section represent smoothed data, but the catch rates given in the text of this section are the raw data. A comparison of unsmoothed daily catch per hour of juvenile salmon for Trap 1 versus Trap 2 by species and age class is presented in Appendix C.

The catch per unit effort (CPUE) for chum salmon fry collected by the two downstream migrant traps during 1983 is presented in Figure 2. Peak catches of chum fry were recorded during late May and early June, and a second peak was observed in early July. The highest daily catch rate of 16.1 chum per hour was observed on July 6. The major outmigration of chum salmon fry had occurred by July 15 and the last chum was captured in the traps on August 20. The total catch for the season was 8,611 juvenile chum salmon.

Sockeye salmon CPUE at the traps was highest during late June and early July (Figure 3). Sixty-two percent of the total catch of sockeye salmon juveniles occurred during this period. The highest catch rate of 16.8 sockeye per hour was recorded on July 1. Age 0+ sockeye salmon (1982 brood year) comprised 99.3% of the total trap captures (12,312 fish) while age 1+ (1981 brood year) comprised the remaining 0.7% (83 fish). The outmigration of age 1+ sockeye from the study reach was completed by the end of June.

Chinook salmon juveniles were collected in the traps throughout the open water period. Small peaks in CPUE were recorded during early June, late June, and early July, and a large peak was observed during early August (Figure 4). The highest catch rate of 21.0 chinook per hour was recorded on August 11. Age 1+ chinook salmon comprised 7.0% (434 fish) of the total juvenile chinook salmon catch (6,202 fish) during 1983, and the outmigration of this age class from the study reach was essentially complete by the middle of July.

Table 5. Population size, rate of emigration, and rate of emergence of chum salmon fry at Slough 11 as estimated by Bailey's Deterministic Model using mark-recapture data collected June 5, 6, and 7, 1983.

Day 1	-	Marked and released 648 chum fry	M_1
Day 2	-	Examined 1,081 chum fry for marks	C_2
		Recaptured 227 chum fry marked on Day 1	R_{12}
		Marked and released 854 chum fry	M_2
Day 3	-	Examined 1,513 chum fry for marks	C_3
		Recaptured 172 chum fry marked on Day 1	R_{13}
		Recaptured 336 chum fry marked on Day 2	R_{23}
		Captured 1005 unmarked chum fry	

Chum fry population present at Day 2 $= \dfrac{M_2 (C_2 + 1) (R_{13})}{(R_{12} + 1)(R_{23} + 1)} = 2068$

Emigration rate of chum fry $= \dfrac{M_2 R_{13}}{M_1 (R_{23} + 1)} = 0.673$[a]

Emergence rate of chum fry $= \dfrac{R_{12} (C_3 + 1)}{C_2 (R_{13} + 1)} = 1.84$[a]

a/ Proportion of the population on a daily basis.

Table 6. Outmigration rates of chum and sockeye salmon fry from Slough 11 and Slough 21 determined by 24 hour weir catches, 1983.

SLOUGH 11			SLOUGH 21		
Date	Chum	Sockeye	Date	Chum	Sockeye
May 24	1,111	2,500	May 21	1,996	45
May 25	716	2,175	May 25	963	8
June 4	649	4,118	May 26	1,590	47
June 5	542	1,623	May 27	798	44
June 6	1,083	2,466	May 28	1,785	93
June 7	1,005	4,043	May 29	1,851	63
MEAN	851	2,821		1,497	50

Table 7. Age separation values by length for juvenile chinook, sockeye, and coho salmon captured over two week intervals on the Susitna River between the Chulitna River confluence and Devil Canyon, 1983.

	Total Length (mm)					
Survey Period	Chinook Age 0+	Chinook Age 1+	Sockeye Age 0+	Sockeye Age 1+	Coho Age 0+	Coho Age 1+[a/]
May 1-15	≤ 55	≥ 56	≤ 55	≥ 56	≤ 45	≥ 46
May 16-31	≤ 65	≥ 66	≤ 60	≥ 61	≤ 50	≥ 51
June 1-15	≤ 70	≥ 71	≤ 65	≥ 66	≤ 60	≥ 61
June 16-30	≤ 75	≥ 76	≤ 70	≥ 71	≤ 65	≥ 66
July 1-15	≤ 80	≥ 81	All	None	≤ 70	≥ 71
July 16-31	≤ 85	≥ 86	All	None	≤ 75	≥ 76
August 1-15	All	None	All	None	≤ 80	≥ 81
August 16-31	All	None	All	None	≤ 85	≥ 86
September 1-15	All	None	All	None	≤ 90	≥ 91
September 16-30	All	None	All	None	≤ 95	≥ 96

a/ Includes all coho age 1+ or older.

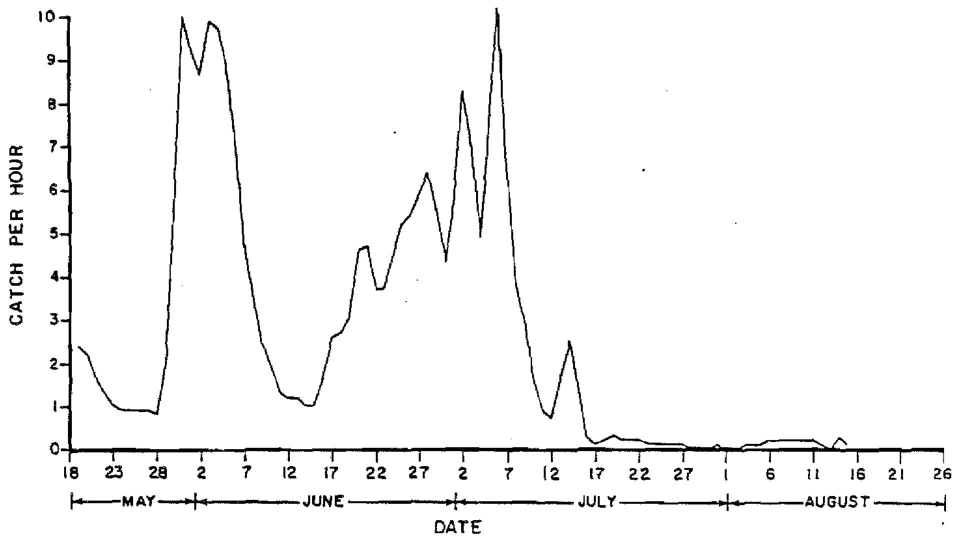

Figure 2. Chum salmon fry daily catch per hour recorded at the downstream migrant traps, May 18 through August 20, 1983, smoothed by $Z_{(t)}=\frac{1}{4}Y_{(t-1)}+\frac{1}{2}Y_{(t)}+\frac{1}{4}Y_{(t+1)}$.

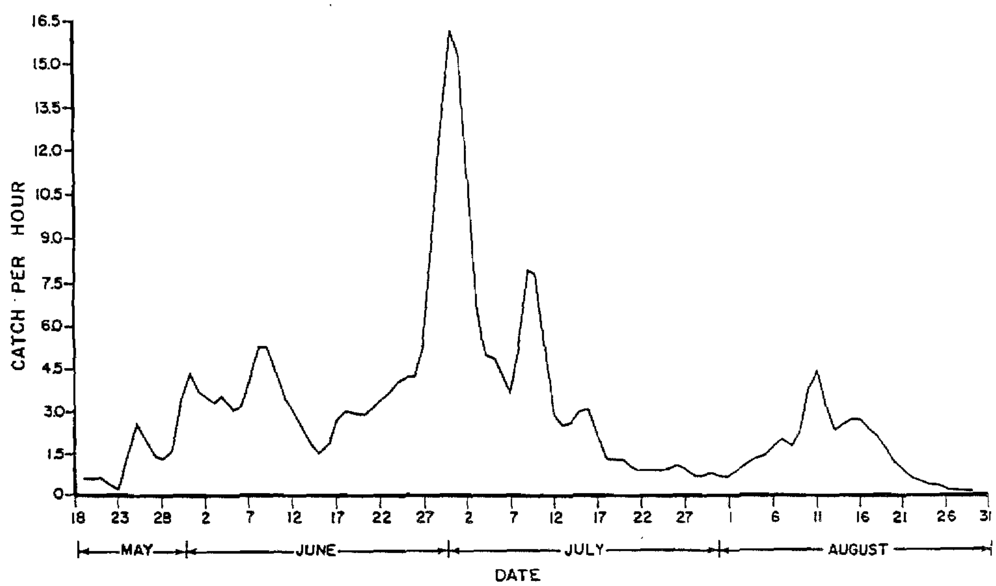

Figure 3. Sockeye salmon fry daily catch per hour recorded at the downstream migrant traps, May 18 through August 30, 1983, smoothed by $Z_{(t)}=\frac{1}{4}Y_{(t-1)}+\frac{1}{2}Y_{(t)}+\frac{1}{4}Y_{(t+1)}$.

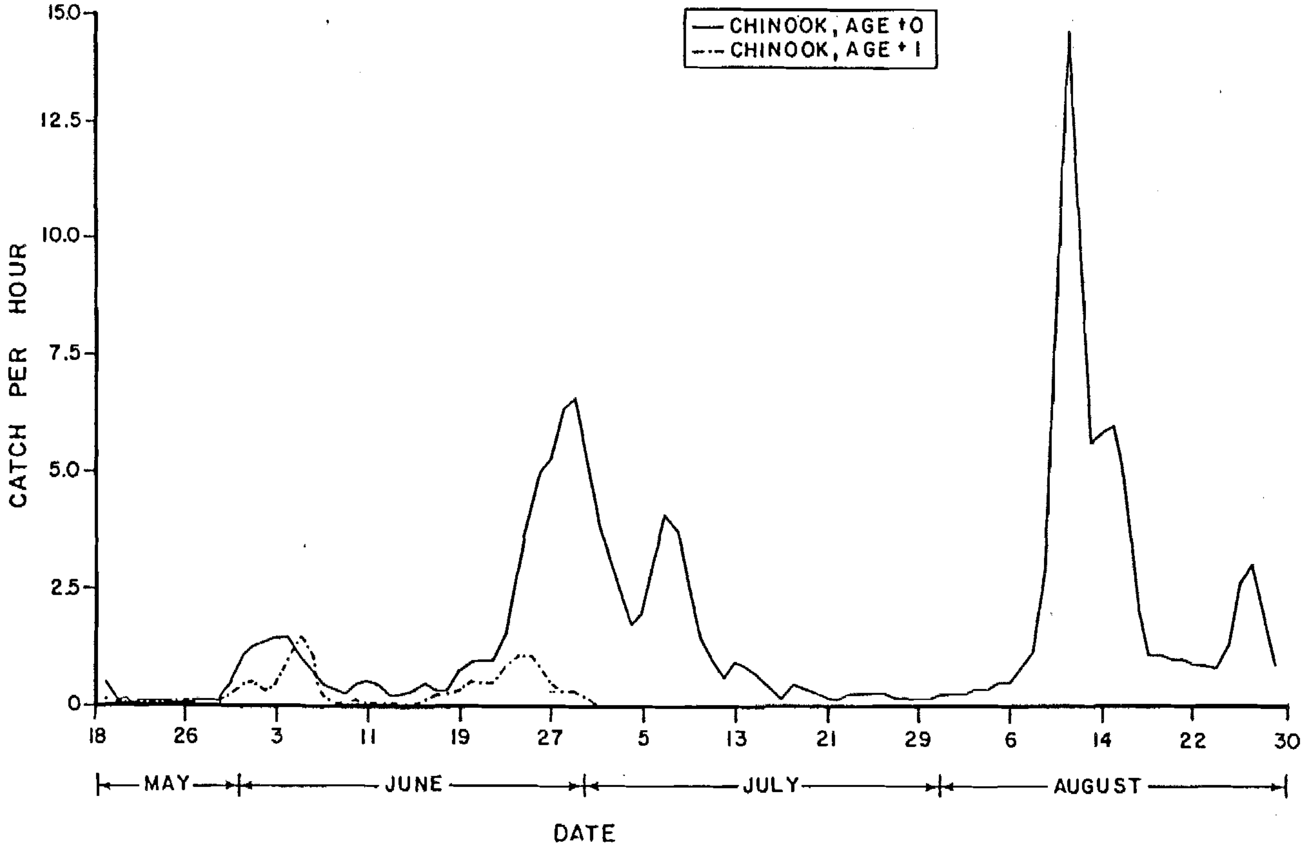

Figure 4. Chinook salmon age 0^+ and age 1^+ daily catch per hour recorded at the downstream migrant traps, May 18 through August 30, 1983, smoothed by $Z_{(t)}=\frac{1}{4}Y_{(t-1)}+\frac{1}{2}Y_{(t)}+\frac{1}{4}Y_{(t+1)}$.

Catch rates for coho salmon juveniles were generally low throughout the survey period with peaks observed during late May and early June, early July and mid-August (Figure 5). The highest CPUE for this species was 9.6 coho per hour recorded August 11. Age 0+ fish comprised 91.6% (5,170 fish) of the total trap captures of coho salmon juveniles while age 1+ and older fish made up the remainder (476 fish) of the catches.

Small numbers of pink salmon fry (245 fish) were collected during May and June in the outmigrant traps (Figure 6). The highest catch rate of 1.3 pink per hour was recorded on June 3 and the last trap capture of pink salmon fry was recorded on July 8.

The adjusted cumulative catch rates for age 0+ salmon by species at the outmigrant traps from May 18 through August 30, 1983 are presented in Figure 7. This figure graphically represents the freshwater residence times and patterns of redistribution and outmigration for each of the species.

3.5 Relation of Outmigration to Habitat Variables

The time series of mainstem discharge, water temperature, and turbidity data collected during 1983 are depicted in Figure 8 and summarized in Table 8. A summary of the juvenile salmon catch per hour statistics by species and age class is presented in Table 9.

Adjacent daily values of discharge, water temperature, and turbidity were closely related as shown by the high autocorrelation coefficients in Table 8. The coefficient for discharge was slightly less than that for the other two variables, indicating that discharge showed more day to day variation than did temperature or turbidity.

In contrast with the habitat variables, the daily catch per hour time series for all species and age classes showed more abrupt fluctuations. The autocorrelation coefficients for all species by age class, with two exceptions, ranged from 0.60 to 0.66 (Table 9). The first exception was age 1+ sockeye salmon, which had a low coefficient of 0.43, but the sample size was small (only 83 age 1+ sockeye salmon were captured). The low coefficient could indicate that these fish outmigrate in sharper pulses than do other species and age classes, perhaps because of schooling tendencies. The other exception was age 0+ coho salmon, which had a higher coefficient than the other species and age classes, indicating a more constant outmigration.

A logarithmic transformation (log(X+1)) considerably improved the autocorrelation coefficients of the catch per hour time series but did little to improve that of the habitat variables, again indicating the sharp fluctuations of the catch rates.

3.5.1 Interrelationship of mainstem discharge, temperature and turbidity

The climatic conditions (air temperature, solar insolation, and rainfall) which influence mainstem discharge also influence mainstem water temperature and turbidity. Hence, these three mainstem variables were correlated with one another.

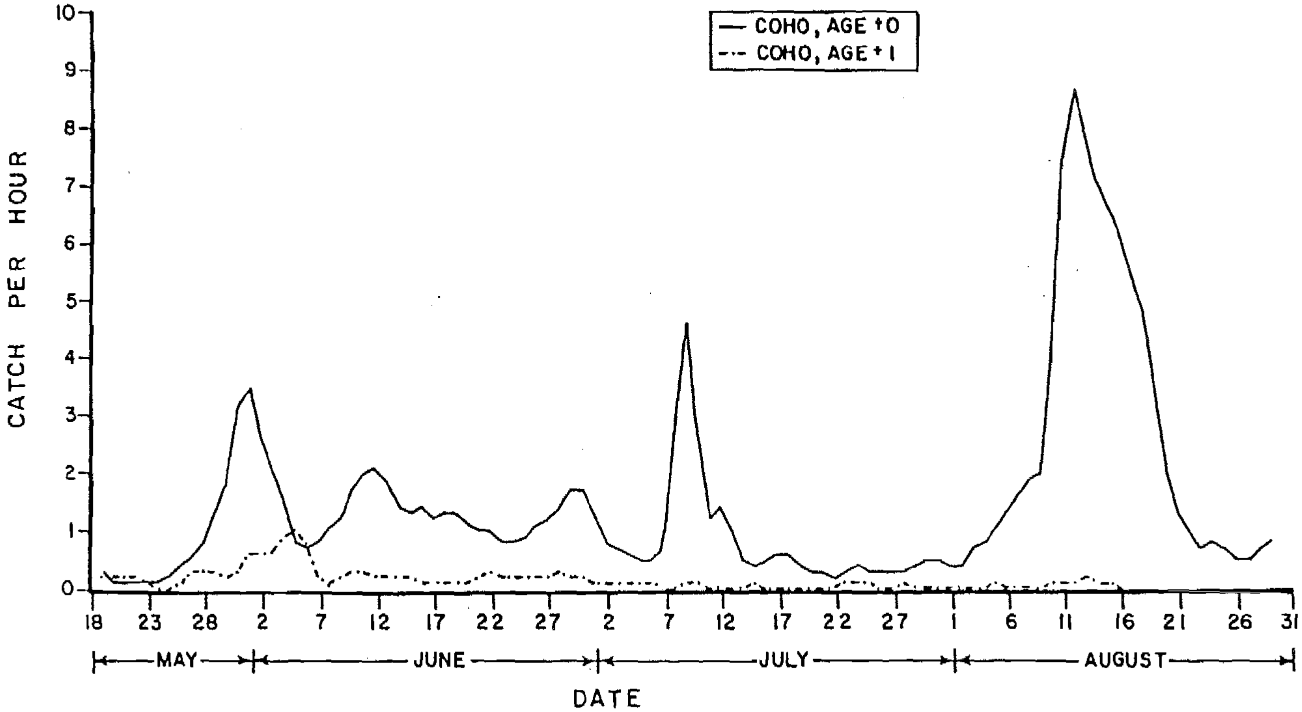

Figure 5. Coho salmon age 0^+ and age 1^+ or older daily catch per hour recorded at the downstream migrant traps, May 18 through August 30, 1983, smoothed by $Z_{(t)}=\frac{1}{4}Y_{(t-1)}+\frac{1}{2}Y_{(t)}+\frac{1}{4}Y_{(t+1)}$.

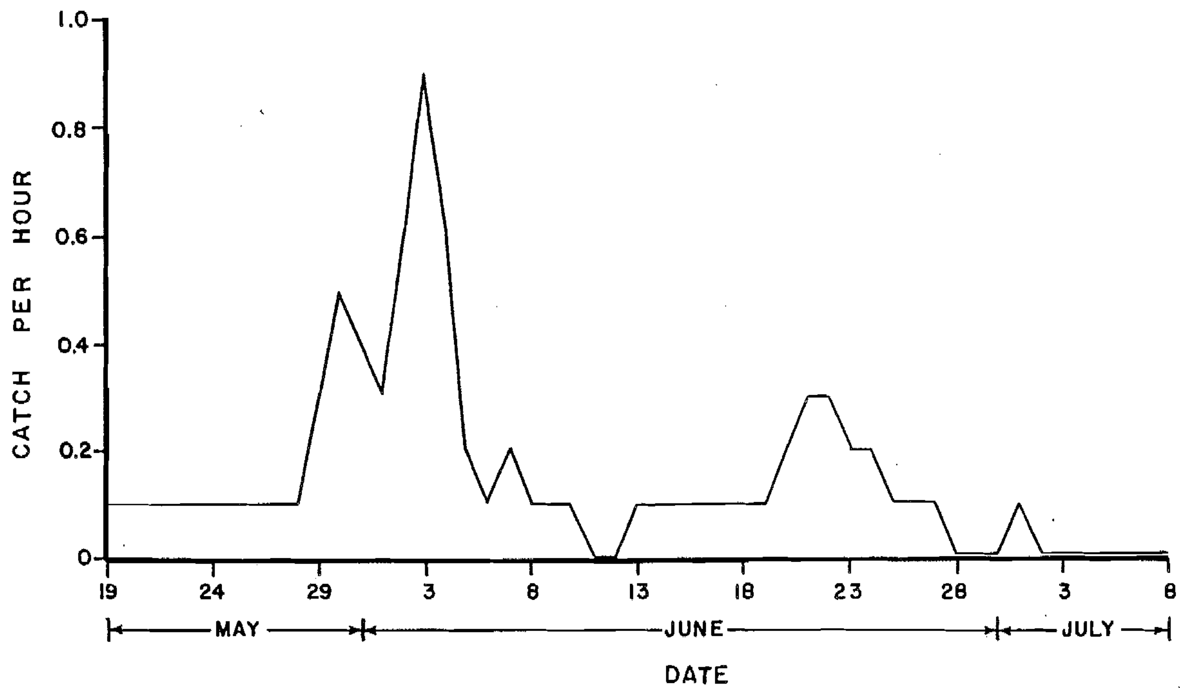

Figure 6. Pink salmon fry daily catch per hour recorded at the downstream migrant traps, May 18 through July 8, 1983, smoothed by $Z_{(t)}=\frac{1}{4}Y_{(t-1)}+\frac{1}{2}Y_{(t)}+\frac{1}{4}Y_{(t+1)}$.

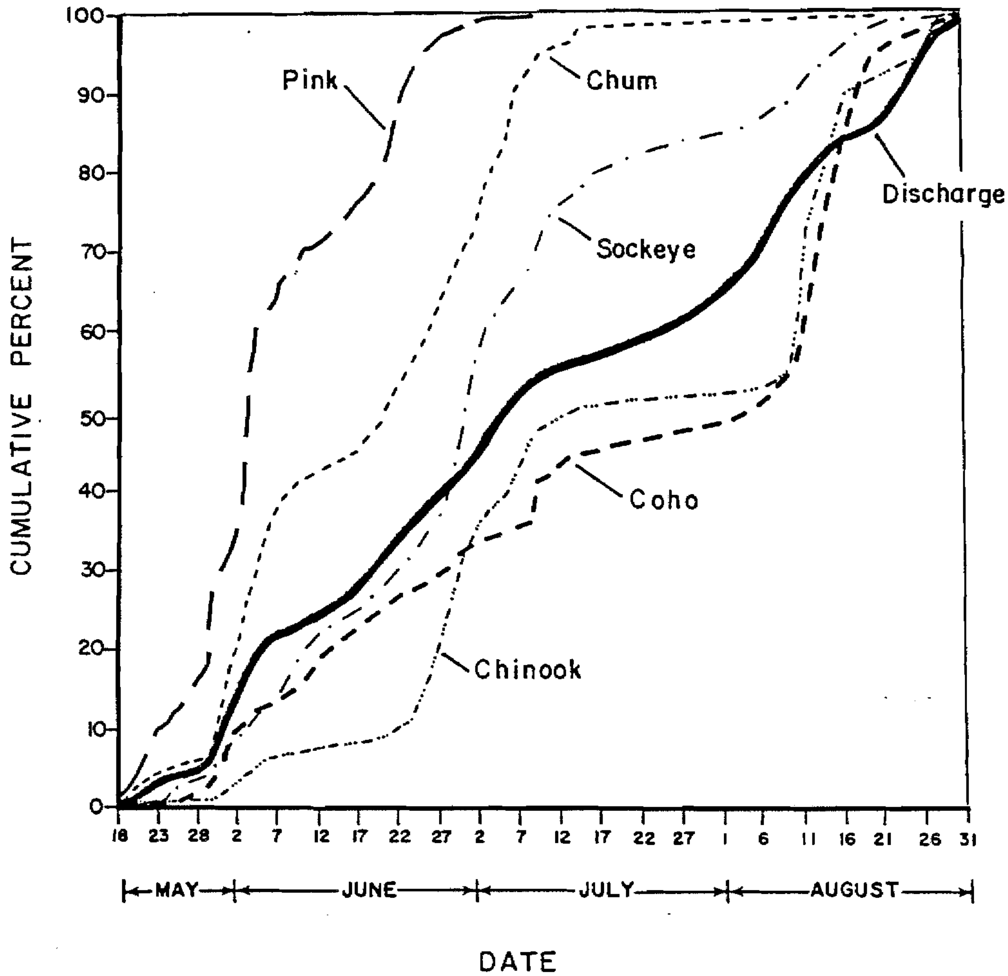

Figure 7. Cumulative catch for age 0+ chinook, coho, sockeye, chum and pink salmon recorded at the downstream migrant traps, May 18 through August 30, 1983, adjusted to 24 hour periods.

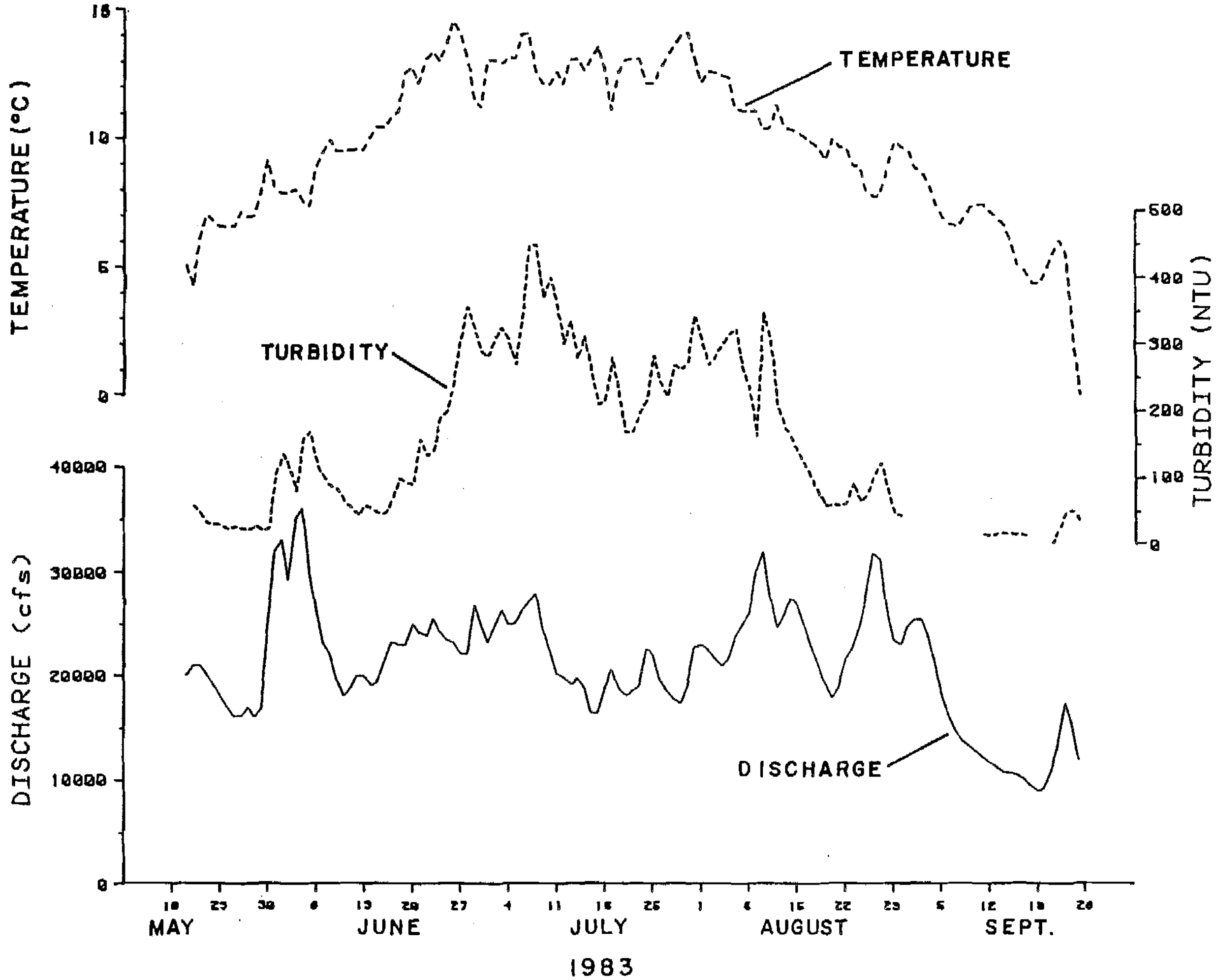

Figure 8. Mainstem discharge, water temperature, and turbidi

Table 8. Summary statistics for habitat variables recorded on the Susitna River between the Chulitna River confluence and Devil Canyon, May 18 to September 25, 1983.

	Min	Max	Mean	Std.Dev.	n	Auto-correl-ation	n
Discharge(ft^3/sec)[a]	10,500	36,000	21,964	4965.5	106	0.87	104
Water temperature (°C)[b]	0.0	14.5	10.2	2.8	106	0.92	104
Turbidity (NTU)[b]	13	560	167	119.6	105	0.93	104

a/ USGS provisional data at Gold Creek, 1983, 15292000.
b/ ADF&G data at Talkeetna Station downstream migrant traps, 1983.

Table 9. Summary statistics for juvenile salmon catch per hour by species and age class recorded at the downstream migrant traps, May 18 through September 25, 1983.

Catch per hour, both traps	Min	Max	Mean	Std.Dev.	n	Auto-correl-ation	n
Chinook 0+	0.0	21.0	1.4	2.6	106	0.66	104
Chinook 1+	0.0	1.8	0.1	0.3	106	0.64	104
Coho 0+	0.0	9.4	1.3	1.8	106	0.73	104
Coho 1+ [a]	0.0	1.3	0.1	0.2	106	0.60	104
Sockeye 0+	0.0	9.4	2.4	2.1	106	0.65	104
Sockeye 1+	0.0	0.3	0.2	0.5	106	0.43	104
Chum	0.0	16.1	2.2	3.3	106	0.65	87
Pink	0.0	1.3	0.1	0.2	105	-	-

a/ Includes all juvenile coho age 1+ or older.

During the four weeks following ice-out (May 18 to June 15), there was no relationship between mainstem discharge and water temperature (Table 10). Discharge was negatively correlated with temperature during the middle part of the season (June 16 to August 31), but positively correlated in September. A similar pattern was observed in 1982 when discharge and temperature were a mirror image during the middle part of the season (ADF&G 1983d). This pattern results from differences among the various thermal inputs - melting ice and snow, rainwater, solar insolation, and air temperature. Correlations were best when there was no time lag (lag=0) between the two variables.

Correlations between mainstem discharge and turbidity were highest when turbidity was lagged one day behind discharge (Table 10). The relationship was strong during the early and late periods but the two variables were not statistically related during the June 16 to August 30 period. During this middle period, turbidity levels increased in late June and decreased in late August (Figure 8), coinciding with the level of solar insolation and the melting of glaciers. However, discharge remained at a more constant level during the same time period as a result of ice and snow melt in the spring and rainfall in late August. A good correlation between discharge and turbidity resulted when the two transition times were eliminated by shortening the time window to the period from June 25 to August 10.

3.5.2 Effects of mainstem discharge on outmigration

Correlation analysis showed that discharge is an important factor in influencing the rate of outmigration (Table 11). This was especially true for chum salmon, which outmigrated primarily during the two discharge peaks which occurred in early June and in early July (Figure 2 and Figure 8). During the period May 18 to July 15 (by which date 98.4% of the total season catch of chums had outmigrated) chum salmon catch rates were strongly correlated with discharge ($r = 0.89$), as shown by Figure 9.

The correlation coefficients for the other species and age classes, except for sockeye salmon, ranged from 0.41 to 0.55. These values suggest that discharge has an important effect on timing of salmon outmigration. The relationships with discharge for both age classes of chinook, coho, and sockeye salmon were strongest when the catch per hour was compared with the discharge of the previous day. Chum and pink salmon correlations were best when there was no lag between discharge and catch per hour. Smoothing the daily catch per hour with the linear filter (see Section 2.4.2) improved the correlation coefficient for all species and age classes except for sockeye juveniles.

The correlation between trap mouth water velocity and mainstem discharge, as recorded at the Gold Creek gaging station, was 0.37 at Trap 1 and 0.30 at Trap 2. Comparing trap velocity with the previous day's discharge did not improve the correlations (the discharge lag between the Gold Creek gaging station and the outmigrant trap is less than one day). The correlations of discharge with trap velocity would have been higher if the traps were fixed in place. However, the traps

Table 10. Correlation coefficients between discharge and temperature, and discharge and turbidity, for the Susitna River between the Chulitna River confluence and Devil Canyon, 1983. The data were not smoothed.

Variables	Period	Correlation Coefficient(r)	Significance Level	Sample Size
Discharge/temperature	May 18-Jun 15	0.07	NS[a]	29
	Jun 16-Aug 31	-0.40	0.01	77
	Sep 01-Sep 25	0.53	0.01	25
	May 18-Sep 25	0.39	0.01	131
$Discharge_{(t-1)}$/turbidity	May 18-Jun 15	0.95	0.01	27
	Jun 16-Aug 31	0.04	NS	76
	Sep 01-Sep 25	0.86	0.01	12
	May 18-Sep 25	0.38	0.01	115

a/ NS = Not significant

Table 11. Correlation coefficients between discharge and juvenile salmon catch per hour by species and age class for the Susitna River between the Chulitna River confluence and Devil Canyon, May 18 through August 30, 1983. Both discharge and catch per hour were smoothed by the linear filter: $Z_{(t)} = \frac{1}{4}Y_{(t-1)} + \frac{1}{2}Y_{(t)} + \frac{1}{4}Y_{(t+1)}$.

Discharge(t-1)/ catch per hour, both traps	Correlation Coefficient(r)	Significance Level (p)	Sample Size
Chinook age 0+	0.50	0.01	102
Chinook age 1+	0.44	0.01	102
Coho age 0+	0.41	0.01	102
Coho age 1+	0.47	0.01	102
Sockeye age 0+	0.34	0.01	102
Sockeye age 1+	0.24	0.01	102
Discharge/ catch per hour both traps			
Chum[a]	0.89	0.01	57
Pink[a]	0.55	0.01	54

[a] Sampling dates - May 18 through July 15, 1983.

were moved closer to shore as mainstem discharge increased in order to maintain that range of velocities through the traps which minimized mortality. Although a rise in mainstem discharge did increase the trap mouth water velocity, correlations between trap velocity and the catch per hour of age 0+ salmon for most species/trap combinations were low and not statistically significant. This indicates that the relationship shown in Figure 9 is not simply a function of fishing a greater volume of water at the higher discharge levels. In contrast, the catch per hour of age 1+ chinook, coho, and sockeye salmon juveniles was positively correlated with trap mouth water velocity. This may relate to trap avoidance by the larger fish and is discussed further in Appendix A.

The discharge/catch per hour correlations for chinook, coho, and sockeye were calculated for the entire season and those for chum and pink were calculated from mid-May to mid-July. The relationship during shorter time periods than these was stronger, as is graphically demonstrated in Figure 7. Inflections in the cumulative discharge curve correspond to inflections in the cumulative catch curves. During the early August discharge peak (Figure 8), there were few chum or pink juveniles left in the reach; the three remaining species all responded to the discharge increase. Only age 0+ chinook fry responded to the late August discharge peak.

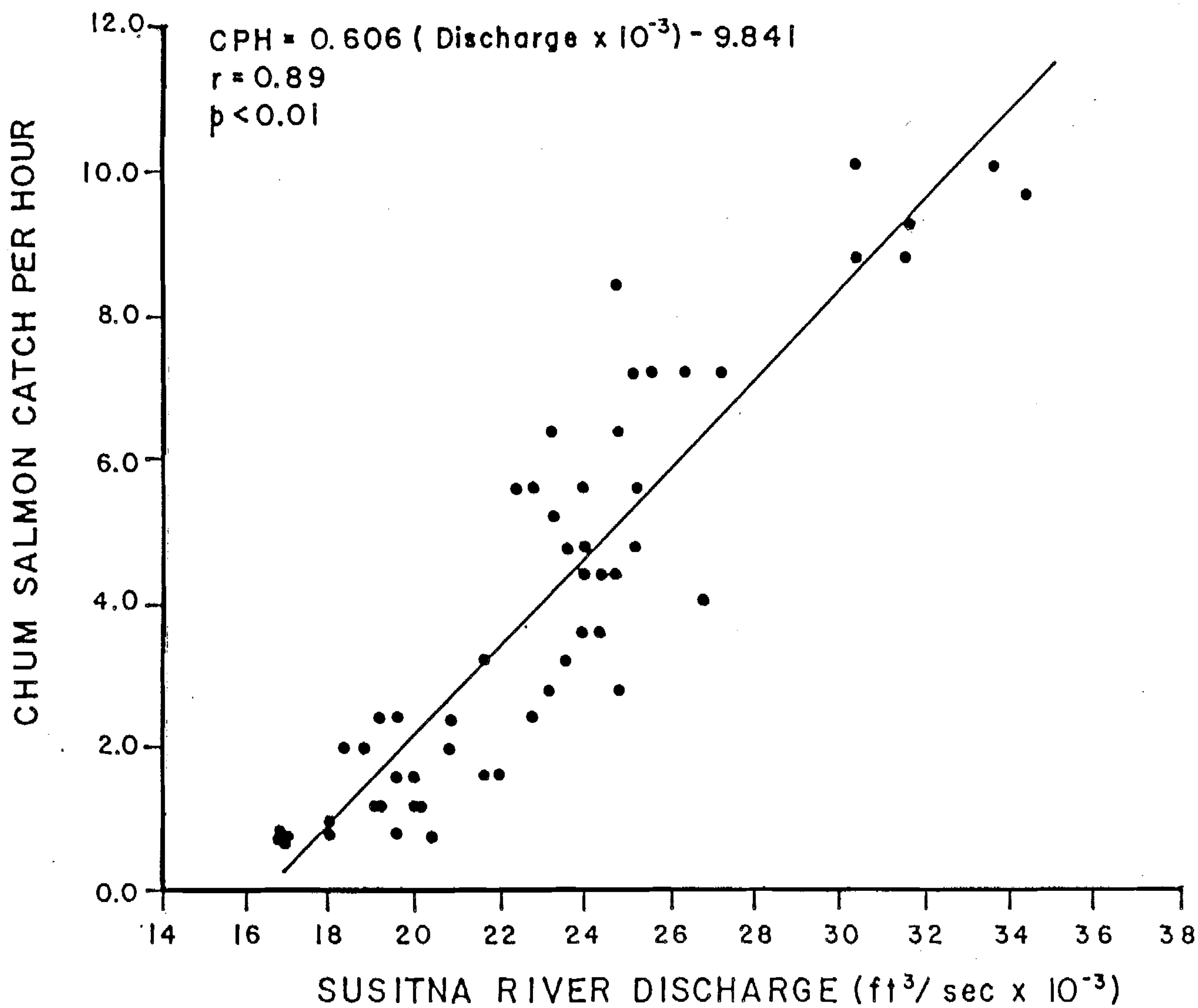

Figure 9. Relationship of mean daily discharge with mean daily chum salmon fry catch per hour at the downstream migrant traps, May 18 through July 15, 1983.

4.0 DISCUSSION

4.1 Coded Wire Tagging and Recovery

Coded wire tagging has been used primarily as a tool to mark salmon smolts prior to their entrance into the marine environment by programs emphasizing the return of adults. The objectives of these programs have been to determine the contribution and timing of specific stocks such as hatchery releases to the overall return of adults to a commercial fishery, or to determine the success of various timings of hatchery smolt releases.

The program conducted on the Susitna River during 1983 was a unique use of coded wire tag methodology. This was the first study to use coded wire tags to mark post-emergent salmon fry in the field rather than under controlled hatchery conditions, and was also the first to use the tags on the small size of fish observed during this study. The sockeye salmon fry were a minimum length of 27 mm total length and averaged up to 3,000 fish per pound.

The objectives of the 1983 program were to quantify the populations and survival rates of outmigrating chum and sockeye salmon fry rather than determining their contributions to the total number of returning adults. Although not an integral part of this study, adult recovery by fishwheels and spawning ground surveys would be useful in determining rates of marine survival and is still very much a possibility but is dependent on future program funding.

Coded wire tagging provided a mark-recovery method which could be successfully incorporated with the current fisheries investigations on the Susitna River. However, for the methods to be useful in providing valid estimates of outmigrant populations and egg-to-outmigrant survival rates, certain assumptions had to be met.

First, neither mortality rates nor catchability should vary between marked and unmarked fish. Previous studies such as Hagar and Jewel (1968), Jefferts et al. (1963) and Opdycke and Zajac (1981) and have shown that marking juvenile salmon with coded wire tags does not affect mortality or catchability.

Secondly, tag retention rates must not vary significantly between tagging and recovery. This assumption was met during 1983 as tag retention rates averaged 97.7% for chum salmon fry at release and were 96.9% during recovery efforts. Sockeye salmon tag retention rates were 96.3% at release and 95.4% during trap recovery.

A third assumption was that the marked fish were randomly distributed within the total outmigrant population at the point of recovery. A comparison of the numbers of marked-to-unmarked fish captured at the traps showed that this assumption was valid. Although the traps were fished on opposite banks of the river, the ratios of recovery of tagged versus untagged fish at each trap were essentially the same.

The fourth assumption was that all marks were recognized and reported during recovery. The efficiency of the field sampling detector to detect the tags and the test of fin clip efficiency showed that all tagged fish were recognizable during the recovery efforts.

The combined mortality rate of 1.2% recorded for chum and sockeye salmon fry during the coded wire tagging procedures was not entirely due to the implantation procedures. Two-thirds of the mortalities were a direct result of handling stress or decreased oxygen levels during capture, or over-exposure to the anesthetic solution. The mortalities related directly to the coded wire tag implementation procedures averaged 0.4% over all the sampling sites.

Although the tagging of small fish worked well for this study, application of these methods to other programs, especially when emphasizing adult returns, should be done cautiously. Our program covers only one season of data and does not provide information concerning changes in tag retention and mortality rates which may occur during the period of marine residence.

4.2 Dye Marking and Outmigration Rates

The dye marking experiments showed the period of dye retention ranged from 12 hours to five days after marking. Most of the dye had faded within 24 hours but was visible on the fins and lower jaw for longer periods. The fish were under stress during the period of dye immersion as shown by the continued gulping of air, flashing, and darting of the fish, but mortality rates were less than one percent. Marking with Bismark Brown dye is effective for short-term marking experiments in which detection is necessary for only a few days, but would not provide an adequate mark for studies extending over longer periods.

The mark-recapture experiment conducted on chum salmon fry at Slough 11 (Section 3.3) demonstrated the possibility of estimating outmigrant rates and populations at specific sites on the Susitna River. This study was time consuming due to the problem of distinguishing dyed fish from coded wire tagged fish which had also been dyed. The use of more distinct marks to delineate groups of fish would minimize this problem.

It would be beneficial to conduct these outmigrant estimates during the 1984 sampling program at numerous study sites over the entire period of outmigration. These data would provide a comparison of outmigration rates by study site and, when compared to the habitat variables recorded at each site, the factors influencing outmigration could be more clearly determined.

Survival rates could also then be generated for each site using the adult spawner counts recorded during the previous season. By comparing these survival rates to the habitat parameters recorded at each site during the period of incubation and emergence, the environmental factors affecting the egg-to-outmigrant survival could also be more clearly defined.

The above data when used in conjunction with trap population estimates and survival rates could ultimately be used to determine the contribution which an individual site or macrohabitat type makes to the total production of juvenile salmon from the reach of river between the Chulitna River confluence and Devil Canyon. This would provide weighted values for each habitat type for use in project flow mitigation.

4.3 Survival of Outmigrants

The survival rates of 12.9 to 14.1 percent estimated for Susitna River chum salmon from potential egg deposition to outmigration are similar to the rates reported for chum salmon survival in other systems. Neave (1948) reported chum salmon freshwater survival rates as low as 0.4 percent while Beacham and Starr (1982) observed chum survival to be as high as 35.4 percent. Hunter (1959) recorded survival rates from 1.0 to 19.4% over a ten year period for chum salmon in a small coastal stream in British Columbia.

Sockeye salmon egg-to-outmigrant survival rates are more difficult to determine due to the more complicated freshwater life history for this species. While chum salmon are strictly age 0+ outmigrants, most sockeye juveniles spend one to two winters in freshwater before outmigrating. Thus, the survival calculations for the period of freshwater residence for sockeye must be made for two or more age classes of outmigrants.

Most previous studies have reported survival rates for sockeye salmon associated with lake systems. In such systems, spawning occurs along the lake shore and in the inlet and outlet streams. Following emergence, the sockeye fry enter the lake, first feeding along the shoreline and later entering the pelagic areas to rear and overwinter (McCart 1967). Outmigrating sockeye smolts are then enumerated as they move through the outlet stream to the ocean. Survival rates reported for these sockeye salmon stocks during the period from egg deposition to outmigration as age 1+ and age 2+ smolts have ranged from 0.6 percent (Russell 1972) to 8.5 percent (Meehan 1966).

In large river systems such as the reach of the Susitna between the Chulitna River confluence and Devil Canyon, the sockeye salmon spawn in sloughs and side channels and, following emergence, the fry rear in these areas and the mainstem river. A major portion of the sockeye salmon juveniles in this reach migrate as young-of-the-year fish to areas located below the Chulitna River confluence. It was for the period from egg deposition through this emigration of age 0+ fish out of the study reach that survival rates of 40.9 to 42.0% were determined for Susitna River sockeye. Thus, the high survival rates determined for Susitna River sockeye cover a shorter period of the life cycle and are not comparable to other studies which have determined survival rates through the entire period of freshwater residence.

The survival rates recorded for the Susitna River do, however, provide an indication of the relative productivity of various salmon spawning habitats used in the study reach. The accuracy of the survival rate estimates is dependent upon the accuracy of the adult escapement counts, by the lower survival rates observed for chum salmon compared to sockeye salmon for the same period of their life cycles are probably a result of the habitat conditions present at the spawning and incubation sites for each species. The sockeye salmon in the study reach spawn almost exclusively in sloughs associated with the mainstem river and the high observed survival rates for this species are primarily a result of the productivity of these sloughs. Chum salmon spawning occurs in the tributaries and sloughs, and the survival to outmigrating fry is determined by the habitat conditions present at a broader range of sites.

Previous studies have shown that natural survival of salmon between the periods of egg deposition and the time of smolt emigration to the ocean is highly variable and is dependent on numerous conditions present in the freshwater environment (Wickett 1958; Hunter 1959). Most mortalities of salmon occur during this critical period of their life cycle and often have the most profound effect on the numbers of returning adults (Henry 1953).

The discrepancy between survival in tributaries and in the side sloughs, as suggested by the differences in egg to outmigrant survival of sockeye and chum salmon, suggests an approach to understand the importance of environmental factors in influencing survival. An examination of the critical habitat components during spawning and incubation at the major tributaries, compared with the sloughs, should suggest the habitat variables that are responsible for these differences. Those factors most apparently different, and that are the subject of other investigations by ADF&G, include:

- Access of adults to sloughs as a function of mainstem flows.
- Winter ground water flows and the prevention of freezing.
- Adverse effects of temperature on development and survival caused by ice processes which lead to overtopping of sloughs.
- Density-dependent mortality because of redd superimposition at both sloughs and tributaries (affected by access or brood year survival).
- Inter-specific competition for redds (chinook, pink, and coho spawn in streams near chum spawning areas).
- Spawning occurs during high flow periods and redds are deposited at areas that are subsequently dewatered and frozen.

All of the factors listed, except for species composition, are affected by mainstem discharge and consequently may be affected, either beneficially or negatively, by flow regulation of the Susitna River.

4.4 Comparison of Trap Catch Rates

A comparison of catch rates of juvenile chum and sockeye salmon collected in the two downstream migrant traps during 1983 showed that catches were not proportional to population size for the two species. Chum salmon comprised only 41 percent of the total captures of both species at the traps, while population estimates from the coded wire tagging program indicated that almost six times as many chum salmon fry migrated past the traps during 1983. This trap selectivity observed for sockeye and chum fry is probably due to the difference in migration patterns between the two species. Chum salmon fry migrate primarily near the water surface and in the center of the channel where water velocity is greatest (Hunter 1959). McCart (1967) observed that downstream migrating sockeye fry were associated with the river banks during the migration.

As the east bank trap (Talkeetna Station, RM 103) was fished during both 1982 and 1983, we compared the catch rates at this trap between the two years for juvenile salmon collected during the same calendar dates. Chinook, coho, and chum salmon catch rates indicate relative abundances were related to the estimated populations of parent spawners at Curry Station. Chum salmon fry catch rates at the east bank trap for the period from June 18 through August 15 averaged 0.7 fish per hour during 1982 and 1.6 fish per hour (2.3 times as high) during 1983. The parent spawners estimated for the 1983 outmigrant population were 2.3 times the number of estimated parent spawners for the 1982 outmigrants (ADF&G 1983a). A comparison of east bank trap catch rates for juvenile chinook and coho salmon captured between June 18 and August 30 to the estimated number of parent spawners showed similar results. Adult coho salmon were estimated to be 2.1 times as abundant in 1982 as 1981 and the trap catch rates were 2.8 times as high in 1983 than in 1982. Although no population estimates were provided for adult chinook salmon during 1981, it appears that the spawning escapement was much smaller than that observed during 1982 (Bruce Barrett, personal communication). Trap catch rates of juvenile chinook salmon were over four times as great in 1983 than for the same calendar period in 1982. These data indicate that the traps provide a comparative index of annual differences in the relative abundance of outmigrants.

East bank trap catch rates for sockeye salmon juveniles during 1983 were 1.4 times higher than the rates recorded during the same calendar period in 1982. Conversely, the estimates of sockeye parent spawners at Curry Station during 1982 were less than half the estimated number past this site in 1981. As the sockeye salmon in the study reach spawn only in the sloughs, the discrepancy between catch rates for this species is probably caused by the environmental factors previously listed, with the most like causes being: (1)The large number of adult sockeye observed during 1981 may have resulted in the superimposition of redds and a density-dependent mortality of eggs. (2)The 1981 spawning occurred during a period of high flows, and as winter progressed, many of the redds may have dewatered and frozen during this low flow period resulting in high mortalities of the incubating eggs.

The survival rates of 1982 brood year sockeye salmon (1,261 adults) from egg deposition to fry outmigration determined during 1983 were very high (over 40%). During years of high adult escapement such as 1981 (2,804 adults), the number of eggs deposited may exceed the productive capacity of the spawning sloughs and result in lower survival rates. Conversely chum, coho, and chinook salmon spawn primarily or entirely in the tributaries which are capable of sustaining much larger spawning escapements because of the larger amount of available habitat.

These data and the comparisons of sockeye and chum salmon fry catch rates at the traps show that although the outmigrant traps can provide an index of relative abundance, they are selective and cannot be used to accurately determine outmigrant population estimates without the inclusion of a mark-recovery program. Trap selectivity also influenced the catch rates of age 1+ salmon juveniles (Appendix A). Transect subsampling as a mechanism to apportion catches would assist in quantifying the extent of trap selectivity.

A comparison of the cumulative catch rates adjusted to 24 hour periods for the east bank trap for the same calendar periods during 1982 and 1983 (June 18 through August 30) showed similar patterns of chum and sockeye outmigration for the two open water periods. Over 90 percent of the chums were captured by July 15 during both years and their outmigration from the study reach was completed by the middle of August (Figure 10). Sockeye salmon juveniles showed an initial pulse of downstream movement during late June and early July, but the emigrational redistribution of this species continued throughout the open water period during both 1982 and 1983 (Figure 10).

Cumulative catch rates for chinook and coho salmon juveniles at the east bank trap were not as similar during the two sampling seasons. Both species showed more even patterns of outmigration during 1982 than in 1983 (Figure 10). Trap catch rates for juvenile chinook and coho salmon were low during July and early August of 1983 and then dramatically increased beginning on August 10. This corresponds to an increase in mainstem discharge from less than 23,000 cfs during July to a peak of 32,000 cfs on August 10. July was also a period of low flows in the primary chinook and coho salmon spawning tributaries (Indian River and Portage Creek), but during early August, significant increases in water levels were recorded for both streams (Report Series 3, Part 1).

The observed high catch rates of juvenile chinook and coho salmon recorded at the outmigrant traps after early August are a result of two factors: (1) Rearing juveniles in Indian River and Portage Creek may have been trapped in side channels and pools and were unable to emigrate to the mainstem river until the high flow periods in early August. This situation was recorded on August 3, when hundreds of juvenile chinook and coho salmon trapped in small pools were observed in Indian River, and (2) The abrupt increase in tributary and mainstem discharge during this period and the subsequent extensive breaching of mainstem rearing areas caused a flushing and downstream displacement of rearing chinook and coho salmon.

As shown in Figure 10, less than 50 percent of the adjusted cumulative catches of chinook and coho salmon juveniles was recorded between June 18 and August 9, and the remaining captures occurred between August 10 and August 30. These data indicate that chinook and coho salmon were

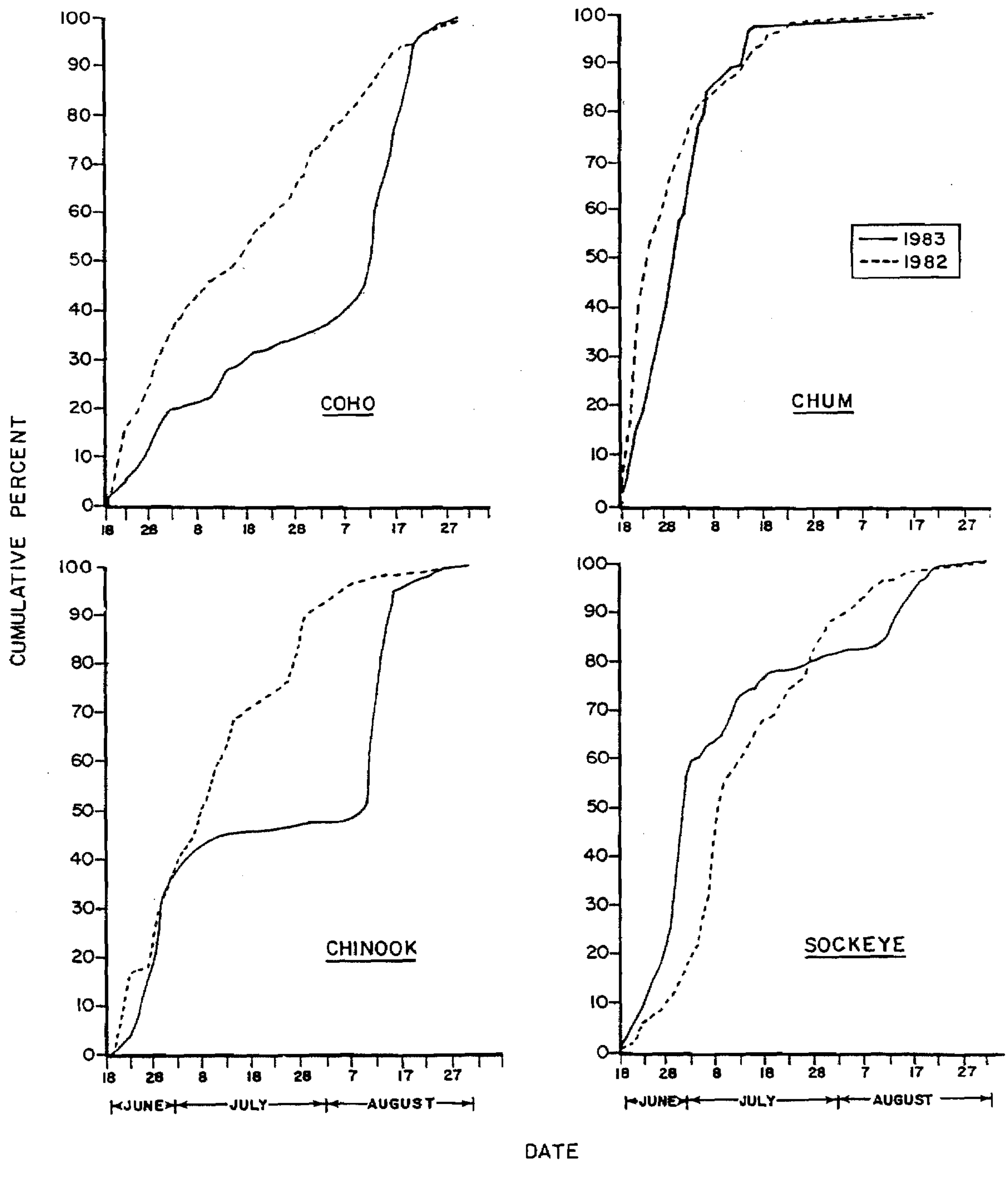

Figure 10. East bank outmigrant trap (Talkeetna Station, RM 103.0) cumulative catch recorded for juvenile coho, chinook, chum, sockeye salmon during 1982 and 1983, adjusted to 24 hour per for the calendar period from June 18 through August 30.

still predominantly in the natal tributaries or in mainstem habitats above the traps until the high flow period in August. Studies of juvenile salmon outmigration at the major spawning tributaries would be valuable in determining the residence time and growth of juvenile salmon at habitats associated with the mainstem Susitna.

4.5 Relation of Outmigration to Habitat Variable

Discharge was an important factor influencing the timing and rate of outmigration of juvenile salmon during 1983. Chum salmon outmigration showed the highest correlation to discharge (Section 3.5.2). Calculations were made for the entire sampling season but higher correlations exist between discharge and outmigration when analyzed during short periods of time. High catch rates for chinook, coho and sockeye juveniles recorded during the middle of August, for example, coincided with a period of high discharge in the mainstem river and major tributaries (Figures 8 and 10). Similarly, catch per unit effort peaks for chinook and chum fry in the Skagit River coincided with peaks in river discharge (Congleton et al. 1981).

Raymond (1968) showed that lower migration rates occurred during periods of low discharge than at moderate discharge levels. Adequate river stage is necessary at the sloughs to allow the outmigrating juveniles access to the Susitna River mainstem. An increase in migration time required for juveniles to reach their marine rearing areas may result in increased predation and a decreased ability of the migrants to make the transition to salt water (Andrew and Geen 1960; Foerster 1968).

Water temperatures at the emergence and rearing areas are also an important factor in triggering outmigration. (Foerster 1937, 1968) found that outmigration of sockeye in lakes begins as temperatures rise above a minimum level during the spring (4.4 to 5.0°C) and may cease during the summer if temperatures become unacceptably high (13.0°C) Mihara (1958, cited by Bakkala 1970) found that in streams in Hokkaido, Japan, chum fry changed from a positive rheotaxis to a negative rheotaxis and moved quickly downstream when the water temperature reached 15°C. This was interpreted as an adaptive response to avoid the high summer stream temperatures. Similar results have been demonstrated by Keenleyside and Hoar (1955). Unseasonably high winter and spring water temperatures resulting from dam operation could trigger juvenile salmon outmigration before optimum downstream and marine habitat conditions are present (McCart et al. 1980).

Turbidity is an important factor in providing cover to outmigrating salmon in large rivers such as the Susitna. Andrew and Geen (1960) suggested that reduced sediment loads (turbidity) might expose migrating juveniles to abnormally high predation levels. It can be speculated that an increase in turbidity occurring when the heads of natal sloughs are overtopped by a rising mainstem discharge could induce juveniles to leave the object cover available in the slough and move to the mainstem.

The correlations of mainstem temperature and turbidity with the daily catch per hour of juvenile salmon were generally low during 1983. This does not mean that these two variables are not important factors in influencing outmigration but, rather, reflects the fact that the temperature and turbidity data were taken at the same location as the outmigrant traps. It is likely that the major effect of the variables as outmigrant stimuli would occur at the rearing areas.

In summary, the time between egg deposition and outmigration is the most critical period in the life history of salmon populations (Henry 1953), and ultimately it has the greatest effect on the numbers of adult fish returning to the commercial and sport fisheries, and the spawning grounds. The development of population estimates for chum and sockeye salmon has allowed estimates of the survival of these species from egg to outmigration. These differences suggest that slough spawners, if they have an opportunity to deposit eggs, have a high probability of producing viable fry and may contribute proportionately more offspring than their counterparts spawning in the tributaries. This is probably because slough discharge during the winter is more stable because of the large groundwater influences. The strong correlation of outmigration with short term discharge peaks suggests discharge changes can be expected to affect the rearing in mainstem habitats and the successful outmigration of smolts. High flows at the proper period (late May and early June) could stimulate outmigration of smolts to ensure minimal freshwater mortality. Similar events in later summer could possibly be detrimental as rearing 0+ fish might be displaced from habitat upstream (Hartman et al. 1982). If optimum habitat were maintained by flows after the fish were displaced, the benefits would be reduced because of the previous downstream displacement of the population.

5.0 CONTRIBUTORS

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APPENDIX A

Sampling Selectivity of the Outmigrant Traps

The downstream migrant traps were designed to capture juvenile resident and anadromous fish as they outmigrated from the Susitna River between the Chulitna River confluence and Devil Canyon. The first trap was deployed at Talkeetna station (RM 103.0) during the 1982 open water season and the second trap was added during 1983. The traps have provided the most effective technique for capturing migrating juveniles in the mainstem, and have been important in collecting information on the biology and timing of emigration of juvenile fishes of the Susitna River.

Beginning in 1983, velocity measurements were collected daily at the mouth of each trap. Velocities for the east bank trap (Trap 1) ranged from 1.4 to 3.1 feet per second (fps) and, over the season, averaged 2.1 fps. The west bank trap (Trap 2) had a higher mean velocity of 2.3 fps, with a range from 1.2 to 4.0 fps.

Large numbers of age 0+ salmon fry have been collected in the traps during the past two seasons, but fewer age 1+ and older fish were captured in the traps. This is a direct result of relative abundance of the two age classes but may also be affected by trap selectivity. In other words, the traps may be more effective at catching the younger, smaller fish than at collecting the larger fish. Thus, the relative abundance of older fish determined from trap catch rates may be less than the actual abundance of these fish passing the traps.

A test of the correlation by species and age class between the raw daily catch per hour and daily water velocity was conducted on the 1983 data to determine if a relationship exists between trap velocity and the resulting collection of different age classes of juvenile fish. The results of these tests are presented in Appendix Table A-1.

The correlations of catch per hour for age 0+ chinook and coho (both traps), and sockeye (one trap) with trap velocity were not significant at the 95% confidence level. Conversely, the correlations of catch per hour for age 1+ chinook, coho, and sockeye salmon to trap velocity were significant (0.31 to 0.56). These relationships were most apparent in Trap 2.

The higher correlations for age 1+ salmon to trap velocity could be a result of the following factors:

1) The high trap velocities and resulting higher catches of age 1+ fish occurred during periods of high mainstem discharge. The larger age 1+ fish may migrate predominantly during these high discharge periods.

2) The higher velocities result in more water passing through the traps per unit time resulting in an increase in catch per hour of the older fish.

3) The traps are more effective at catching the larger fish when the trap velocities are higher, because the migrating fish are less able to avoid capture.

The outmigrant traps do not appear to be selective in the collection of age 0+ salmon, but the relative abundance of age 1+ and older fish may be biased due to trap avoidance by the larger fish. The traps do, however, provide a measure of the seasonal timing of outmigration and comparative changes in relative abundance for the older fish.

Appendix Table A-1. Correlation coefficients (r) for juvenile salmon catch per hour and trap velocity at each of the downstream migrant traps, by species and age class, 1983. The data were not smoothed.

		Trap 1			Trap 2		
Species	Age Class	Corr. Coeff(r)	p	n	Corr. Coeff(r)	p	n
Chinook	0+	0.09	0.20	95	-0.02	0.44	91
Chinook	1+	0.39	0.00	95	0.56	0.00	91
Coho	0+	0.15	0.07	95	-0.07	0.26	91
Coho	1+	0.40	0.00	95	0.53	0.00	91
Sockeye	0+	0.22	0.01	95	-0.11	0.15	91
Sockeye	1+	0.31	0.00	95	0.44	0.00	91
Chum	0+	0.29	0.02	54	-0.03	0.41	52
Pink	0+	0.38	0.00	54	0.44	0.00	51

APPENDIX B

The Schaefer Estimate of Population Size

One of the assumptions of a mark-recapture program which must be met to provide a valid population estimate is that, during tagging and recovery, the marked individuals are randomly distributed within the unmarked population. A biased Petersen estimate would result if the marking and recapture efforts were selective. Schaefer (1951) pointed out that when generating a population estimate for migrating fishes, the fact that some fish do not always migrate as a single population should be considered, so that the mixing of marked and unmarked fish between the time of tagging and recovery may be incomplete.

Schaefer (1951) provided a method for estimating the population, when using numbered tags, by estimating the relation between time of tagging and recovery when migration extends over a considerable period of time. By using numbered tags, both the date of tagging and date of recovery is known for each fish recovered and the population can be divided into a series of distinct units.

Specific to the coded wire tag, mark-recapture program conducted on the Susitna River during 1983, there may be a tendency for fish which emerge earliest to outmigrate earliest, resulting in a positive correlation between time of tagging at the emergence sites and the time of migration past the recovery site. When such a correlation exists, the recovery during any single period would not be a random sample of the whole population.

The method proposed by Schaefer uses the summation of populations for individual periods of tagging and recovery to estimate the total population. A table is first generated which shows the number of fish tagged and recovered during each time interval. Using these data, a second table can be formed which estimates the population for each period; the sum of these being the total population estimate.

The population estimate (N) was determined from the formula from Ricker's (1975) modification of Schaefer's (1951) equation:

$$N = N_{ij} = R_{ij} \cdot \frac{M_i}{R_i} \cdot \frac{C_j}{R_j}$$

where: R_{ij} = the number of fish which were marked during a tagging period (i) and subsequently recaptured during a recovery period (j).

M_i = the number of fish marked during a single tagging period.

R_i = the total marked fish recaptured from a single tagging period.

C_j = the number of fish captured and examined for marks during a recovery period.

R_j = the number of marked fish which were recaptured during a recovery period.

N_{ij} = the estimate of the available for marking during a period (i) and available for recovery in a period (j).

Tagging and recovery periods for the Susitna River study were grouped by eight day intervals. The data collected for the estimate of the population of sockeye salmon outmigrants is tabulated by the Schaefer method in Appendix Table B-1. The computation of these data and the resulting population estimate are presented in Appendix Table B-2. This estimate is very close to the population determined from the Petersen estimate (Section 3.2), indicating a random distribution of marked and unmarked sockeye salmon fry between the time of tagging and time of recovery during 1983.

The mark-recovery data for chum salmon are presented in Appendix Table B-3, and the computations and final population estimate are provided in Appendix Table B-4. This estimate is lower than the population determined for chum salmon fry by the Petersen estimate (Section 3.2). The difference is probably a result of incomplete mixing of marked and unmarked chum fry between tagging and recovery, due to the comparatively shorter time interval of chum outmigration compared to that of sockeye salmon fry.

With the use of distinct marks, successive groups of tagged fish maintain a separate identity and can be treated as separate populations. Using the methods provided by Schaefer (1951), it is possible to generate population estimates for each time interval both at tagging and recovery. This allows the comparison of population estimates not only between years, but between given time periods of the outmigration during a single year.

Appendix Table B-1. Data collected on the coded wire tag, mark-recapture experiment for sockeye salmon fry to provide a population estimate using the methods outlined by Schaefer (1951). Tagging and recovery periods are by eight day intervals, May 23 through September 27, 1983.

Period of Recovery (j)	Period of Tagging (i) 1	2	3	4	Tagged Fish Recovered (R_j)	Total Fish Recovered (C_j)	C_j/R_j
1	24	0	0	0	24	555	23.125
2	8	0	2	0	10	582	58.200
3	9	0	88	0	97	1,294	13.340
4	1	0	15	2	18	1,101	61.167
5	28	0	72	7	107	3,403	31.804
6	14	0	45	3	62	2,066	33.323
7	8	0	20	5	33	1,356	41.091
8	2	0	6	0	8	395	49.375
9	1	0	3	3	7	290	41.429
10	1	0	3	2	6	477	79.500
11	0	0	8	4	12	445	37.083
12	0	0	6	2	8	278	34.750
13	0	0	0	1	1	16	16.000
14	0	0	0	0	0	0	0
15	1	0	0	0	1	8	8.000
Total Tagged Fish Recovered (R_i)	97	0	268	29	394	12,666	
Total Fish Tagged (M_i)	4,553	0	10,599	2,881	17,963		
M_i/R_i	46.938	0	39.549	96.931			

Appendix Table B-2. Computation of the sockeye salmon fry outmigrant population from the data presented in Appendix Table B-1.

Period of Recovery (j)	Period of Tagging (i) 1	2	3	4	Total
1	26,051	-	-	-	26,051
2	21,854	-	4,604	-	26,458
3	5,635	-	46,427	-	52,062
4	2,871	-	36,286	11,858	51,015
5	41,799	-	90,563	21,580	153,942
6	21,898	-	59,305	9,690	90,893
7	15,430	-	32,502	19,915	67,847
8	4,635	-	11,716	-	16,351
9	1,945	-	4,915	12,047	18,907
10	3,732	-	9,432	15,412	28,576
11	-	-	11,733	14,378	26,111
12	-	-	8,246	6,737	14,983
13	-	-	-	1,551	1,551
14	-	-	-	-	-
15	376	-	-	-	376
Total	146,226	-	315,729	113,168	575,123

Appendix Table B-3. Data collected on the coded wire tag, mark-recapture experiment for chum salmon fry to provide a population estimate using the methods outlined by Schaefer (1951). Tagging and recovery periods are by eight day intervals, May 19 through July 13, 1983.

Period of Recovery (j)	Period of Tagging (i) 1	2	3	4	Tagged Fish Recovered (R_j)	Total Fish Recovered (C_j)	C_j/R_j
1	1	-	-	-	1	328	328.000
2	-	5	-	-	5	725	145.000
3	6	2	1	-	9	1,301	144.556
4	2	2	2	1	7	640	91.429
5	-	3	2	25	30	1,751	58.367
6	-	-	-	9	9	2,114	234.889
7	-	-	-	1	1	1,396	1,396.000
Total Tagged Fish Recoverd (R_i)	9	12	5	36	62	8,255	
Total Fish Tagged (M_i)	2,579	8,555	3,553	9,600	24,287		
M_i/R_i	286.556	712.917	710.600	266.667			

Appendix Table B-4. Computation of the chum salmon outmigrant population from the data of Appendix Table B-3.

Period of Recovery (j)	Period of Tagging (i) 1	2	3	4	Total
1	93,990	-	-	-	93,990
2	-	516,152	-	-	516,152
3	248,540	206,113	102,721	-	557,374
4	52,399	130,363	129,939	24,381	337,082
5	-	124,832	82,951	389,114	596,897
6	-	-	-	563,734	563,734
7	-	-	-	372,267	372;267
Total	394,929	977,460	315,611	1,349,496	3,037,496

APPENDIX C

Comparison of Daily Catch Per Hour Between Outmigrant Trap 1 and Trap 2

The raw daily mean catch per hour of Trap 1 was compared with that of Trap 2 for all species by paired t-tests. The means between traps for half of the species by age class groups were significantly different (Appendix Table C-1). Smoothing the data with a three day moving average to reduce the possibility of daily peaks causing a difference did not change the results. Trap 2 had a higher catch per hour for the majority of fishing days for all species by age class except age 0+ coho; however, the Trap 1 to Trap 2 proportion varied throughout the season.

We can conclude from these results that juvenile salmon do not outmigrate in a uniform manner across the breadth of the mainstem river. Rather, individual groups appear to follow one shore or another or perhaps the mid-channel; their location can change depending on the level of discharge, the origin of the fish, and several other factors. This pattern of outmigration should be considered when interpreting the results from the data collected at the outmigrant traps.

Appendix Table C-1. Comparison of unsmoothed daily catch per hour of juvenile salmon in Trap 1 versus Trap 2, by species and age class.

Species by Age Class	Corr. Coeff (r)[a/]	t-test of means[b/] n	t value	df	Signif.	Percent of Days when Trap 1 catch/hr > Trap 2 catch/hr
Chinook, 0+	0.84	97	-3.48	96	$p < 0.01$	32.6
Chinook, 1+	0.90	97	0.47	96	NS[c/]	45.8
Coho, 0+	0.47	97	0.72	96	NS	80.0
Coho, ≥ 1+	0.67	97	2.65	94	$p < 0.01$	63.5
Sockeye, 0+	0.64	97	-4.89	96	$p < 0.01$	20.7
Sockeye, 1+	0.43	97	-1.45	96	NS	21.4
Chum	0.69	97	-2.59	93	$p < 0.01$	41.4
Pink	0.74	96	-0.98	92	NS	19.7

a/ May 18 - Sep 25, 1983; all significant at 95% confidence level
b/ May 22 - Aug 30, 1983
c/ NS = Not significant at 95% confidence level.

PART 2

The Distribution and Relative Abundance of Juvenile Salmon in the Susitna River Drainage above the Chulitna River Confluence

THE DISTRIBUTION AND RELATIVE ABUNDANCE OF JUVENILE SALMON IN THE SUSITNA RIVER DRAINAGE ABOVE THE CHULITNA RIVER CONFLUENCE

1984 Report No. 2, Part 2

by Lawrence J. Dugan, David A. Sterritt, and Michael E. Stratton

Alaska Department of Fish and Game
Susitna Hydro Aquatic Studies
2207 Spenard Road
Anchorage, Alaska 99503

ABSTRACT

The Juvenile Anadromous Habitat Study was undertaken to determine the seasonal distribution and abundance of juvenile salmon by macrohabitat type in the Susitna River drainage between the Chulitna River confluence and Devil Canyon. Thirty-five sites representing four macrohabitat types were sampled from May through September, 1983; limited sampling was conducted in October and November. Side channels and tributaries were found to be important rearing areas for juvenile chinook salmon with tributaries important early in the summer and side channels of the mainstem Susitna increasing in importance as the summer progressed. Coho salmon were most abundant in tributaries and upland sloughs. Natal side sloughs and backwater areas provided rearing areas for chum and sockeye salmon fry. Upland sloughs, the most lake-like environment, had concentrations of sockeye and coho salmon juveniles. Macrohabitat type and time of year were found to be significantly ($p < 0.10$) related to the distribution of all species.

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1.0 INTRODUCTION

The Resident and Juvenile Anadromous Fish Studies (RJ) have been directed toward accomplishing the general objectives described in 1979 by the Alaska Department of Fish and Game for the Susitna Hydroelectric Project (ADF&G 1979). These objectives are stated below:

A. Define seasonal distribution and relative abundance of resident and juvenile anadromous fish in the Susitna River between Cook Inlet and Devil Canyon.

B. Characterize the seasonal habitat requirements of selected anadromous and resident species within the study area.

Five species of Pacific salmon spawn in the reach of the Susitna River above the Chulitna River confluence. With the exception of pink salmon, substantial freshwater rearing and growth occur in this reach of river.

The Resident and Juvenile Anadromous Fisheries Studies began in November 1980 with general surveys of the Susitna River mainstem and associated habitats between Cook Inlet and Devil Canyon conducted during the open water season of 1981. Beginning in the winter of 1981 and the spring and summer of 1982, the studies concentrated on those areas of the mainstem and associated habitats that may be most affected by the development of the Susitna Hydroelectric Project.

The data collected during 1981 and 1982 outlined the general distribution patterns of these species and their habitat utilization (ADF&G 1981b, 1981c, 1983c). The 1982 studies also investigated the response of selected macrohabitat areas to mainstem discharge changes and demonstrated species differences in the use of "hydraulic zones" (ADF&G 1983d). These zones were subsections of the slough and tributary mouth areas that were affected by backwater of the mainstem Susitna River, mixing areas of the mainstem with slough or tributary flow, and free-flowing tributary or slough water above the back water. The relative use of the hydraulic zones by each species of juvenile salmon was analyzed to provide an incremental index of habitat availability for each species. This analysis provided evidence that the relative use by juvenile salmon of these macrohabitat areas was affected by changes in mainstem flow. During the course of the 1982 study, observations of the distribution of juvenile salmon indicated certain microhabitat parameters within the zone may respond to discharge changes at a higher rate than does zone surface area. These microhabitat factors include cover and turbidity, with depth and velocity having a somewhat lesser importance.

The objectives of the 1983 Juvenile Anadromous Habitat Study (JAHS) program were to correlate juvenile salmon habitat use to microhabitat parameters and further document the seasonal distribution and relative abundance of juvenile salmon (except pinks) in macrohabitat types (tributaries, upland sloughs, side sloughs and side channels) associated with the Susitna River above the Chulitna River confluence. Pink salmon are not discussed because of the short time they spend in this reach of the river between emergence and outmigration. The purpose of this paper is to present the data on spatial and seasonal distribution and relative abundance for each species and to discuss the causative factors behind the observed distributions.

Juvenile salmon distribution and abundance data will be used to determine the proportion of use of the macrohabitats associated with the mainstem river. In addition, the data can be used in the assignment of dam flows throughout the summer to minimize the effects on life stages of different juvenile anadromous species. Furthermore, the data will be integrated into macrohabitat indices compiled by E.W. Trihey and Associates which project the percentages of suitable rearing habitat for each juvenile salmon species over a range of mainstem flows between 9,000 cfs and 23,000 cfs. Distribution and abundance data were also used in conjunction with microhabitat studies including the juvenile salmon habitat suitability functions (Part 3 of this report), the juvenile salmon habitat modelling (Part 4), and the IFG-4 modelling (Part 7).

2.0 METHODS

2.1 Field Sampling Design

Two Juvenile Anadromous Habitat Study (JAHS) field crews collected distribution and abundance data at rearing habitats used by juvenile salmon. Selected side sloughs, upland sloughs, tributaries and mainstem side channels of the Susitna River between the Chulitna River confluence (RM 98.5) and Portage Creek (RM 148.8) were sampled during the open water season. Crews operated out of tent camps and used river boats for transportation with helicopter support when necessary.

2.1.1 Study site locations and selection criteria

Thirty-five study locations on the Susitna River and its major tributaries between the Chulitna River confluence and Devil Canyon were sampled (Table 1). Rearing habitat at thirteen of the sites was subsequently modelled using either RJHAB (Part 4) or an IFG model (Part 7). Sites sampled more than three times are shown in Figure 1.

Sites selected for study included: (1) sites where relatively large numbers of spawning adult salmon were recorded in 1982 (ADF&G 1983b), (2) sites where concentrations of rearing juvenile salmon were observed or collected in 1981 and 1982, and (3) sites representing macrohabitat types associated with the Susitna River that are affected by changes in mainstem flow.

In 1982, sampling sites were classified on the basis of morphological features into one of four macrohabitat types: tributary, upland slough, side slough, or side channel. Upland sloughs are areas which have heads vegetated with trees and brush that are rarely overtopped. Side sloughs are sites with unvegetated heads that are sometimes overtopped by mainstem flows during the open water season of a normal year. Side channels convey mainstem flows overtopped, during most of the open water season of a normal year.

Side sloughs are morphologically and hydraulically distinct from side channels for several reasons. A mainstem backwater area is frequently present at the mouths of side sloughs. Fewer backwater areas occur at the mouth of side channels because the gradient of the side channels is typically greater than that of sloughs. The infrequency of strong flows in the sloughs over the course of several years has allowed silt, debris, and deadfall to accumulate. Debris and silt is often flushed out of the side channels and sometimes the streambed may become armored. The water in sloughs is often clear and moving slowly and is therefore more conducive to the growth of aquatic and emergent vegetation.

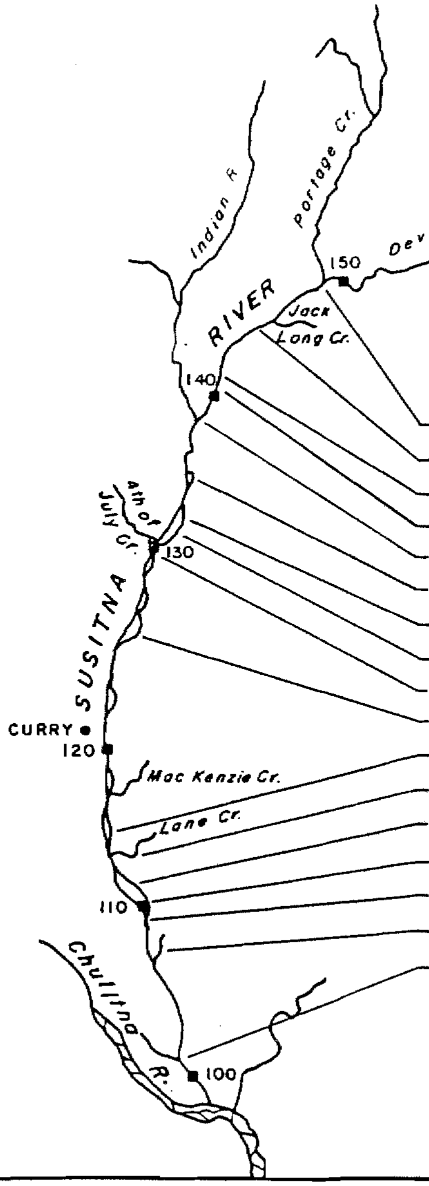
In 1983, side sloughs and side channels were distinguished using a discharge-based classification scheme which depends on the status of the head of the site. Under this criterion, sites are classified as side sloughs only when the head is not overtopped by mainstem discharge. When the head is overtopped by the mainstem, these sites are classified as side channels. Classification of upland sloughs did not change.

Table 1. Juvenile Anadromous Habitat Study (JAHS) sites sampled on the Susitna River between the Chulitna River confluence and Devil Canyon, May through November 1983.

Site	River Mile	Macro-habitat Type[a/]	Fish Distribution Site	RJHAB Modeling Site	IFG Modeling Site
Whiskers Creek Slough	101.2	SS/SC	X	X	
*Whiskers Creek	101.2	T	X		
*Slough 3B	101.4	SS	X		
*Mainstem at head of Whiskers Creek Slough	101.4	SC	X		
Chase Creek	106.9	T	X		
Slough 5	107.6	US	X	X	
Oxbow I	110.0	SC/SS	X		
Slough 6A	112.3	US	X	X	
*Mainstem above Slough 6A	112.4	SC	X		
*Lane Creek	113.6	T	X		
Slough 8	113.6	SS	X	X	
Mainstem II	114.4	SC/SS	X		
*Lower McKenzie Creek	116.2	T	X		
*Upper McKenzie Creek	116.7	T	X		
*Side Channel below Curry	117.8	SC	X		
*Oxbow II	119.3	SC/SS	X		
Slough 8A	125.3	SS	X		X
Side Channel 10A	127.1	SC	X	X	
Slough 9	129.2	SS/SC	X		X
Side Channel 10	133.8	SC/SS	X		X
*Lower Side Channel 11	134.6	SC	X		X
Slough 11	135.3	SS	X		
*Upper Side Channel 11	136.2	SC	X		X
Indian River - Mouth	138.6	T	X		
Indian River-TRM 10.1	138.6	T	X		
*Slough 19	140.0	US	X		
*Slough 20	140.1	SS/SC	X		
Side Channel 21	140.6	SC			X
Slough 21	142.0	SS/SC			X
Slough 22	144.3	SS/SC	X	X	
*Jack Long Creek	144.5	T	X		
Portage Creek Mouth	148.8	T	X		
Portage Creek TRM 4.2	148.8	T	X		
Portage Creek TRM 8.0	148.8	T	X		
		Total	35	6	7

a/ T - Tributary
US - Upland Slough
SS - Side Slough
SC - Side Channel

*These sites sampled three times or less.



Site	Tributary	Upland Slough	Side Slough	Mainstem Side Channel
1 Portage Creek	▲			
2 Slough 22			▲	▲
3. Slough 21			▲	▲
4. Side Channel 21				▲
5. Indian River	▲			
6. Slough 11			▲	
7. Side Channel 10			▲	▲
8. Side Channel 10A				▲
9. Slough 9			▲	▲
10. Slough 8A			▲	
11. Mainstem 2			▲	▲
12. Slough 8			▲	
13. Slough 6A		▲		
14. Oxbow One			▲	▲
15. Slough 5		▲		
16. Chase Creek	▲			
17. Whiskers Cr. Sl.			▲	▲

Macrohabitat Type

Figure 1. Juvenile Anadromous Habitat Study (JAHS) sites sampled more than three times by macrohabitat type, 1983.

This is the classification method which was used by E.W. Trihey and Associates to measure the total surface area of each macrohabitat type in this reach of river; this method is used in all parts of this report.

The discharge-based method is useful when considering fish distribution because of the major habitat changes which occur when the head of a slough is overtopped. The geomorphological-based method is useful because the frequency of overtopping has an important influence on the distribution of substrate and object cover which are important to juvenile and spawning salmon. A classification based on the discharge acknowledges the instantaneous effect of mainstem discharge, while one based on geomorphological differences emphasizes long-term consequences. Both effects are important.

2.1.2 Field data collection

Each of the study sites was divided into one or more grids. Grids were located to keep water quality (temperature, turbidity) within the site as uniform as possible and to encompass a variety of depth, velocity, cover, and substrate types. Each grid consisted of a series of transects which intersected the channels of the study sites at right angles (Figure 2). There were one to three cells (6 ft. in width by 30 ft. in length = 300 sq. ft.) at every transect within the grid. An attempt was made to confine uniform habitat within each cell. Further descriptions of the grid system used are detailed in the 1983-84 Procedures Manual (ADF&G 1984). Habitat data collection methods are further described in Parts 3 and 4 of this report.

Backpack electrofishing units (Coffelt, Model BP1C and Smith-Root, Model XVBPG) and beach seines were used to collect fish. Procedures used for sampling with these techniques are described in the 1982-83 Procedures Manual (ADF&G 1983a). Juvenile salmon collected were identified to species, measured for total length in millimeters and released in the cell from which they were captured. A few specimens were preserved in 10% formalin for later identification.

Fish were usually sampled from a minimum of seven cells within each grid at each site. The cells were selected to represent the complete range of habitat types available within the grid. Fish density was estimated by electrofishing or beach seining the entire cell, attempting to capture all fish. Catch per unit effort (CPUE) was defined as the catch (number of fish) per cell. With this definition, electrofishing and beach seining effort could be compared; also, the extra time required to capture fish in difficult locations would not bias the results as it would have had if we defined CPUE as catch per unit time.

2.1.3 Schedule of activities and frequency of sampling

The sampling schedule was dependent on the target species. Sites that predominantly had juvenile chum, pink, and sockeye salmon were sampled in May and June. In late June and early July, sampling efforts were redirected toward sites previously identified in 1981 and 1982 as rearing areas for chinook and coho salmon. The chinook and coho salmon sites were sampled until freezeup in early November. Because the

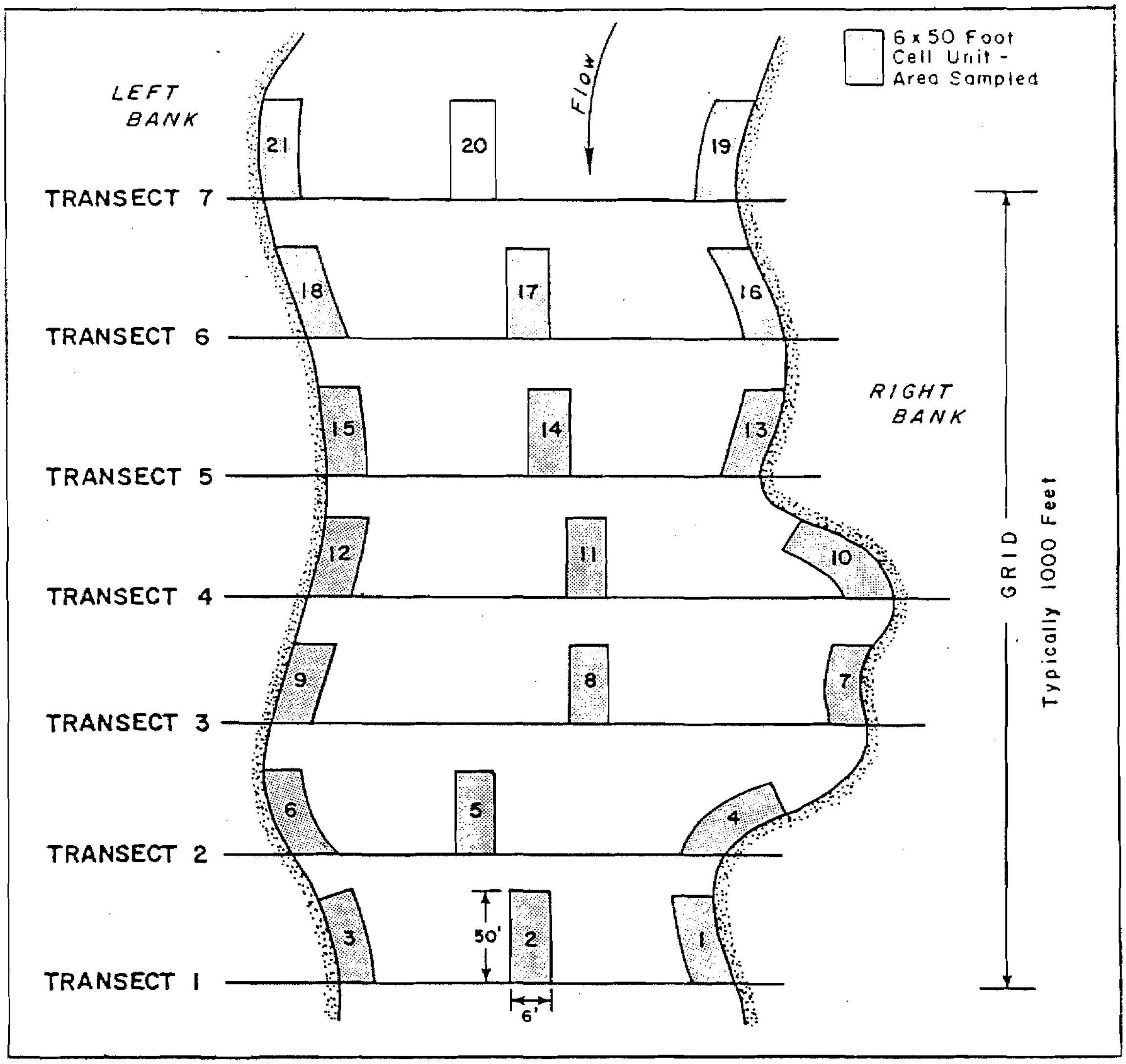


Figure 2. Arrangement of transects, grids, and cells at a Juvenile Anadromous Habitat Study (JAHS) site.

primary objective of the JAHS study was microhabitat suitability and habitat modelling, there was not equal sampling effort at all sites, which would be more desirable, from the standpoint of a distribution and relative abundance study. This problem was partially solved by using catch per unit effort data.

2.2 Data Recording and Analysis

All field data were recorded on data forms and transmitted to the office, where they were entered into a mainframe computer data base. Data sorts and summary retrievals were extracted from this data base as needed.

2.2.1 Macrohabitat use

Percentage distribution of each salmon species among macrohabitat types was calculated by dividing the catch/cell for each type by the sum of the catch/cell for all types. The equations are:

$$\text{Percentage}_i = \frac{(\text{Total Fish})_i/(\text{Total Cells})_i}{\sum_{i=1}^{n} (\text{Total Fish})_i/(\text{Total Cells})_i} \times 100$$

where: i = each macrohabitat type

n = number of macrohabitat types = 4

2.2.2 Analysis of variance

An analysis of variance (ANOVA) was conducted to examine the effect of several habitat variables on the distribution of each species. The two major variables considered were macrohabitat type and time of year. Site habitat characteristics (which contribute to differences among macrohabitat types) considered were: mean water depth, mean water velocity, mean percent cover, water temperature, and turbidity. All of these can be influenced by discharge level. Temperature and turbidity are influenced by time of year; the other variables are indirectly influenced by time of year in that discharge levels have a seasonal pattern.

All sites were grouped into the four macrohabitat types - tributary, upland slough, side slough, or side channel. Periods were taken as the nine half-month periods from late May (May 16-May 30) to late September (Sept. 16-Sept. 30). Study site depth, velocity, and percent cover were calculated as the mean values of all 300 sq ft cells sampled in a particular interval of each parameter, such as 0.1 to 0.6 ft. There were usually at least seven cells sampled at each sampling site on each occasion. Because the cells were not randomly distributed at the site, the ANOVA is weakened for the three variables (depth, velocity, cover) which were taken as means of the cells sampled. However, it appeared that the means of these three would generally characterize each site.

All variables were transformed by natural log (x+1) prior to running the ANOVA. The intervals and frequencies for all the variables are given in Appendix Table A-1. The intervals were selected to be physically or biologically meaningful while still allowing for an adequate sample size in each interval. For example, the first interval for turbidity is 0 to 10 NTU, which covers the non-flood tributary conditions.

Fish density data were taken as the total number of fish captured in a particular interval, divided by the number of 300 sq. ft. cells sampled in that interval. Mean catch per cell for each species was transformed by natural log (x+1).

The analysis of variance was run on BMDP Statistical Software, using the regression approach. One run was conducted for macrohabitat type and period, with fish catch/cell as the dependent variable and a second run was conducted for mean depth, mean velocity, mean percent cover, water temperature, and turbidity, with fish catch/cell as the dependent variable. Because of empty cells in the analysis of variance table, interactions among variables were not calculated.

3.0 RESULTS

3.1 Distribution of Juvenile Chinook Salmon

A total of 4,443 juvenile chinook salmon were captured at JAHS sites located between the Chulitna River (RM 98.6) confluence and Portage Creek (RM 148.8) from May 1 to November 15, 1983. Approximately 99% of these fish were Age 0+ and the rest were Age 1+. Chinook juveniles were captured at all of the study sites surveyed at least four times (Figure 3). Chinook juvenile salmon were widely distributed from early July through September. Portage Creek and Indian River produced the highest densities of chinook salmon through the ice free field season. Increases in densities were apparent as the season progressed at several sites.

Chinook juvenile salmon were unequally distributed among macrohabitats Side channels contributed 22.6 percent of the catch per unit effort (CPUE), the highest percentage of the three macrohabitats influenced by mainstem flows (Figure 4). The CPUE of chinook juveniles captured from side channels was twice that of side sloughs, and twelve times that of upland sloughs. (See also Appendix Table 1, which gives the means used in the analysis of variance). Four side channels (Slough 22, Side Channel 10A, Oxbow I and Slough 9) accounted for 80.8 percent of the juvenile chinook captured at 13 side channels sampled during the 1983 field season. Side channel 10A (RM 127.1) contributed 31.1 percent of the chinook juvenile captured at this macrohabitat type.

Chinook juvenile salmon CPUE by macrohabitat type ranged from less than one fish per cell in May at upland slough and side slough study sites to 26.4 fish per cell at tributary macrohabitats in early July (Figure 5). Consistently higher densities of chinook salmon were recorded for tributary sites than for upland slough, side slough, or side channel sites from May through early August. Peak densities of 26.4 fpc and 19.5 fpc were recorded at tributary sites in early July and August, respectively. Chinook juvenile densities were higher in tributaries in July and August than in side sloughs or side channels. Chinook juvenile densities increased at mainstem associated macrohabitats in late July. Chinook juveniles were redistributing into mainstem side channels, side sloughs and to a lesser extent upland sloughs during this time following outmigration from tributaries. Comparison of chinook juvenile salmon densities between side slough and mainstem side channel macrohabitats is illustrated in Figure 6. In general, side channel CPUE's were higher than those in side sloughs. Chinook juvenile densities in both areas gradually increased until late August or early September. Side channel densities of juvenile chinook salmon gradually decreased after August. Densities at side sloughs were higher in September and October than earlier in the season. Densities were five times greater at side sloughs in surveys conducted during September through November than before September.

3.2 Distribution of Juvenile Coho Salmon

A total of 2,023 juvenile coho salmon were captured at sites located between the Chulitna River (RM 98.6) and Portage Creek (RM 148.8).

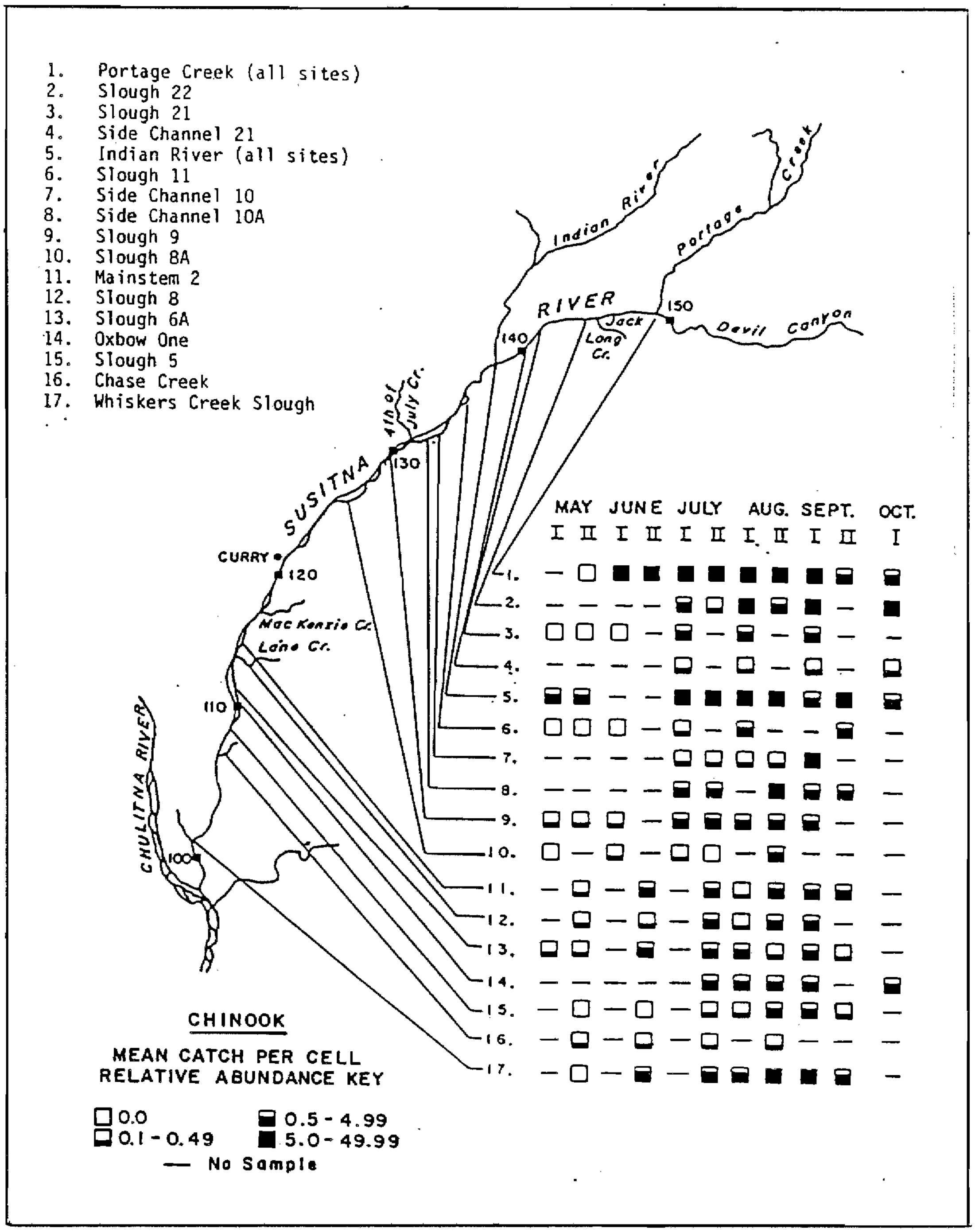


Figure 3. Seasonal distribution and relative abundance of juvenile chinook salmon on the Susitna River between the Chulitna River confluence and Devil Canyon, May through November 1983.

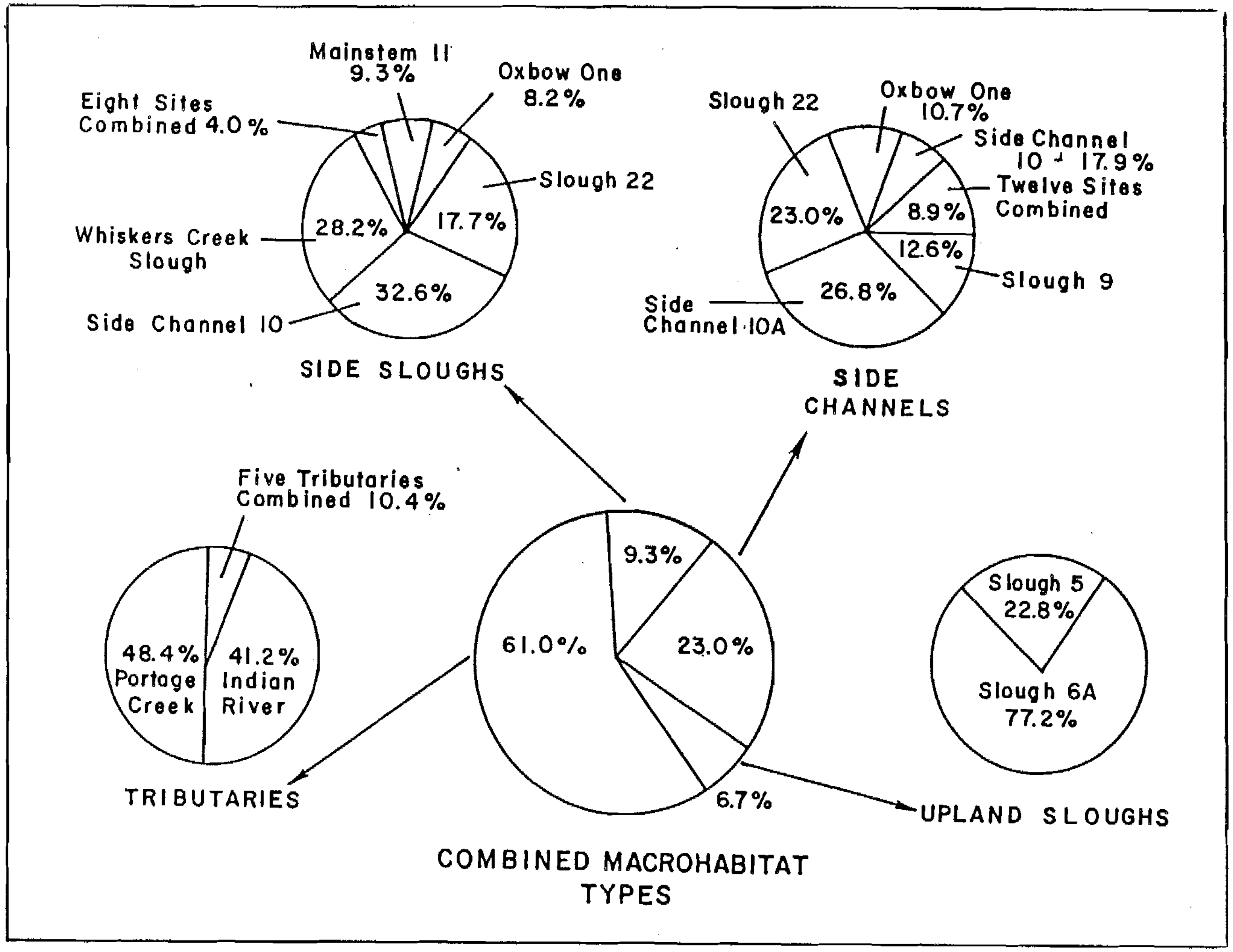


Figure 4. Density distribution and juvenile chinook salmon by macrohabitat type on the Susitna River between the Chulitna River confluence and Devil Canyon, May through November 1983. Percentages are based on mean catch per cell.

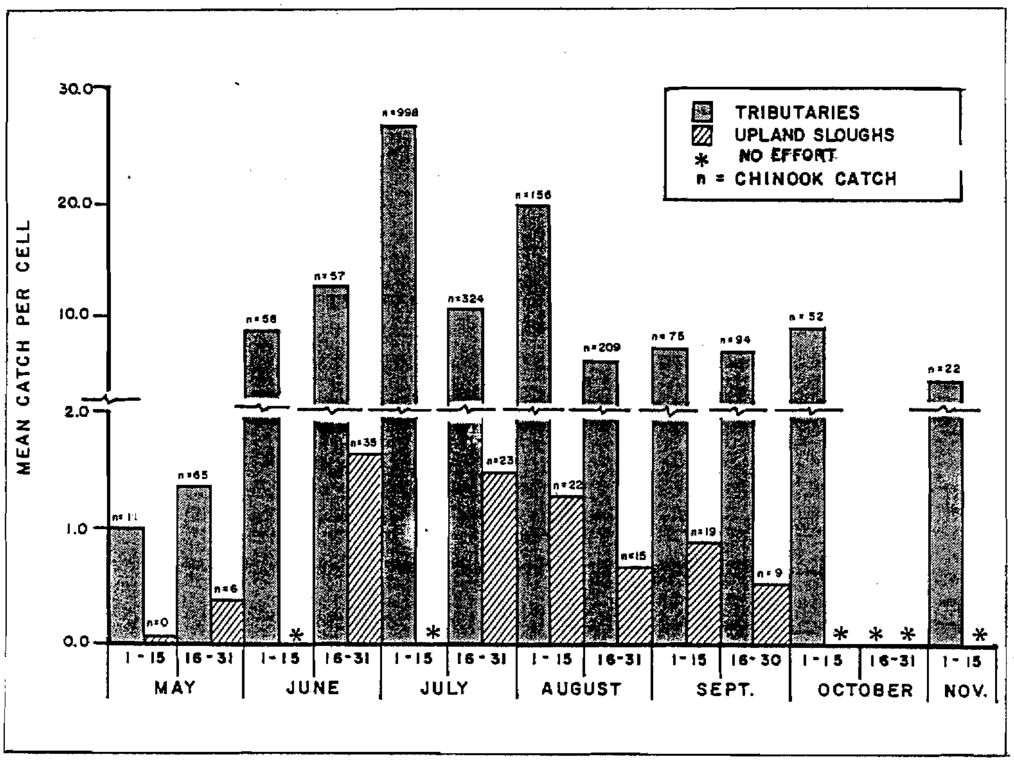


Figure 5. Juvenile chinook salmon mean catch per cell at tributaries and upland sloughs by sampling period, May through November 1983.

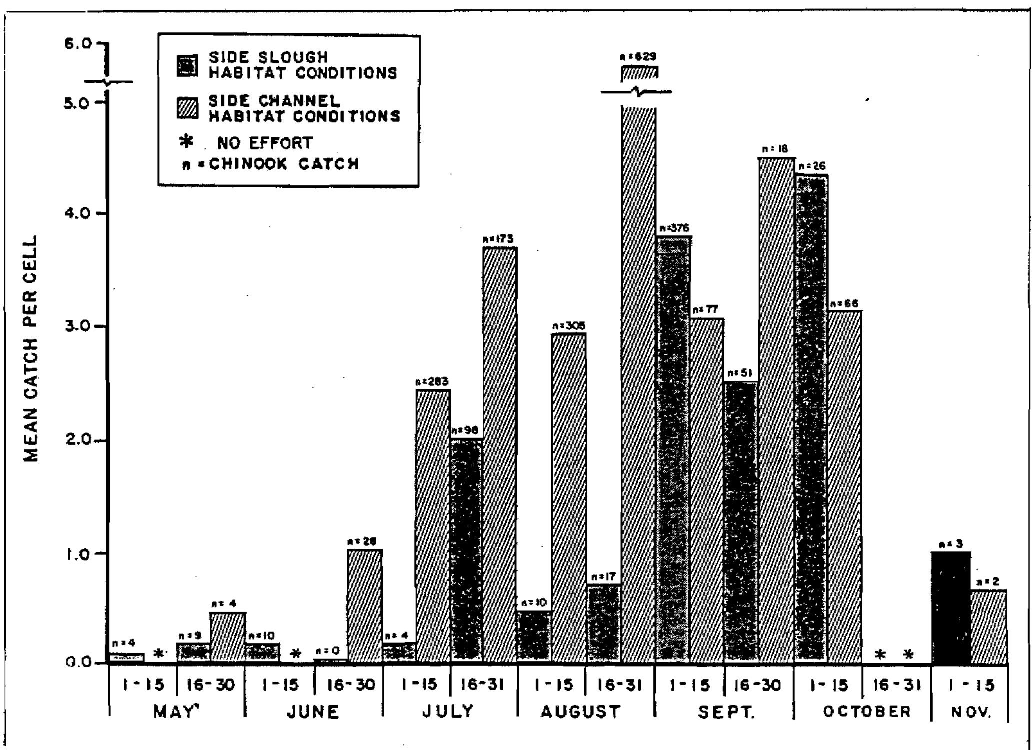


Figure 6. Juvenile chinook salmon mean catch per cell at side sloughs and side channels by sampling period, May through November 1983.

Three age classes of juvenile coho salmon from the 1980, 1981 and 1982 brood years (age 2+, 1+, and 0+ respectively) were captured. Ninety-seven percent of the coho juvenile salmon captured at JAHS sites in 1983 were from the 1982 brood year (age 0+), three percent were age 1+, and less than one percent were age 2+ fish.

In general, coho juvenile salmon were widely distributed in low densities at many sites in the Chulitna River to Devil Canyon reach of the Susitna River, although high tributary densities were observed in early July and August (Figure 7). Juvenile coho CPUE's were frequently highest at sites located in the lower segment of the Chulitna River to Devil Canyon reach.

The comparative distribution of coho juvenile salmon by macrohabitat types is depicted in Figure 8. Coho juveniles were captured mainly in tributaries and upland sloughs, with Whiskers Creek and Chase Creek being the primary tributary capture sites and Slough 5 and Slough 6A being the primary upland slough capture sites. Coho juvenile salmon were rarely encountered in side channels. Twelve side channel sites were sampled during 1983 and less than one percent of the juvenile coho salmon were captured at this macrohabitat type. Side channels appear to function as a pathway for redistribution of fish from tributaries macrohabitat into upland sloughs and side sloughs such as Whiskers Creek Slough and Slough 8. Side sloughs contributed 10% of the coho juvenile salmon total CPUE. Whiskers Creek Slough and Slough 8 contributed 99 percent of the juvenile coho captured at side sloughs.

Coho juvenile salmon catches ranged from 20 fish per cell at tributaries, to less than one fish per cell at side channels and side sloughs (Figure 9). Densities were higher in upland and side sloughs during late summer than in early summer or in autumn.

The highest densities of coho juvenile salmon were captured at tributaries in late June. Upland slough catch rates were higher from late July through late September than the catch rates for the other macrohabitat types. The highest densities of coho juvenile salmon at upland sloughs occurred in late July and then catch rates gradually declined through late September.

Seasonal trends in juvenile coho salmon in densities in side slough and side channel macrohabitats were not observed (Figure 10). Side slough densities of coho juvenile salmon were consistently higher than densities in side channels except during late June.

3.3 Distribution of Juvenile Chum Salmon

A total of 1,174 juvenile chum salmon were captured by electrofishing and beach seining at the JAHS sites from early May through July. During this same time period, the downstream migrant trap captured 8,555 juvenile chum salmon. The outmigration of chum salmon from this reach of river by early August is apparent from Figure 11.

The percent of total juvenile chum catch by two week period is presented in Figure 12. Catches at JAHS sites peaked in late May, by which time

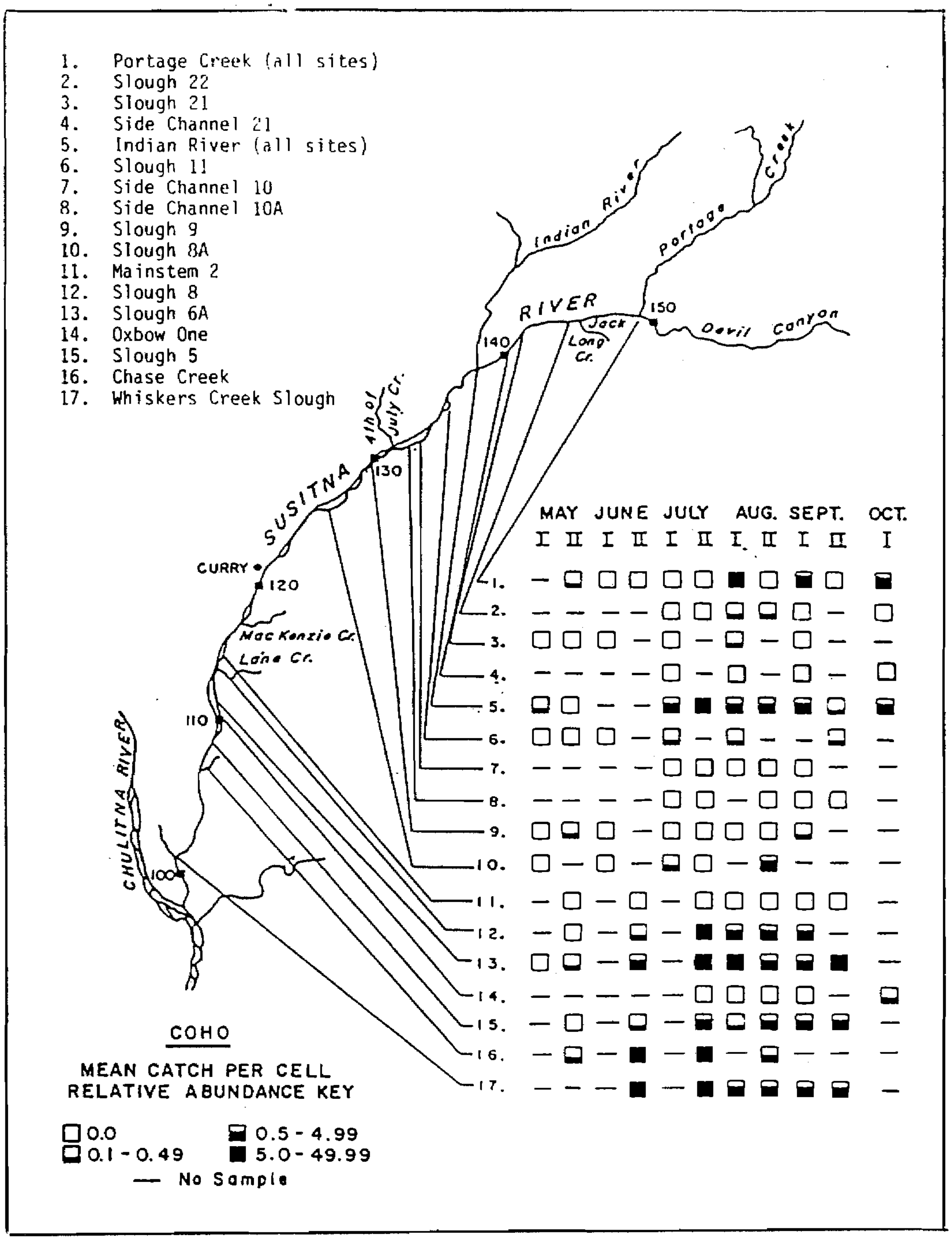


Figure 7. Seasonal distribution and relative abundance of juvenile coho salmon on the Susitna River between the Chulitna River confluence and Devil Canyon, May through November 1983.

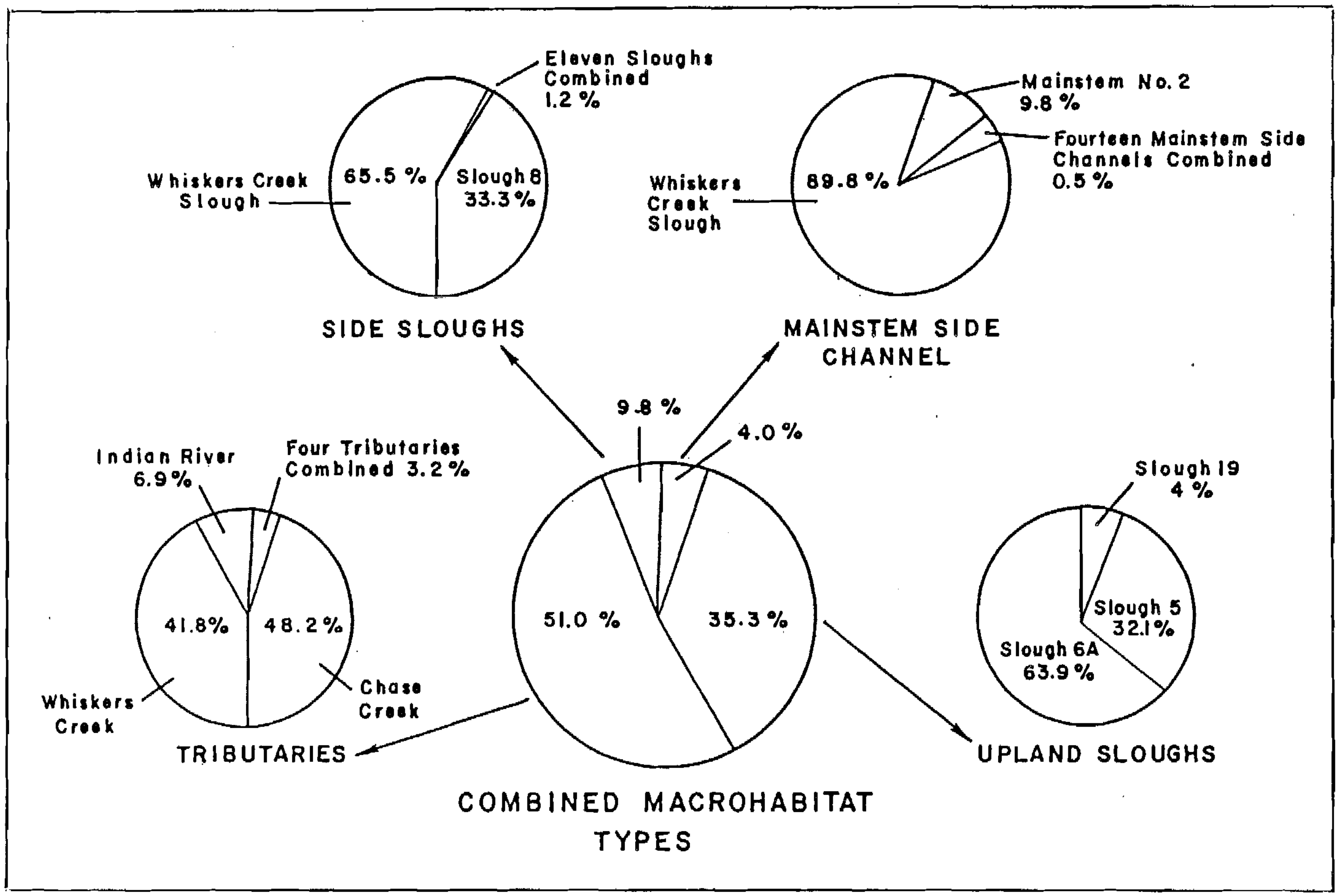


Figure 8. Density distribution of juvenile coho salmon by macrohabitat type on the Susitna between the Chulitna River confluence and Devil Canyon, May through November 1983. Percentages are based on mean catch per cell.

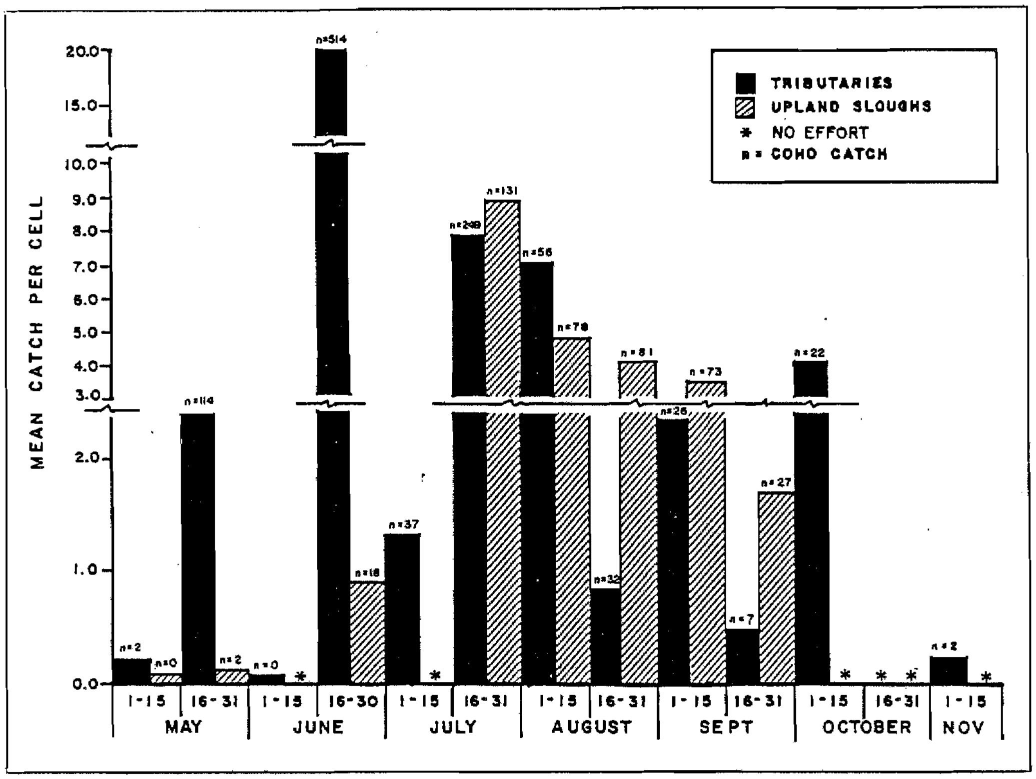


Figure 9. Juvenile coho salmon mean catch per cell at tributaries and upland sloughs by sampling period, May through November 1983.

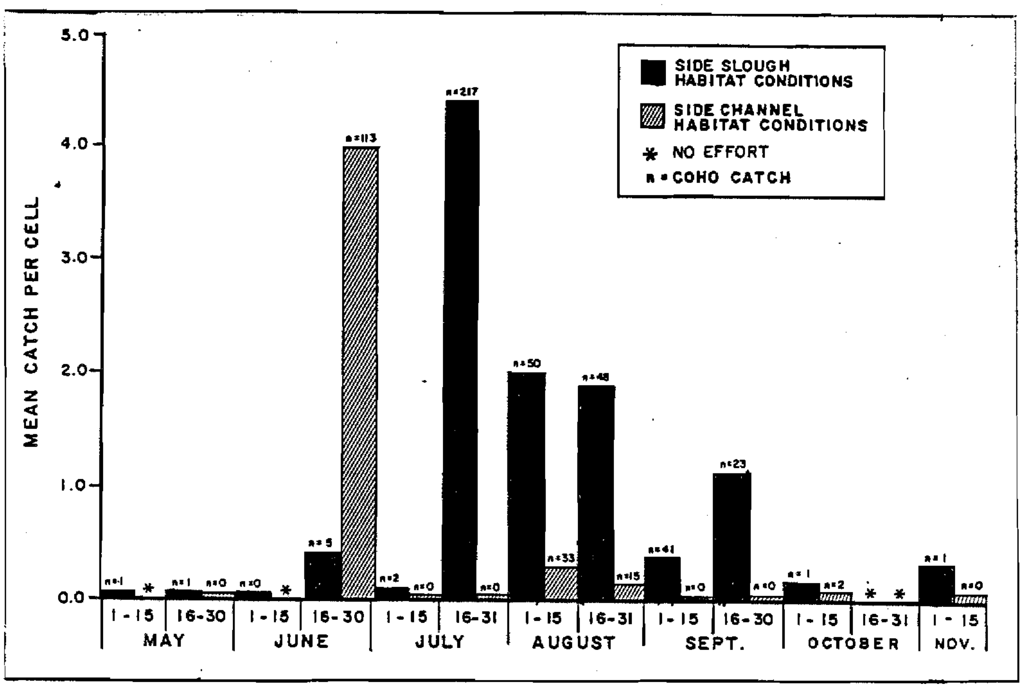


Figure 10. Juvenile coho salmon mean catch per cell at side sloughs and side channels by sampling period, May through November 1983.

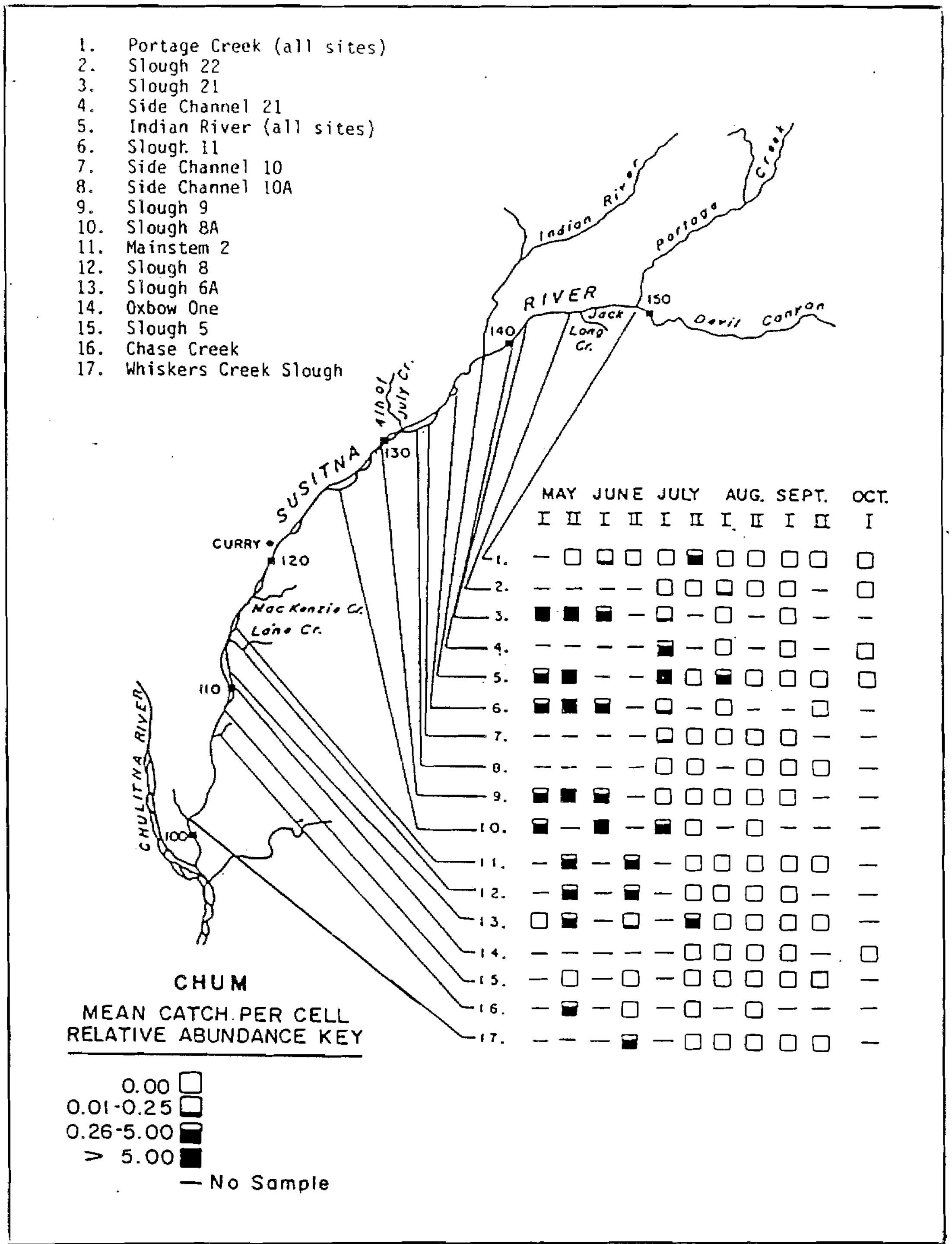


Figure 11. Seasonal distribution and relative abundance of juvenile chum salmon on the Susitna River between the Chulitna River confluence and Devil Canyon, May through November 1983.

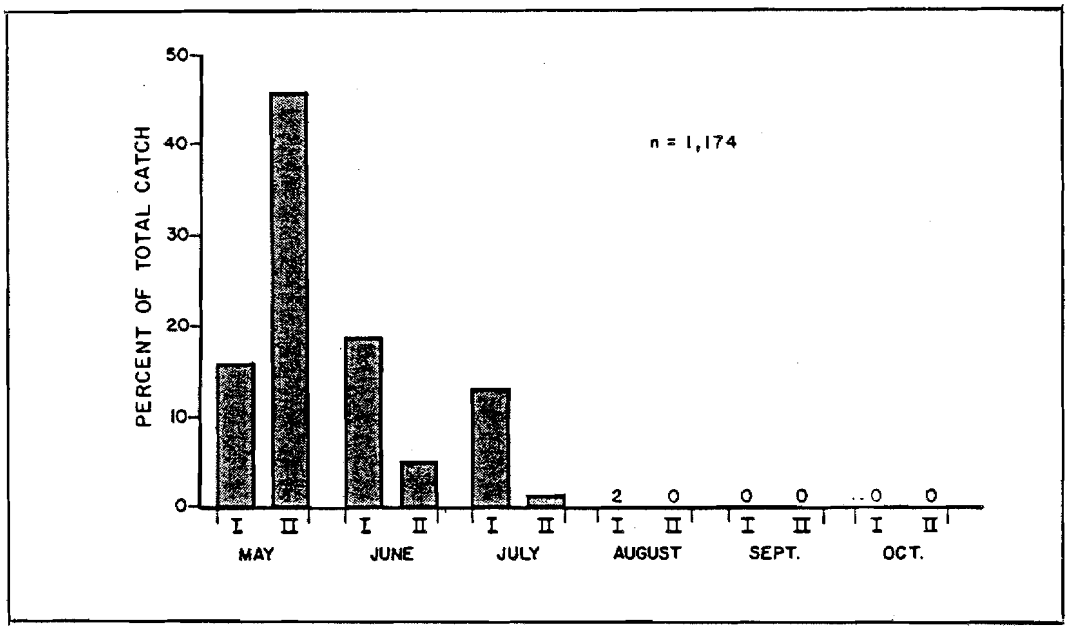


Figure 12. Percentages of the total juvenile chum salmon catch by sampling period, May through October 1983.

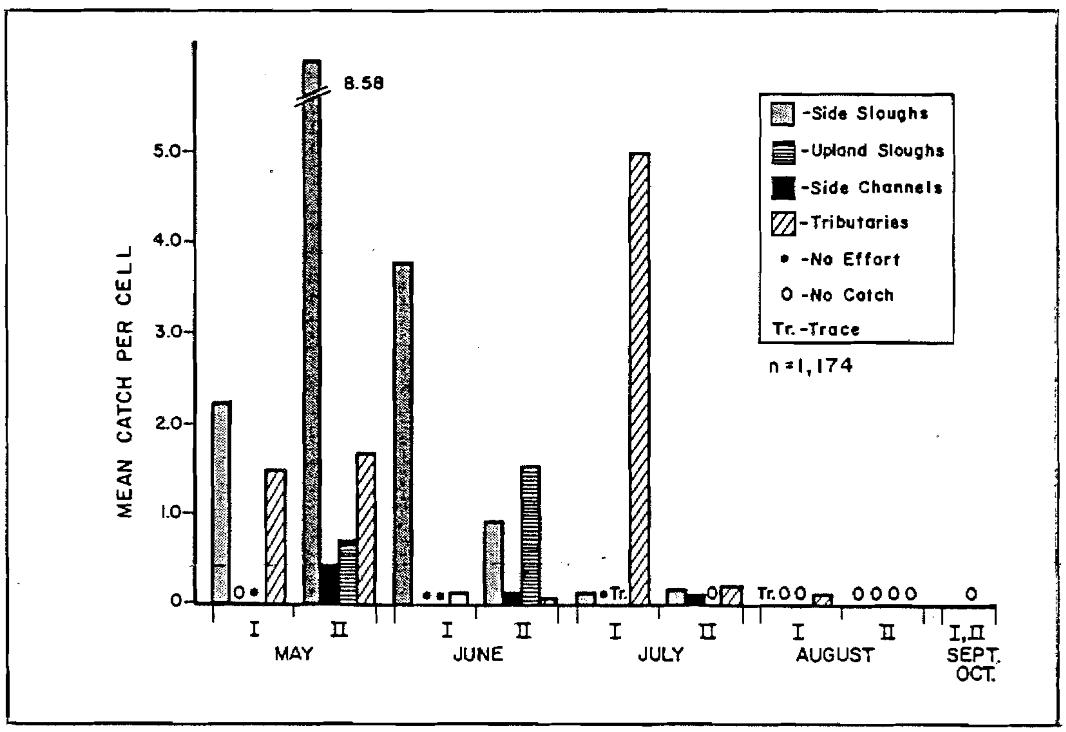


Figure 13. Juvenile chum salmon mean catch per cell at the four macrohabitats by sampling period, May through October 1983.

over 60% of the total catch had occurred. The downstream migrant trap recorded two peaks, one in early June and one in early July.

Juvenile chum salmon were abundant during May and June at sites having previous year spawning and were absent from the study sites by the end of July. Catch rates were highest in side slough and tributary macrohabitats and low in upland slough and side channel macrohabitats (Figure 13). Only 5% of the total catch was captured in these latter macrohabitats.

The comparative distribution of juvenile chum salmon densities is presented in Figure 14. Juvenile chum salmon were most dense at tributaries and side sloughs. As catches at side sloughs decreased, catches at upland sloughs used for rearing increased.

3.4 Distribution of Juvenile Sockeye Salmon

A total of 1,010 juvenile sockeye salmon were captured by electrofishing and beach seining at the JAHS sites from early May through September. All juvenile sockeye salmon actually captured at JAHS sites were age 0+. A few Age 1+ fish were visually observed at Slough 11.

The downstream migrant trap, located at RM 103.0 captured 12,395 juvenile sockeye between May 18 and September 25. Juvenile sockeye salmon were captured at 12 (71%) of the 17 JAHS sites sampled at least four times (Figure 15). They were absent from the study sites above Slough 8A after mid August; catches were still being made at sites below this until the end of September. The percent of total juvenile sockeye catch by two-week period is presented in Figure 16. Two peaks occurred in the catches, one in late May-early June and one in early August. The major peak at the downstream migrant trap occurred in mid-July.

Catch rates were highest in side sloughs and upland sloughs and lowest in side channels and tributaries (Figure 17). A single catch of four juvenile sockeye occurred in early June in Portage Creek, the sole tributary found to contain juvenile sockeye salmon.

The relative distribution of juvenile sockeye salmon among macrohabitat types is given in Figure 18. Juvenile sockeye salmon were predominantly found at side sloughs and upland sloughs. Almost all of the sockeye were caught at either upland sloughs or near their natal areas (side sloughs). The higher densities observed at Slough 11 are attributable to the amount of spawning occurring there in 1982 (ADF&G 1983b).

3.5 Analysis of Variance

The mean values of the transformed catch per cell which were compared among the intervals of each parameter are shown for each species in Appendix Table 1. If any one of the means within a parameter is significantly different from any of the other means, then the parameter is considered to influence the varying levels of catch associated with the distribution of that species. The confidence level for this analysis was taken to be 90%.

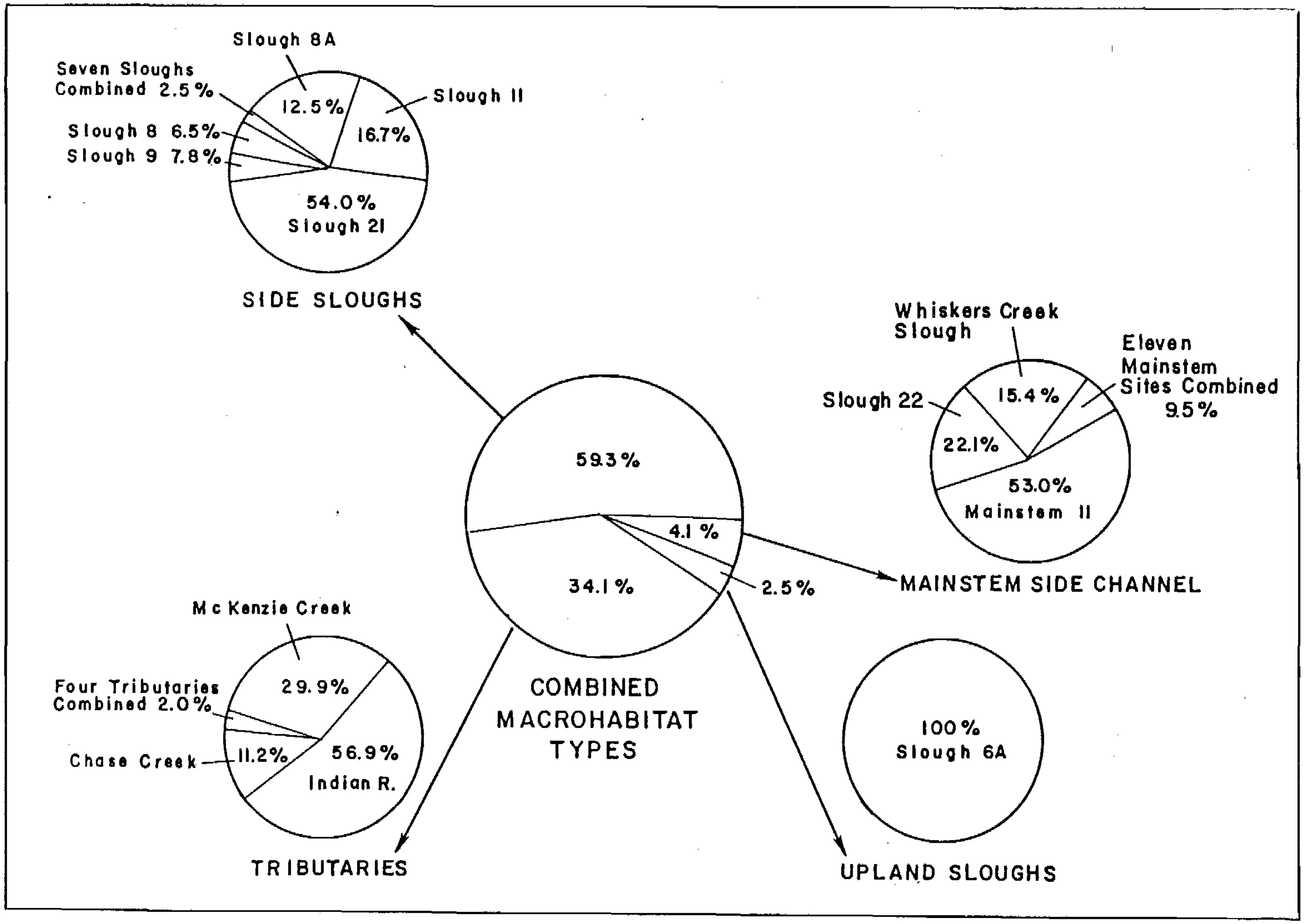


Figure 14. Density distribution of juvenile chum salmon by macrohabitat type on the Susitna River between the Chulitna River confluence and Devil Canyon, May through October 1983. Percentages are based on mean catch per cell.

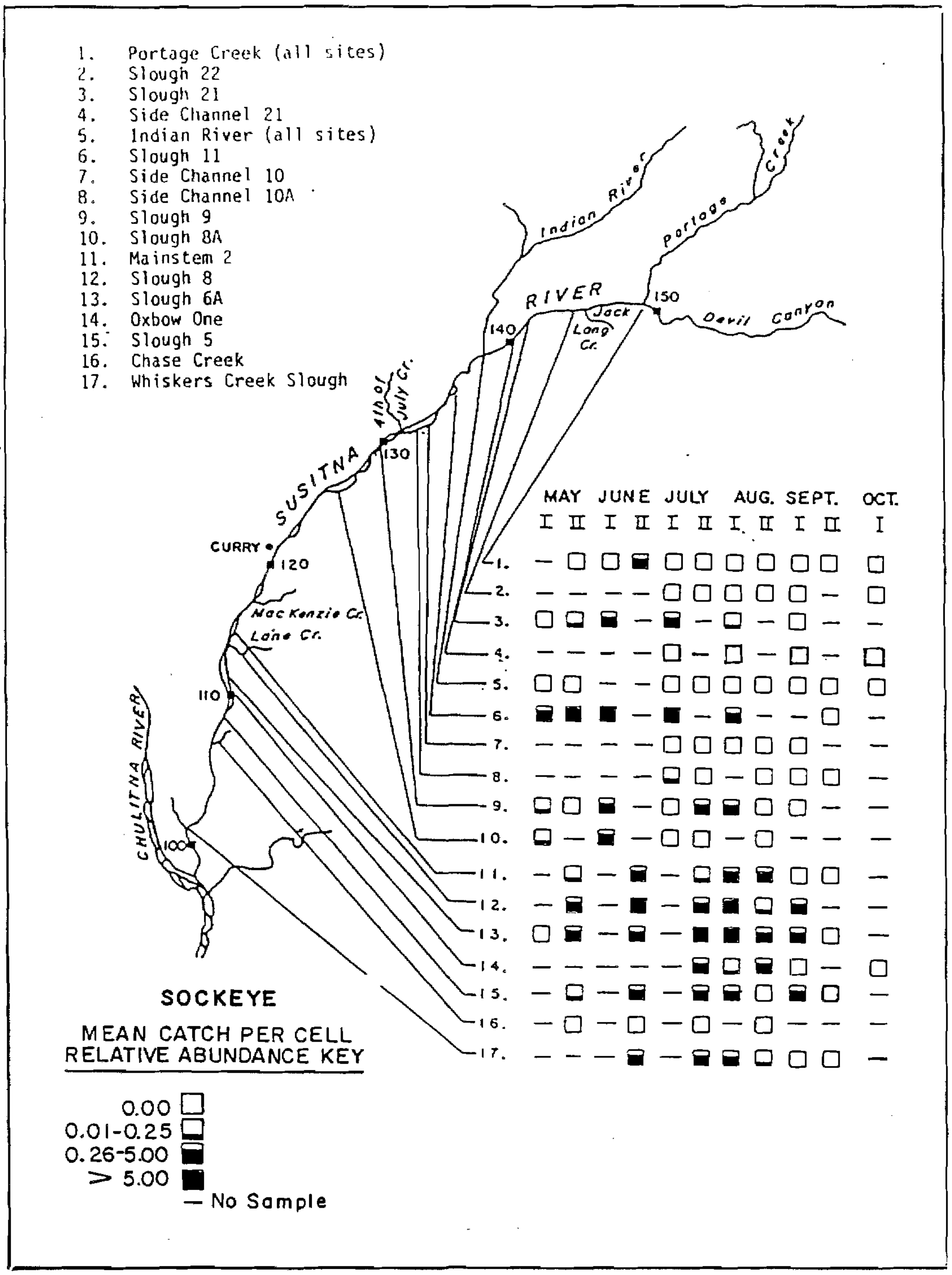


Figure 15. Seasonal distribution and relative abundance of juvenile sockeye salmon on the Susitna River between the Chulitna River confluence and Devil Canyon, May through November 1983.

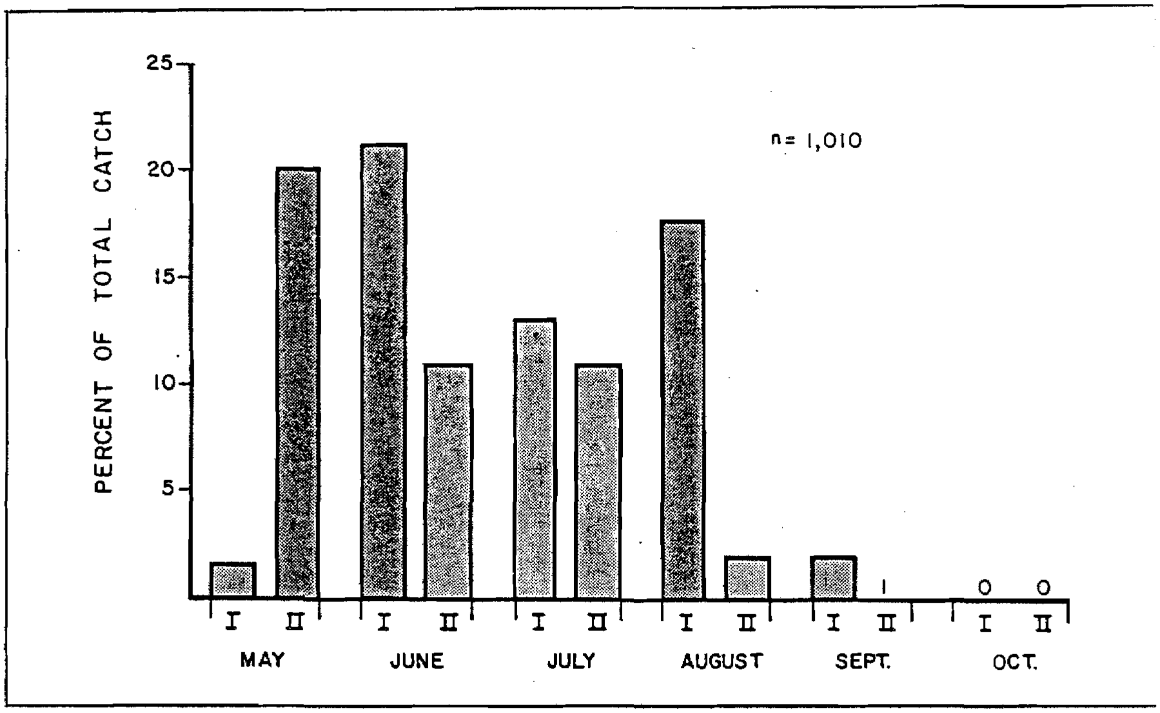


Figure 16. Percentages of the total juvenile sockeye salmon catch b sampling period, May through October 1983.

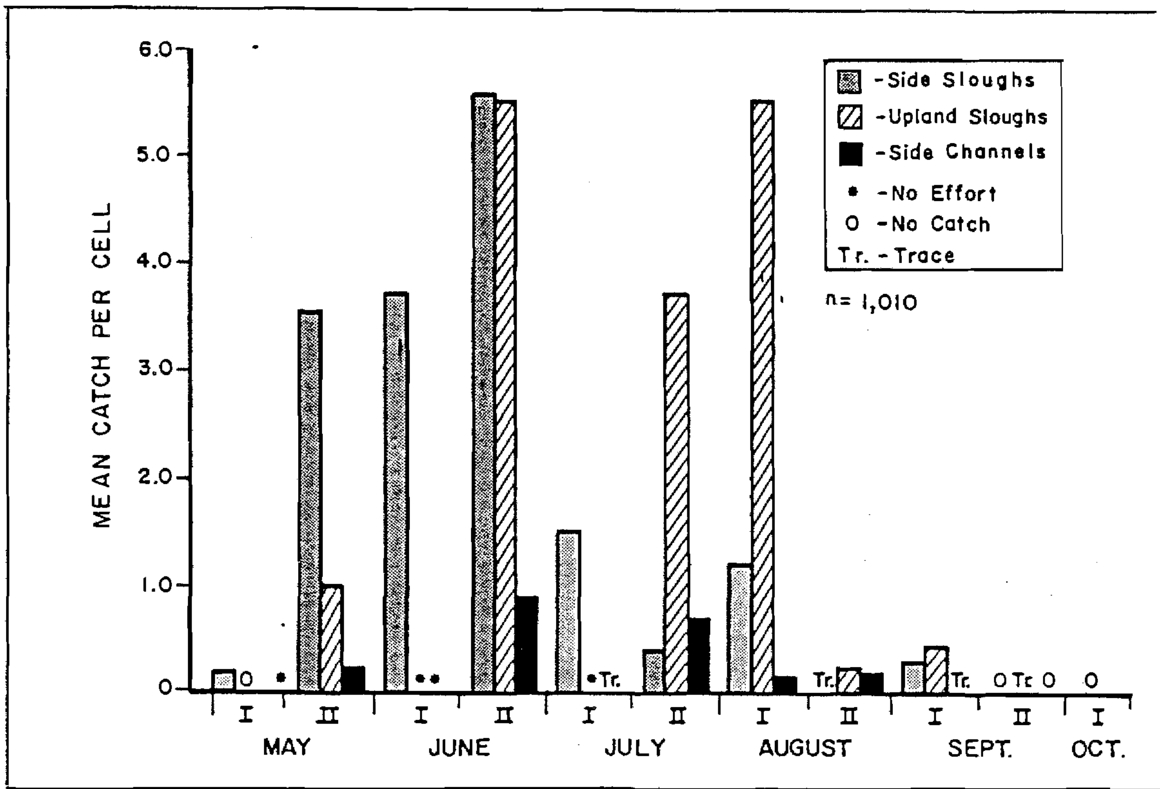


Figure 17. Juvenile sockeye salmon mean catch per cell at three macro-habitats by sampling period, May through October 1983.

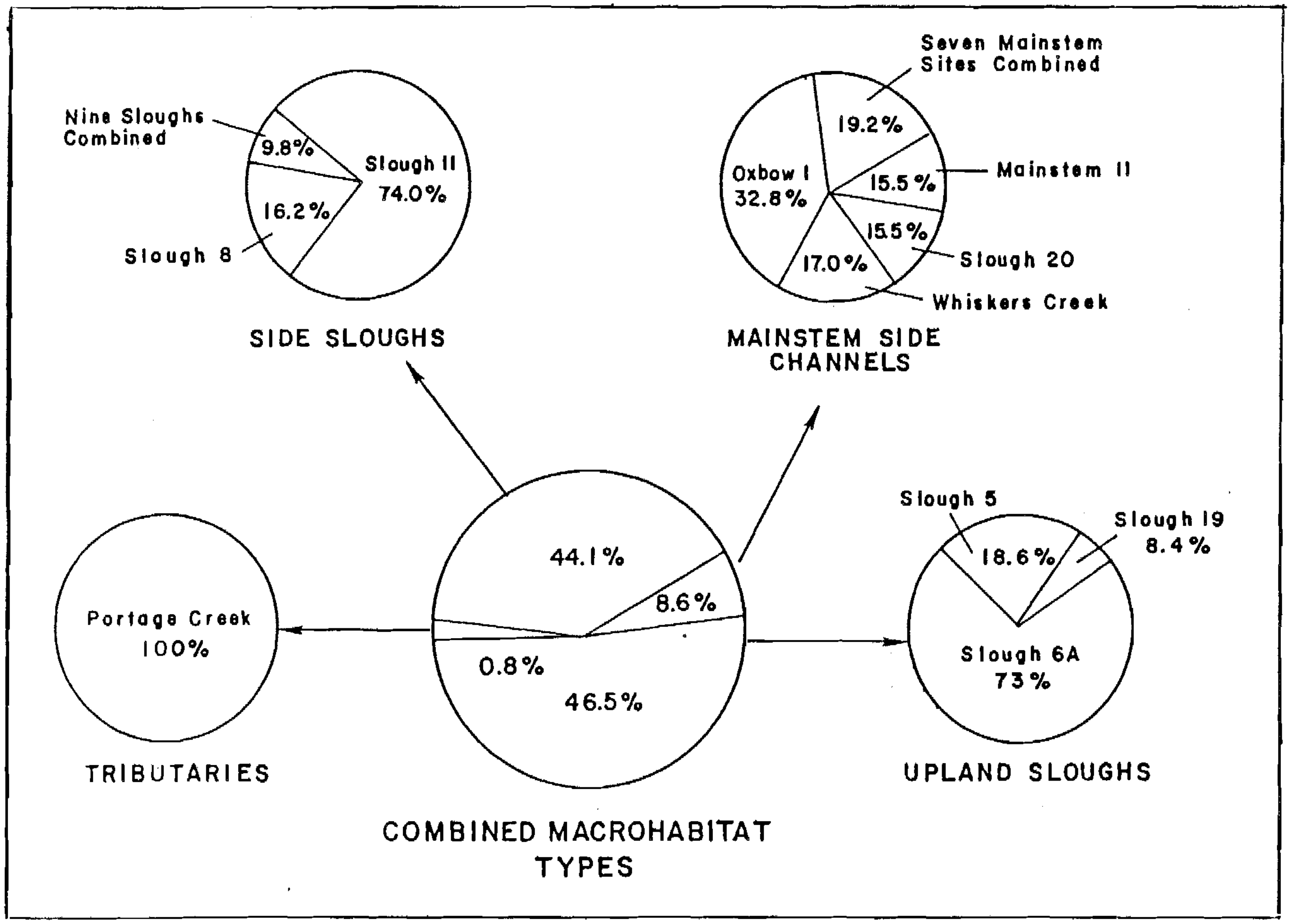


Figure 18. Density distribution of juvenile sockeye salmon by macrohabitat type on the Susitna River between the Chulitna River confluence and Devil Canyon, May through October 1983. Percentages are based on mean catch per cell.

Both macrohabitat type and sampling period were significantly linked to the distribution of all four species (Table 2). These results lend credence to the pie charts presented earlier in this section in which the catch per cell for each species is compared among different macrohabitat types and sampling periods. All species show preferences for certain macrohabitat types over others. They also exhibit seasonal differences in their distribution.

The analysis suggests that mean catches/cell for chinook and coho were significantly different for different levels of turbidity. The power of the analysis to detect significant differences in depth, velocity, and percent cover was weakened because of the non-randomness of the cells from which the means of these three variables were calculated. The effect of percent cover is compounded by the fact that fish use turbidity as cover. Because of many empty cells in the analysis of various table, interactions among variables were not calculated. Consequently, conclusions about the parameters other than macrohabitat type, sampling period, and turbidity are provisional.

Table 2. Results of analysis of variance of juvenile salmon catch/cell by selected habitat variables. A parameter is considered to be significant if the probability is less than 0.10. The first two parameters were run together and then the next five parameters were run together. Catch/cell was the response variable in both runs.

	Probabilities for each Species			
Parameter	Chinook	Coho	Chum	Sockeye
Macrohabitat type	0.00	0.00	0.09	0.01
Sampling period	0.00	0.00	0.00	0.01
Mean depth	0.42	0.01	0.53	0.47
Mean velocity	0.01	0.87	0.87	0.05
Mean percent cover	0.24	0.40	0.43	0.51
Water temperature	0.35	0.21	0.37	0.32
Turbidity	0.03	0.02	0.60	0.98

4.0 DISCUSSION

4.1 Limitations of the Data

4.1.1 Sampling limitations

The macrohabitat types depicted in the pie charts do not include the mainstem macrohabitat, a type which constitutes a large portion of the wetted surface area in this reach of river. The mainstem was not included because of the difficulty in effectively sampling deep, fast, turbid water for juvenile salmon and because these high velocity waters have little potential for rearing salmon. The side channels which were sampled were relatively small, near shore side channels, with riparian vegetation and often with some kind of clear water input such as a small tributary, an upwelling area, or hillside runoff. Large portions of the surface area of the river which can be classified as side channel are larger or mid-channel side channels which are devoid of cover other than substrate. Also, the heads of side channels where the best data were collected as a rule tend to overtop at a higher level of discharge than many mid-river side channels. Therefore, the fish collection side channels were actually side sloughs a higher proportion of the time than are many of the mid-river side channels.

The overall distribution of juvenile salmon in this reach of river can be classified as a contagious (clumped) distribution. There are areas of fish concentrations in areas such as natal sloughs or tributary mouths and there are other areas where fish density is much lower. Sampling sites have not been selected randomly throughout the reach. The Susitna River has clear water sloughs and tributary mouths and vegetated side channels interspersed amongst large areas of fast, turbid mainstem water. These main channel areas are important as pipelines between rearing areas and as an outmigration corridor. Their overall value as rearing areas is unknown but the amount of rearing habitat in these areas is limited by velocity.

4.1.2 Gear efficiency

Minnow traps, beach seines and electrofishing equipment have been used extensively as sampling methods for conducting fisheries surveys (Bennett 1970; Delaney et al. 1981; ADF&G 1981b, 1983c). However, minnow traps are selective for juvenile chinook and coho salmon and beach seining and electrofishing appear to be selective for smaller sized juvenile salmon (ADF&G 1983c). Burger et al. (1982) and Dauble and Gray (1980) have concluded that beach seining and electrofishing, when used in conjunction, provide a reliable index of species diversity, distribution, and relative abundance for juveniles of all salmon species except pink salmon. Minnow traps were not used in the Juvenile Anadromous Habitat Study (JAHS) in 1983. However, as with any sampling technique, the data collected were affected by gear bias and limitations. Electrofishing and beach seining methods were sometimes difficult to use in sampling the entire range of the available habitat utilized by juvenile salmon.

Results from two preliminary gear efficiency experiments presented in Appendix B indicate that (1) the capture efficiency of electrofishing decreases as percent cover increases and (2) that beach seining was more effective in water with high turbidity and electrofishing was more effective in water with low turbidity. However, these experimetns are not considered to be definative tests. Until these experiments can be repeated with a larger number of cells for all salmon species, we consider the above findings preliminary.

Differences in gear efficiency undoubtedly exist, however these differences are thought to be small in comparison to the seasonal variation in numbers of fish at a given site and the variations in numbers of fish among sites.

4.2 Chinook Salmon

The low numbers of age 1+ chinook salmon captured can be attributed to sampling gear bias and to the outmigration of this age class from the study area before July 15. Outmigrant trap data collected during the same time period indicated that a higher number of age 1+ chinook were present in the study area above the Chulitna River and subsequently rearing in the four macrohabitat types than the data from the distribution study indicated. Seven percent of the seasonal catch at the outmigrant trap consisted of age 1+ chinook. Of course, since age 1+ chinook would be most likely to outmigrate, one would expect a higher proportion of age 1+ chinook at an outmigrant sampling location.

Early in the summer, densities (fish per cell) of the two age classes of chinook salmon were considerably higher at tributaries as compared to upland sloughs, side sloughs, and side channels. Tributaries provided the highest concentrations of chinook early in the summer with side channel concentrations increasing in July.

Heavier cover in tributaries and the turbidity in side channels probably reduced gear effectiveness. The data presented reflect minimum densities at those sites. The effects of gear efficiency were probably not as important at side sloughs. In general, sites which represented this macrohabitat type such as Slough 22 and Whiskers Creek Slough, consisted of shallow, relatively clear water habitats with low to moderate cover which permitted effective use of electrofishing gear.

Densities of age 0+ chinook salmon were higher at side sloughs from July through November than before July. Lower densities at side sloughs before June were due to the tributary outmigrations which had not yet occurred.

One percent of the seasonal catch was collected in upland sloughs. Preference for habitat conditions that optimize rearing and proximity of study sites to natal tributaries were the two major factors which affected distribution. Previous studies conducted by Delaney and Wadman (1979), ADF&G (1983c), and Burger et al. (1983) concluded that the preferred habitat included moderate water velocities and water depths. Low densities of chinook salmon at upland sloughs may have resulted from the avoidance of this habitat type because of their preference for areas with moderate flow. The analysis of variance confirmed this preference. (See also Part 3 of this report which presents suitability criteria curves for each species).

Habitat conditions at side channels were more favorable for chinook salmon juveniles and, consequently, significantly more fish were found rearing in this habitat type. Fish collected from side channels were actively feeding at these sites although they were never directly observed in this activity. Examination of stomach contents indicated that some feeding was occurring at these sites in spite of the relatively high water turbidity. Turbidity was found by the analysis of variance to be a significant factor affecting distribution. We have observed that chinooks in side slough/side channels such as Slough 22 are widely distributed at the site when the head is overtopped and the water is therefore turbid. When the head is no longer overtopped and the water clears, the fish either move to the available cover such as cobble or leave the site.

Chinook salmon juveniles occurred in large numbers at tributary sites, because these fish originated in these tributaries and were rearing to attain sufficient size prior to dispersing into side channel or side slough macrohabitat.

The high densities of chinook juvenile salmon observed at side sloughs in September was a response to changes in side channel conditions. Decreasing side channel water temperatures may have stimulated chinook juveniles to migrate into side sloughs where conditions were more favorable for over-wintering. Also, as mainstem discharges decreased, some side channels, which harbored large numbers of juveniles, became side sloughs and fish moved into any available cover or outmigrated. It can be speculated that they may have stayed in higher densities than would normally occur when temperatures were higher and there was more competition for available food. Although water temperature was not found by the analysis of variance to be a significant factor in affecting chinook distribution during the open water season, our observations suggest that temperature is a factor during the fall re-distribution.

A comparison of outmigration from the tributaries or out of the lower river may provide some insight as to how catch rates are related to migration. Two peaks in catch rates for chinook juvenile salmon occurred at the four macrohabitat types and the outmigrant trap located at RM 103.0 (Figure 19). The first peak in catch rates was recorded at tributary study sites in early July. Large numbers of age 0+ fish left the natal tributaries to redistribute into the other major macrohabitats (upland sloughs, side sloughs, and side channel). Some of these fish outmigrated from the study area above the Chulitna River. A second peak in catch rates occurred at tributaries and the outmigrant trap in mid August. A substantial number of the juvenile chinook salmon in August apparently moved into mainstem associated areas as catches at these locations peaked in late August. Although overall catch rates declined in September for juvenile chinook in the study area, relatively high densities were recorded at side sloughs at this time. Apparently, fish were immigrating into side sloughs to overwinter prior to freeze up possibly because of the warmer temperatures associated with upwelling groundwater in the side sloughs.

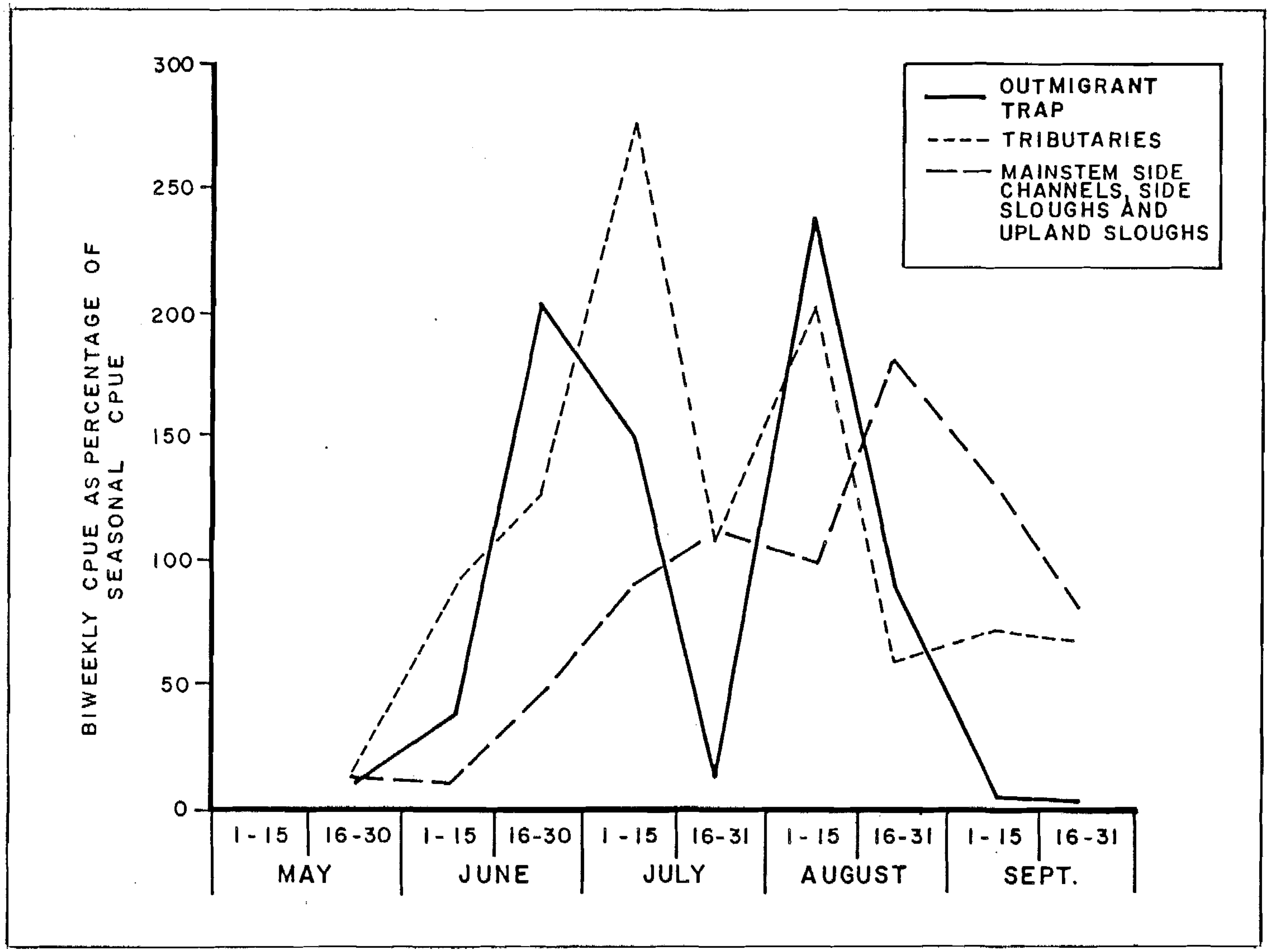


Figure 19 Seasonal deviation of catch per unit effort of juvenile chinook salmon on the Susitna River between the Chulitna River confluence and Devil Canyon, May through September 1983.

A decline in catch rates was reported by Riis and Friese (1978) at tributaries and side sloughs. Furthermore, Riis and Fries concluded that juvenile chinook overwinter in side channels as opposed to tributaries or side sloughs. However, the conclusions were based on a small sample size. Surveys conducted in October and November 1983 by the present study encountered substantial numbers of chinook juvenile salmon utilizing tributaries, side sloughs and, to a lesser extent, side channels.

Although exact comparisons of the relative abundance of chinook salmon fry among the three open water seasons sampled to date cannot be made because of different gear and effort it is apparent that 1982 was a year of low abundance of chinook juveniles in this reach, relative to 1981 and 1983.

4.3 Coho salmon

Juvenile coho salmon were distributed primarily in tributaries, upland sloughs, and side sloughs associated with the Susitna River above the Chulitna River confluence. The highest densities of juvenile coho were found in natal tributaries such as Chase Creek and Indian River which were documented as spawning areas for adult coho salmon by ADF&G (1983b). Tributaries are only affected by changes in Susitna River mainstem flows at areas located near the mouths of the tributaries (ADF&G 1983c). Consequently, macrohabitat types which are critical rearing areas for juvenile coho salmon and were affected by mainstem flows consisted of upland sloughs and side sloughs. Changes in flows can affect access to and usability of these sloughs and consequently the distribution and abundance of juvenile coho.

Upland sloughs, such as Slough 6A (RM 112.3) and Slough 5 (RM 107.6), and side sloughs are generally warmer than mainstem side channels or tributaries. Delaney and Wadman (1979) and Northcote (1969) concluded that warmer water attracted juvenile salmonids. Furthermore, Balchen (1976) argued that fish migration and redistribution was a behavioral response to seek optimal temperatures to maximize "comfort".

Upland sloughs probably enhance the survival of coho juvenile salmon by providing shelter from high discharges common for the Susitna River during the summer months. Skeesick (1970) and Cederholm and Scarlett (1981) concluded that juvenile coho immigration into lateral tributaries and riverine ponds was a behavioral response to high mainstem flows, to assure the viability of individuals under adverse flow conditions, and to escape high flow levels and turbid water.

Side sloughs and upland sloughs are generally clear to slightly turbid water environments, in contrast to mainstem or side channel water. Water clarity in the sloughs is not affected by turbidity levels in the mainstream Susitna River, except at backwater zones near the mouths of these macrohabitat types. Juvenile coho apparently immigrate into these macrohabitat types for rearing, since mainstem turbidity levels within the 70-100 NTU range may impair feeding (Alabaster 1972; Bisson and Bilby 1982). Sigler et al. (1984) found, in a laboratory study, that turbidity as low as 25-50 NTU caused a reduction in juvenile coho salmon growth; also, more coho juveniles emigrated from channels with this level of turbidity than from channels with clear water. The analysis of variance confirmed the preference of Susitna River juvenile coho for waters with a lower turbidity level.

Studies conducted by Delaney and Wadman (1979) in the Little Susitna River found high densities of post emergent fry near the spawning areas of adult coho salmon from April through June. After that, the fry disperse from the redds.

Substantial increases in coho fry density at upland sloughs and, to a lesser degree, at side channels were detected during the same sampling periods when high densities were recorded for tributaries. Increases in the number of coho juveniles occurred in late July at Slough 8, Slough 6A, and Whiskers Creek Slough. Although Delaney and Wadman (1979) concluded that 60mm was the average length for coho juveniles before indications of outmigration from tributaries and redistribution into suitable habitat, data collected in 1983 indicated that mobility size was considerably less (37mm - 45mm). The smaller size age 0+ coho salmon captured at upland sloughs and side sloughs were fish probably displaced from natal tributaries because of high flow events, intraspecific competition with other juvenile coho and or interspecific competition with juvenile chinook salmon. Small coho juveniles were also captured at the Talkeetna outmigrant trap from late June through July.

The deviations in catch rates of coho juvenile salmon are compared between tributaries, mainstem influenced macrohabitats, and the Talkeetna outmigrant trap (RM 103.0) in Figure 20. Although direct comparisons of catch rates are impossible, because of the different units used to calculate catch per unit effort (catch/hour, trap; catch/cell, macrohabitat types), an examination of variability in the of catch rates gives some indication allows comparisons of seasonal abundance.

The distribution and outmigrant patterns do not provide clear trends. Catch rates at the sites sampled in both tributaries and adjacent to the mainstem had similar catch rate variations but were not duplicated at the outmigrant traps.

Outmigrant trap catch rates declined sharply after mid August as compared to catch rates at side and upland sloughs during the same time period. This decline at the outmigrant trap may be attributed to redistribution of coho juvenile salmon into suitable rearing macrohabitat at sites above the location of the trap or a decline in the number of age 0+ coho outmigrating from the upper reaches of the Susitna River. The higher rates of catch recorded at habitats adjacent to the mainstem suggest use of these areas for wintering.

Catch rates of coho juveniles generally declined at all macrohabitats sampled from summer to winter. Similar decreases in catch rates were also reported by Riis and Friese (1978) at tributaries and side sloughs. Furthermore, Riis and Friese concluded that coho juveniles probably over winter in mainstem sidechannels, as opposed to tributaries or side sloughs because of reductions in rearing habitat resulting from lower flows. However, data collected during the 1981 through 1983 studies

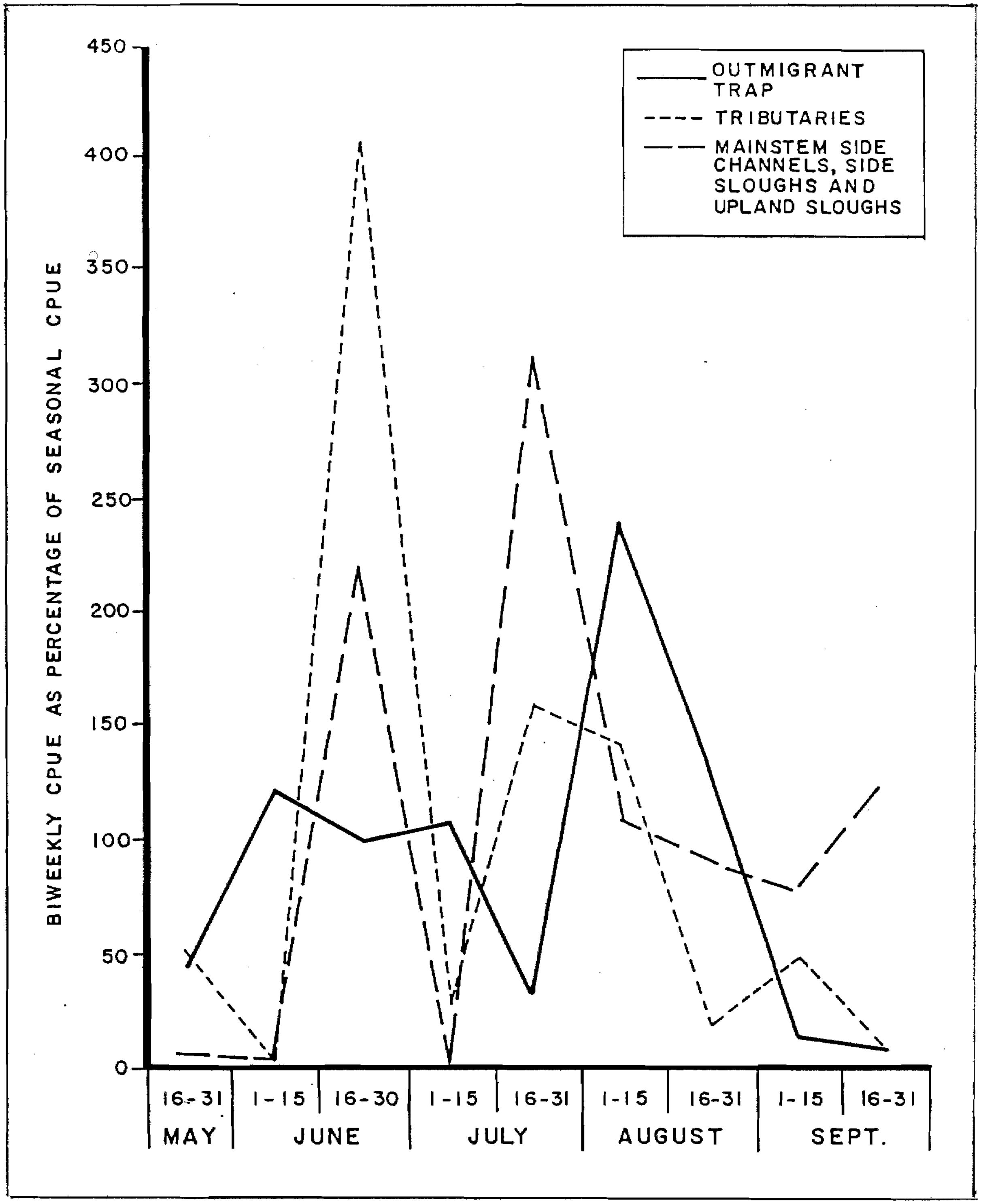


Figure 20. Seasonal deviation of catch per unit effort of juvenile coho salmon on the Susitna River between the Chulitna River confluence and Devil Canyon, May through September 1983.

(ADF&G 1981b; 1983c) indicate that substantial winter rearing occurs in side sloughs and upland sloughs.

Studies conducted by Peterson (1980) indicate that upland slough coho juveniles incur a much lower winter mortality than the typical stream resident. In the winter, juvenile salmon are inactive and hide in the gravel or deep pools, ensuring that they are not carried out of the system (Thorpe 1981).

4.4 Chum

An accurate record of the true distribution of juvenile chum and sockeye salmon may not be shown by 1983 data due to biases associated with the sampling techniques. During this and previous studies, beach seining and electrofishing have been the two most effective methods of collecting juvenile chum and sockeye salmon (ADF&G 1981b, 1983c). Beach seining and electrofishing efficiencies are directly correlated to mainstem discharge and turbidity levels at many macrohabitat locations. Burger et al. (1982) found that as the discharge and turbidity of the Kenai River increased, electrofishing efficiency decreased while beach seining efficiency increased. Comparisons of this year's data with previous year's studies on the Susitna River are also biased. During the 1981 Juvenile Anadromous studies, CPUE's were based mainly on minnow trapping, with only a minimal amount of beach seining effort. Minnow trapping is not an effective method of capturing juvenile chum and sockeye salmon.

A total of 1,174 juvenile chum salmon were captured in 1983 above the Chulitna River, while 1,104 were captured in the same reach in 1982. All of the sites where chum salmon were collected during 1982 studies and which were sampled in 1983 again produced juvenile chums (ADF&G 1983c).

Tributaries and side sloughs accounted for 92% of the total juvenile chum catch in 1983, of which 92% were captured in natal sloughs and tributaries. In 1982, a large school of fish captured at upland slough 6A accounted for 81% of the total catch for all macrohabitat types. This uneven distribution creates biases in results when catch per unit effort data are used.

Although upland sloughs accounted for only 1% of the total catch, visual observations both within and outside the designated study areas and 1982 catches (ADF&G 1983c) confirmed that juvenile chum use upland sloughs for rearing, as do sockeye juveniles.

High velocity side channel and mainstem environments are not considered prime rearing areas for juvenile chum salmon. Juvenile chums are captured in the mainstem, but usually in lower velocity backwater zones.

Basically, juvenile chum salmon were found in high densities in natal side sloughs and tributaries early in the season (May-early June) and in upland sloughs and side channels in late June and July. After July, catches and observations of juvenile chums within any of the macro-habitats were extremely rare. Chum salmon catches at the downstream migrant traps also plummeted after mid-July, indicating that the bulk of the outmigration had taken place (see Part 1 of this report).

Figure 13 illustrates the possibility of two distinct outmigrating juvenile chum populations; one from the natal sloughs in late May and one from the tributaries in early July. These peaks correspond with peak catches at the downstream migrant traps (See Part 1 of this report). Although the tributary chums generally spawn earlier than the slough populations (ADF&G 1983b), the colder intragravel temperatures found in the tributaries in the winter (Estes and Vincent-Lang 1984) could account for a delayed emergence and outmigration.

Juvenile chums have been found to prefer the shallower, flowing waters of side sloughs and upland sloughs, as opposed to the low flow, deeper pools preferred by juvenile sockeye. Juvenile chum salmon were more widely distributed than sockeye juveniles during 1983, the reason being that chum salmon spawn in more sloughs than sockeyes. This was also true in 1982 (ADF&G 1983b).

Although tributaries are not affected by mainstem flow, except at the confluence, higher mainstem flows usually occurred at times of higher tributary flows. Higher tributary flows acted as a flushing device, with fewer fish being present in natal areas and more fish being present at rearing and outmigrating areas after the high flows.

The first major peak of mainstem discharge in May coincided with the highest juvenile chum catch rates. By the time the peak mainstem discharge occurred in early June, the majority (62%) of the total juvenile chum catch had already occurred. Juvenile chum salmon from natal sloughs tend to take advantage of the first major rise in mainstem discharge and start outmigrating. This was also true in 1982 when the last juvenile chum was observed by mid July (ADF&G 1983c). The exact stimulus for outmigration is not known, but is probably a combination of innate behavior, increased cover (turbidity), increased water temperatures and the higher flows. Few juvenile chum were captured at tributary sites until early July, after the peak spring discharge in the mainstem. Similarly, few chum juvenile were captured (using the same methods) until late June in 1982, well before the peak mainstem discharge.

4.5 Sockeye Salmon

Gear bias also affected the catch data for sockeye salmon. Beach seining on the Kenai River, in areas where no sockeye juveniles were captured in minnow traps, proved that sockeye were present (Burger et al. 1982). The 1983 catches by location in the Susitna River can be loosely compared with 1982 data, as beach seining was the main sampling method used in 1982. Juvenile sockeye salmon have been found to school in the clear waters of some of the side sloughs. Often, schools were observed just prior to sampling, but unavoidable disturbances caused the fish to move out of the sampling grid and few, if any, would be captured. Sockeye juveniles were also observed to use the deeper pools and interstitial spaces in the larger substrate. Due to their depth, many of the deeper pools were inaccessible to effective sampling. Fish using substrate as cover might remain within the substrate during electrofishing and beach seining passes and, once again, the data would not reflect this presence.

A total of 1010 juvenile sockeye salmon were captured in 1983 above the Chulitna River. Distribution within this reach was similar in both 1982 and 1983, with 57% and 66% of the total catch occurring above RM 125.0 during 1983 and 1982, respectively. All of the sites where sockeyes were collected during 1982 sampling, were found to contain sockeye in 1983.

Side sloughs accounted for 71% of the total juvenile sockeye catch in 1983, of which 65% were captured in natal sloughs. Side sloughs accounted for 31% of the total catch during 1982. The major reason for this lower number during 1982 is the large number of fish captured at the upland slough, Slough 6A, (62% of the total catch for all habitat types). These differences are probably a result of collection methodology rather than any major difference in distribution between years.

Upland sloughs accounted for 20% of the total catch in 1983, with the highest catch rates occurring late in the summer (July-August). A distinct redistribution of sockeye juveniles from side slough natal areas to upland slough rearing areas at this time can be seen in Figure 18. Slough 6A, the major upland slough used by outmigrating and/or rearing sockeye juveniles, accounted for 86% of the total upland slough catch. Juveniles sockeye generally rear in lakes although slough populations are not uncommon (Foerster 1968, McCart et al. 1980). With the exception of the unique habitat at Slough 6A, including low velocity, clear water, depth and abundant cover and aquatic vegetation, major concentrations of juvenile sockeye salmon were found in natal side sloughs. Slough 5, an upland slough with shallow depths and low gradient banks, did not have large numbers of sockeye. This slough was broadly covered with emergent vegetation.

With the exception of backwater areas, side channel and mainstem environments are not used extensively as rearing areas by juvenile sockeye. Mainstem 2 and Oxbow I are both side channels that were breached during much of the 1983 season and both had these backwater zones. Sockeye juveniles were captured at both of these sites. The preference of sockeye juveniles for low velocity water was clearly demonstrated by the analysis of variance.

Tributary spawning by sockeye salmon is rare in the Chulitna confluence to Devil Canyon reach. During the past three years, six adult sockeyes have been observed in the tributaries, four of them in Portage Creek during 1982 (ADF&G 1981a, 1983b; Barrett et al. 1984). Few juveniles have been captured in tributaries during the past three years because of this lack of tributary spawning (ADF&G 1983c). Basically, juvenile sockeye salmon in the study reach primarily use side and upland sloughs for rearing.

Two of the major natal areas of sockeye salmon (Sloughs 9 and 21) were directly affected by mainstem discharges overtopping the head of the sloughs in 1983. Slough 11, the major sockeye spawning area in the upper Susitna River is only breached by very high flows, the last time in 1981 (ADF&G 1981c). Small changes occur at the mouths of side sloughs which are not breached, with increases in depth, turbidity, pool sizes and cover occurring at higher flows. Sockeyes have been found to utilize lower velocities and greater depths than the other juvenile salmon species. (See Part 3 of this report).

As mainstem discharges increase in May and June, catch rates also increased (Figure 16). The peak catch rate in the primary natal sloughs occurred in early June when the discharge was at its seasonal peak of 34,000 cfs. Sockeye juveniles may respond to increases in water depth, velocity, and turbidity in the breached slough (now a side channel) by outmigrating. Whatever the stimulus, lower catch rates in natal sloughs after head breaching reflects outmigration.

Intraspecific competition for available rearing habitat could also initiate outmigration. The highest catch/hour of sockeye juveniles at the downstream migrant trap occurred in early July, corresponding to the highest catches at natal sloughs before July and at rearing sites during and after July.

Observations at rearing sites and downstream migrant catch data indicate that some overwintering in this reach by juvenile sockeye salmon does occur. Age 1+ sockeye were captured and observed in Slough 11 during 1981, 1982 and 1983. The downstream migrant trap juvenile sockeye catches included 1.1 and 0.7 percent catches of Age 1+ fish in 1982 and 1983, respectively. During the past three years of study, Age 1+ sockeyes have been observed at Slough 9, Slough 11 and Slough 6A (ADF&G 1981b, 1983c).

The capture at non-natal sites of juvenile sockeye during August and September that were coded wire tagged in early June suggests that overwintering in sloughs 6A and 11 and presumably other sites may occur.

Sockeye 0+ fry have been observed to remain in the shallower waters near shore both in rearing areas and while outmigrating early in the summer. As they grow, they start using the deeper waters. Age 1+ fish, if they follow the same pattern, may be using the deepest waters of the macrohabitats for both rearing and outmigrating and therefore would not be susceptible to our sampling technique.

5.0 CONTRIBUTORS

Field work for the project was conducted by Larry Dugan, Paul Suchanek, Bob Marshall, and Dave Sterritt.

Dana Schmidt and Steve Hale assisted with the study design and analysis.

The data base was keypunched by Donna Buchholz and managed by Allen Bingham, Gail Heineman, and Alice Freeman.

The analysis of variance section was prepared by Allen Bingham and Steve Hale. Steve Hale and Paul Suchanek wrote the section on analysis of gear efficiency.

Bruce Barrett and Larry Bartlett reviewed the draft copy of this paper and provided helpful comments.

Sally Donovan and Carol Kerkvliet drafted the figures and the typing was done by Skeers Word Processing.

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APPENDIX A

Summary Statistics for Transformed Catch/Cell Data

Appendix Table A-1. Summary statistics for transformed catch/cell data of each species, by groups for each habitat parameter.

PAGE 13 BMDP1D STATISTICS OF GROUPED JAHS DATA (RJ8301) - BY HABITAT VARIABLES

VARIABLE NO. NAME	GROUPING VARIABLE	LEVEL	TOTAL FREQUENCY	MEAN	STANDARD DEVIATION	ST.ERR OF MEAN	COEFF. OF VARIATION	SMALLEST VALUE	SMALLEST Z-SCORE	LARGEST VALUE	LARGEST Z-SCORE	RANGE
15 LCHIN			133	1.112	.905	.0785	.81361	0.000	-1.23	3.965	3.15	3.965
	MACNUM	UPSLOUGH	24	.624	.584	.1192	.93668	0.000	-1.07	2.079	2.49	2.079
		SISLOUGH	42	.744	.703	.1084	.94480	0.000	-1.06	2.140	1.99	2.140
		SICHANNE	39	1.233	.634	.1016	.51431	0.000	-1.94	2.845	2.54	2.845
		TRIBUTAR	28	1.914	1.133	.2141	.59183	0.000	-1.69	3.965	1.81	3.965
	PERIOD	LMAY	15	.334	.496	.1280	1.48690	0.000	-.67	1.609	2.57	1.609
		EJUN	6	.516	.868	.3542	1.68174	0.000	-.59	2.230	1.96	2.230
		LJUN	10	.618	.610	.1929	.98733	0.000	-1.01	1.504	1.45	1.504
		EJUL	16	1.629	1.347	.3367	.82651	0.000	-1.21	3.965	1.73	3.965
		LJUL	19	1.246	.852	.1955	.68397	0.000	-1.46	2.868	1.90	2.868
		EAUG	18	1.128	.907	.2137	.80364	0.000	-1.24	3.186	2.27	3.186
		LAUG	20	1.274	.829	.1853	.65014	0.000	-1.54	2.845	1.90	2.845
		ESEP	20	1.343	.570	.1274	.42410	.531	-1.43	2.230	1.56	1.699
		LSEP	9	1.248	.707	.2356	.56622	.262	-1.39	2.542	1.83	2.279
	MEANDEP	0.1-0.6	52	1.214	1.018	.1412	.83878	0.000	-1.19	3.965	2.70	3.965
		0.7-0.9	46	1.188	.883	.1302	.74350	0.000	-1.34	3.640	2.78	3.640
		1.0-1.2	17	.779	.763	.1850	.97957	0.000	-1.02	2.845	2.71	2.845
		1.3-1.5	9	.887	.848	.2828	.95620	0.000	-1.05	2.701	2.14	2.701
		1.6+	9	.993	.472	.1572	.47489	0.000	-2.11	1.649	1.39	1.649
	MEANCOV	0-5%	71	1.100	.796	.0944	.72306	0.000	-1.38	3.186	2.62	3.186
		6-25%	53	1.255	1.042	.1431	.82986	0.000	-1.21	3.965	2.60	3.965
		26-100%	9	.364	.389	.1298	1.07142	0.000	-.93	1.099	1.89	1.099
	MEANVEL	0.0-0.5	103	.995	.860	.0848	.86494	0.000	-1.16	3.965	3.45	3.965
		0.6+	30	1.515	.952	.1738	.62821	0.000	-1.59	3.487	2.07	3.487
	SWATTEMP	0.0-5.0	13	1.283	.751	.2082	.58499	0.000	-1.71	2.542	1.68	2.542
		5.1-10.0	63	1.247	1.061	.1336	.85061	0.000	-1.18	3.965	2.56	3.965
		10.1+	56	.925	.714	.0954	.77173	0.000	-1.30	3.640	3.80	3.640
	TURB	0-10	85	.987	.938	.1017	.94969	0.000	-1.05	3.640	2.83	3.640
		>10-50	16	1.207	.744	.1859	.61589	0.000	-1.62	2.701	2.01	2.701
		>50-100	6	1.208	.537	.2190	.44430	.470	-1.37	1.841	1.18	1.371
		>100-200	11	1.664	.629	.1896	.37785	.993	-1.07	2.845	1.88	1.852
		200+	10	.857	.361	.1142	.42149	.262	-1.65	1.308	1.25	1.046

Appendix Table A-1 (cont.). Summary statistics for transformed catch/cell data of each species, by groups for each habitat parameter.

15 BMDP1D STATISTICS OF GROUPED JAHS DATA (RJ8301) - BY HABITAT VARIABLES

TABLE NAME	GROUPING VARIABLE	LEVEL	TOTAL FREQUENCY	MEAN	STANDARD DEVIATION	ST.ERR OF MEAN	COEFF. OF VARIATION	SMALLEST VALUE	SMALLEST Z-SCORE	LARGEST VALUE	LARGEST Z-SCORE	RANGE
LCOHO			133	.587	.899	.0780	1.53114	0.000	-.65	3.421	3.15	3.421
	MACNUM	UPSLOUGH	24	1.161	.944	.1926	.81247	0.000	-1.23	3.258	2.22	3.258
		SISLOUGH	42	.361	.715	.1103	1.98163	0.000	-.50	2.845	3.48	2.845
		SICHANNE	39	.199	.566	.0906	2.84859	0.000	-.35	2.380	3.85	2.380
		TRIBUTAR	28	.976	1.105	.2088	1.13132	0.000	-.88	3.421	2.21	3.421
	PERIOD	LMAY	15	.244	.591	.1526	2.41938	0.000	-.41	1.758	2.56	1.758
		EJUN	6	0.000	0.000	0.0000	0.00000	0.000	0.00	0.000	0.00	0.000
		LJUN	10	1.256	1.294	.4092	1.03025	0.000	-.97	3.421	1.67	3.421
		EJUL	16	.127	.368	.0921	2.90231	0.000	-.34	1.482	3.68	1.482
		LJUL	19	1.037	1.310	.3005	1.26296	0.000	-.79	3.258	1.70	3.258
		EAUG	18	.756	.965	.2276	1.27631	0.000	-.78	2.398	1.70	2.398
		LAUG	20	.564	.675	.1509	1.19666	0.000	-.84	1.988	2.11	1.988
		ESEP	20	.469	.707	.1581	1.50582	0.000	-.66	2.175	2.41	2.175
		LSEP	9	.652	.661	.2202	1.01305	0.000	-.99	1.792	1.72	1.792
	MEANDEP	0.1-0.6	52	.380	.712	.0988	1.87315	0.000	-.53	2.845	3.46	2.845
		0.7-0.9	46	.535	.924	.1363	1.72801	0.000	-.58	3.266	2.96	3.266
		1.0-1.2	17	.891	1.120	.2716	1.25738	0.000	-.80	3.421	2.26	3.421
		1.3-1.5	9	.633	.710	.2365	1.12067	0.000	-.89	1.758	1.58	1.758
		1.6+	9	1.433	.998	.3325	.69625	0.000	-1.44	2.667	1.24	2.667
	MEANCOV	0-5%	71	.406	.784	.0931	1.93026	0.000	-.52	3.258	3.64	3.258
		6-25%	53	.777	1.037	.1424	1.33379	0.000	-.75	3.421	2.55	3.421
		26-100%	9	.897	.581	.1938	.64827	.182	-1.23	1.988	1.88	1.806
	MEANVEL	0.0-0.5	103	.649	.961	.0947	1.48178	0.000	-.67	3.421	2.88	3.421
		0.6+	30	.376	.609	.1112	1.61840	0.000	-.62	1.792	2.32	1.792
	SWATTEMP	0.0-5.0	13	.558	.658	.1824	1.17850	0.000	-.85	1.792	1.88	1.792
		5.1-10.0	63	.534	.858	.1081	1.60542	0.000	-.62	3.258	3.18	3.258
		10.1+	56	.662	1.002	.1339	1.51200	0.000	-.66	3.421	2.75	3.421
	TURB	0-10	85	.764	.979	.1062	1.28176	0.000	-.78	3.421	2.71	3.421
		>10-50	16	.450	.809	.2024	1.79741	0.000	-.56	2.313	2.30	2.313
		>50-100	6	.244	.314	.1281	1.28808	0.000	-.78	.788	1.74	.788
		>100-200	11	.288	.798	.2407	2.77239	0.000	-.36	2.667	2.98	2.667
		200+	10	0.000	0.000	0.0000	0.00000	0.000	0.00	0.000	0.00	0.000

Appendix Table A-1 (cont.). Summary statistics for transformed catch/cell data of each species, by groups for each habitat parameter.

PAGE 16 BMDP1D STATISTICS OF GROUPED JAHS DATA (RJ6301) - BY HABITAT VARIABLES

VARIABLE NO. NAME	GROUPING VARIABLE	LEVEL	TOTAL FREQUENCY	MEAN	STANDARD DEVIATION	ST.ERR OF MEAN	COEFF. OF VARIATION	SMALLEST VALUE	SMALLEST Z-SCORE	LARGEST VALUE	LARGEST Z-SCORE	RANGE
18 LCHUM			133	.246	.588	.0510	2.39483	0.000	-.42	2.856	4.44	2.856
	MACNUM	UPSLOUGH	24	.035	.101	.0207	2.86181	0.000	-.35	.405	3.65	.405
		SISLOUGH	42	.467	.806	.1244	1.72529	0.000	-.58	2.856	2.96	2.856
		SICHANNE	39	.102	.287	.0460	2.82787	0.000	-.35	1.435	4.64	1.435
		TRIBUTAR	28	.294	.658	.1243	2.23501	0.000	-.45	2.715	3.68	2.715
	PERIOD	LMAY	15	1.029	1.014	.2618	.98556	0.000	-1.01	2.856	1.80	2.856
		EJUN	6	1.130	.757	.3089	.66933	.095	-1.37	2.001	1.15	1.906
		LJUN	10	.448	.494	.1563	1.10252	0.000	-.91	1.435	2.00	1.435
		EJUL	16	.248	.673	.1682	2.70800	0.000	-.37	2.715	3.66	2.715
		LJUL	19	.087	.201	.0462	2.31837	0.000	-.43	.788	3.49	.788
		EAUG	18	.020	.065	.0152	3.24798	0.000	-.31	.262	3.76	.262
		LAUG	20	0.000	0.000	0.0000	0.00000	0.000	0.00	0.000	0.00	0.000
		ESEP	20	0.000	0.000	0.0000	0.00000	0.000	0.00	0.000	0.00	0.000
		LSEP	9	0.000	0.000	0.0000	0.00000	0.000	0.00	0.000	0.00	0.000
	MEANDEP	0.1-0.6	52	.399	.774	.1073	1.93835	0.000	-.52	2.856	3.17	2.856
		0.7-0.9	46	.125	.400	.0590	3.20910	0.000	-.31	2.001	4.69	2.001
		1.0-1.2	17	.194	.510	.1237	2.63547	0.000	-.38	2.001	3.54	2.001
		1.3-1.5	9	.272	.420	.1398	1.54322	0.000	-.65	1.030	1.81	1.030
		1.6+	9	.049	.100	.0334	2.02522	0.000	-.49	.262	2.13	.262
	MEANCOV	0-5%	71	.217	.520	.0617	2.40068	0.000	-.42	2.603	4.59	2.603
		6-25%	53	.327	.705	.0968	2.15894	0.000	-.46	2.856	3.59	2.856
		26-100%	9	0.000	0.000	0.0000	0.00000	0.000	0.00	0.000	0.00	0.000
	MEANVEL	0.0-0.5	103	.254	.588	.0579	2.31058	0.000	-.43	2.856	4.43	2.856
		0.6+	30	.216	.600	.1096	2.77718	0.000	-.36	2.715	4.16	2.715
	SWATTEMP	0.0-5.0	13	.154	.555	.1540	3.60555	0.000	-.28	2.001	3.33	2.001
		5.1-10.0	63	.373	.755	.0951	2.02046	0.000	-.49	2.856	3.29	2.856
		10.1+	56	.128	.294	.0392	2.29794	0.000	-.44	1.435	4.45	1.435
	TURB	0-10	85	.338	.696	.0755	2.06024	0.000	-.49	2.856	3.62	2.856
		>10-50	16	.143	.365	.0913	2.55629	0.000	-.39	1.435	3.54	1.435
		>50-100	6	.159	.390	.1593	2.44949	0.000	-.41	.956	2.04	.956
		>100-200	11	.049	.092	.0277	1.87422	0.000	-.53	.262	2.32	.262
		200+	10	.010	.030	.0095	3.16228	0.000	-.32	.095	2.85	.095

Appendix Table A-1 (cont.). Summary statistics for transformed catch/cell data of each species, by groups for each habitat parameter.

PAGE 14 BMDP1D STATISTICS OF GROUPED JAHS DATA (RJ8301) - BY HABITAT VARIABLES

VARIABLE NO. NAME	GROUPING VARIABLE	LEVEL	TOTAL FREQUENCY	MEAN	STANDARD DEVIATION	ST.ERR OF MEAN	COEFF. OF VARIATION	SMALLEST VALUE	SMALLEST Z-SCORE	LARGEST VALUE	LARGEST Z-SCORE	RANGE
16 LSOCK			133	.300	.621	.0538	2.06598	0.000	-.48	3.246	4.75	3.246
	MACNUP	UPSLOUGH	24	.456	.694	.1417	1.52396	0.000	-.66	2.557	3.03	2.557
		SISLOUGH	42	.452	.819	.1263	1.81076	0.000	-.55	3.246	3.41	3.246
		SICHANNE	39	.245	.463	.0742	1.88967	0.000	-.53	2.197	4.21	2.197
		TRIBUTAR	28	.017	.089	.0168	5.29150	0.000	-.19	.470	5.10	.470
	PERIOD	LMAY	15	.297	.683	.1763	2.30000	0.000	-.43	2.632	3.42	2.632
		EJUN	6	.875	1.201	.4901	1.37235	0.000	-.73	3.246	1.98	3.246
		LJUN	10	.661	.773	.2444	1.16947	0.000	-.86	2.282	2.10	2.282
		EJUL	16	.234	.592	.1480	2.53521	0.000	-.39	2.361	3.59	2.361
		LJUL	19	.397	.653	.1497	1.64390	0.000	-.61	1.960	2.40	1.960
		EAUG	18	.476	.783	.1844	1.64385	0.000	-.61	2.557	2.66	2.557
		LAUG	20	.076	.139	.0312	1.82463	0.000	-.55	.336	1.87	.336
		ESEP	20	.109	.276	.0617	2.54142	0.000	-.39	1.163	3.82	1.163
		LSEP	9	.011	.032	.0106	3.00000	0.000	-.33	.095	2.67	.095
	MEANDEP	0.1-0.6	52	.279	.685	.0950	2.45872	0.000	-.41	3.246	4.33	3.246
		0.7-0.9	46	.175	.380	.0561	2.17911	0.000	-.46	2.197	5.32	2.197
		1.0-1.2	17	.356	.553	.1342	1.55408	0.000	-.64	1.629	2.30	1.629
		1.3-1.5	9	.639	.802	.2675	1.25624	0.000	-.80	2.282	2.05	2.282
		1.6+	9	.627	.973	.3244	1.55257	0.000	-.64	2.557	1.98	2.557
	MEANCOV	0-5%	71	.240	.524	.0622	2.18115	0.000	-.46	2.632	4.57	2.632
		6-25%	53	.373	.738	.1013	1.97905	0.000	-.51	3.246	3.90	3.246
		26-100%	9	.350	.591	.1970	1.68730	0.000	-.59	1.609	2.13	1.609
	MEANVEL	0.0-0.5	103	.376	.684	.0674	1.82012	0.000	-.55	3.246	4.20	3.246
		0.6+	30	.042	.136	.0247	3.25665	0.000	-.31	.588	4.03	.588
	SWATTEMP	0.0-5.0	13	.007	.026	.0073	3.60555	0.000	-.28	.095	3.33	.095
		5.1-10.0	63	.359	.748	.0943	2.08359	0.000	-.48	3.246	3.86	3.246
		10.1+	56	.308	.517	.0691	1.67991	0.000	-.60	2.197	3.65	2.197
	TURB	0-10	85	.303	.664	.0720	2.18942	0.000	-.46	3.246	4.43	3.246
		>10-50	16	.353	.678	.1695	1.92212	0.000	-.52	2.557	3.25	2.557
		>50-100	6	.419	.363	.1481	.86600	0.000	-1.15	1.099	1.87	1.099
		>100-200	11	.431	.709	.2138	1.64459	0.000	-.61	1.960	2.16	1.960
		200+	10	.086	.141	.0444	1.63690	0.000	-.61	.405	2.27	.405

APPENDIX B

Gear Efficiency Experiments

INTRODUCTION

Realizing that beach seining and electrofishing have different capture efficiencies and that these efficiencies vary with the turbidity level, amount of cover, and other factors, we conducted two small experiments in an attempt to be better able to interpret the catch data.

METHODS

The first experiment was designed to determine if backpack electrofishing was equally efficient in cells with different amounts of cover. Previous experience had suggested that capture efficiencies might be low in cells with little cover because the fish are easily disturbed and leave the area. Capture efficiencies might also be low in cells with a large amount of cover because all the fish could not be extracted from the substrate or dense vegetation.

We approached this problem by calculating the capture probabilities of fish in cells which ranged from low percent cover cells to high percent cover cells. Capture probabilities would remain relatively constant over this range if percent cover had no effect on capture efficiency. Capture probabilities were calculated by a computer program designed to estimate population size from multiple removal data (Platts et al. 1983). This program was implemented on a portable battery-powered microcomputer (Epson HX-20) so that the biologists would have on-site verification that they were using appropriate sampling techniques.

This experiment was conducted at Slough 11 on June 8th and at Slough 8 on August 2nd. Seven cells with a typical range of cover available to juvenile salmon were sampled at each site with a backpack electrofishing unit on three successive trials. At the completion of each trial, the fish were identified and counted and held until the end of the third trial. Successive trials were separated by about one hour. Turbidity was low at both sites and did not provide cover.

In the second experiment, five cells at Side Channel 10A were first sampled with beach seines and then with backpack electrofishing gear. This was done on two different dates, once when the turbidity level was high (150 NTU) and once when the turbidity level was low (24 NTU). The objective was to study the effect of turbidity on the sampling efficiency of the two gear types.

RESULTS

Effects of Cover Density on Electrofishing Efficiency

Only chum and sockeye salmon at Slough 11 were captured in sufficient numbers to compare capture probabilities among cells with different percentages of cover. The low numbers of other species captured at this site and at Slough 8 led to high standard errors on the capture probability. All species/cells combinations where the standard error was greater than 2.0 were rejected from this analysis. The capture probability for chum salmon was high in cells where the percent cover was low and then steadily declined as the percent cover increased (Appendix

Table B-1). The capture probability for sockeye salmon also decreased as percent cover increased. These results should be regarded as preliminary because most percent cover categories are represented by only one cell.

Appendix Table B-1. Capture probabilities for chum and sockeye salmon at Slough 11 as a function of percent cover.

Species	Percent cover	Capture Probability	Standard Error
Chum	0-5	0.9	0.06
	6-25	0.8	0.12
	26-50	0.8	0.13
	51-75	0.7	0.10
Sockeye	6-25	0.9	0.03
	26-50	0.3	0.12
		0.9	0.09
		0.7	0.14

Comparison of Beach Seining with Backpack Electrofishing

On two occasions when turbidity levels were very different, five cells at Side Channel 10A were first sampled with beach seines and then with backpack electrofishing gear (Appendix Table B-2). A comparison of the mean catches of chinook salmon fry suggests that beach seining was more effective in water of high turbidity (150 NTU), while electrofishing was more effective in clearer waters (24 NTU). The Wilcoxon Rank Sum test failed to reject the null hypothesis that the means are equal; however, the sample size was only five. Electrofishing at 150 NTU was difficult even though the cells where the comparisons were made only ranged to 0.4 ft. in mean depth.

Appendix Table B-2. Comparison of beach seining and backpack electrofishing juvenile chinook catches at five cells fished at two different turbidity levels.

Date	Turbidity (NTU)	Electrofishing Catch/Cell Chinook Salmon (Mean ± S.E.)	Beach Seining Catch/Cell Chinook Salmon (Mean ± S.E.)	Wilcoxon Rank Sum Test Significance Level)
9/07	24	1.6 ± 0.8	0.2 ± 0.2	0.27
7/22	150	1.2 ± 0.6	2.4 ± 0.4	0.19

DISCUSSION

Results from the preliminary experiment on the effect of percent cover on electrofishing efficiency indicate that capture efficiency decreases as percent cover increases. This is probably attributable to the difficulty of seeing fish when cover is abundant and also to the increased likelihood of stunned fish not rising to the surface in dense cover.

Although the standard errors of the capture probabilities were high, capture probabilities also appeared to be lower in the 0-5% cover category for both sockeye at Slough 11 and coho at Slough 8. When cover is not abundant, the fish are perhaps more likely to flee the cell being sampled.

The lowest capture probabilities for all three species occurred in the 51-75% cover category (the highest percent cover category sampled in this experiment). However, cells with high percent cover were infrequently encountered during the 1983 juvenile salmon sampling. Only 13% of cells sampled at all sites throughout the season had greater than 50% cover. Therefore, the unequal sampling efficiency over cells with different amounts of cover was probably not much of a problem, although it is likely that catch/cell was probably underestimated for cells with a high percentage of cover. This experiment should be repeated with a larger number of cells for all species of salmon.

The test conducted of beach seining and electrofishing efficiency at different levels of turbidity indicated that beach seining was more effective in water with a high turbidity and electrofishing was more effective in water with a low turbidity. Beach seining is not as effective in clear water because the fish are often hiding in deadfall, cobble, or other cover where the beach seine can not reach them. Electrofishing is not as effective in water with a high turbidity level because the samplers can not see the shocked fish.

In conclusion, it may be assumed that estimates of fish density, as determined by beach seining or electrofishing catches, are often underestimated. This contrasts with our minnow trap data (for chinook and coho) of previous years in that minnow traps attract fish to an area.

PART 3

Juvenile Salmon Rearing Suitability Criteria

JUVENILE SALMON REARING SUITABILITY CRITERIA

1984 Report No. 2, Part 3

by Paul M. Suchanek, Robert P. Marshall, Stephen S. Hale, and Dana C. Schmidt

Alaska Department of Fish and Game
Susitna Hydro Aquatic Studies
2207 Spenard Road
Anchorage, Alaska 99503

ABSTRACT

Changes in flow regimes in the Susitna River may affect the habitat used by rearing juvenile salmon. In order to model changes in habitat usability, data were collected for development of suitability criteria for the habitat attributes of cover, velocity, and depth used by juvenile chinook, coho, sockeye, and chum salmon. Representative sites between the Chulitna River confluence and Devil Canyon were sampled for juvenile salmon and habitat attributes were measured. Analysis was primarily univariate and data were pooled over site and season. Turbidity was apparently used by chinook salmon as cover prompting development of suitability criteria for clear (<30 NTU) and turbid (>30 NTU) conditions. Catches were insufficient for analysis of the other species by turbidity level. Suitability criteria for percent cover, cover type, velocity, and depth were developed for all four species of salmon. Composite weighting factors were formulated and correlated or compared with observed fish catch. Limitations of the suitability criteria and possible uses in habitat analysis are discussed.

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1.0 INTRODUCTION

Studies to date (ADF&G 1983a) of the rearing salmon species which occur between the Chulitna River confluence and Devil Canyon, indicate that successful rearing is dependent on a variety of physical parameters. The instream flow incremental methodology has been developed for use in evaluating fish habitat (Bovee 1982) and can be used in the Susitna River basin to evaluate effects of mainstem discharge on sites used by rearing juvenile salmon. In order to implement this methodology, habitat suitability criteria need to be developed which express the optimum, marginal, and unusable ranges of habitat variables on a one (optimum) to zero (unusable) basis. These criteria are then coupled with hydraulic models by using a system of computer programs called the Physical Habitat Simulation (PHABSIM) system (Bovee 1982). Output from PHABSIM includes calculations of the amount of equivalent optimum habitat called weighted usable area.

The present work develops suitability criteria for four species of juvenile salmon in the Chulitna River to Devil Canyon reach of the Susitna River for application in incremental simulations of rearing habitat as a function of mainstem flows. Criteria developed for these species are univariate suitability functions for cover type and percent cover, depth, and velocity. Functions for each of these environmental attributes were developed for juvenile chinook, coho, sockeye and chum salmon rearing. Different criteria for low and high turbidity water were developed as data permitted. Pink salmon were not considered because they do not rear in the study reach.

Suitability criteria have been formulated in a variety of ways (Bovee 1982) although most methods have been oriented towards describing the requirements for readily observable individuals in a relatively uniform or predictable macrohabitat. Since rearing juvenile salmon are neither easily observed nor sampled in the Susitna River's diverse glacial environment and related salmon rearing habitats, alternate criteria development techniques were used in this study. The criteria developed are specific to the Susitna River reach between the Chulitna River confluence and Devil Canyon.

The criteria developed in this report have been used with hydraulic models for seven sites on the Susitna River to provide weighted usable area projections at a wide variety of discharges (see Part 7 of this volume). They also have been used to study changes in the usability of habitat at six habitat model sites as natural mainstem discharge changes (see Part 4 of this volume). These results will be used in combination with other information to develop estimates of total usable rearing area for the Chulitna confluence to Devil Canyon reach of river at incremental levels of mainstem discharges.

2.0 METHODS

2.1 Study Locations

Locations selected as fish preference sites had substantial numbers of rearing juvenile salmon in 1981 and 1982 or were thought to be typical sites having the potential for juvenile rearing. The sites are located on the Susitna River reach between Whiskers Creek (RM 101.2) and Portage Creek (RM 148.8). Seven tributary sites, two upland sloughs, and 12 other sites which naturally oscillate between being side sloughs or side channels were sampled at least four times (Figure 1). There were also nine sites sampled only once and five sites sampled two or three times (see Part 2 of this report for a listing). These sites were thought to represent a wide cross section of habitat conditions experienced by rearing juvenile salmon in this reach of the Susitna River since tributaries, upland sloughs, side sloughs, and side channels were all intensively sampled. A limited amount of sampling was done in the mainstem channel and large side channels because of the difficulty in sampling these areas and because we believed high velocities limit juvenile rearing habitat.

2.2 Field Data Collection

2.2.1 Biological

Detailed descriptions of the site layout and data collection techniques are available in other reports (ADF&G 1984, and Part 2 of this report). Eight to 10 day field samplings were made twice monthly between May and October 1983. Twenty-three sites were sampled from three to seven times while the other 12 sites were only incidentally sampled once or twice. About eight staked transects from 75 to 200 feet apart were established across the study site. Upstream from each transect, sampling cells 50 feet long by six feet wide (300 ft^2) were delineated along each shoreline. Another mid-channel cell was located between the shoreline cells. The grid of transects and cells was normally located in areas of relatively uniform water temperature, pH, dissolved oxygen, conductivity, and turbidity. Transects were placed to maximize within site variability of habitat types sampled while also attempting to maintain uniform physical habitat within individual sampling cells. Cells were selected to represent a wide range of habitat types and approximately 20 cells were sampled per day.

During the field season, we directed sampling effort towards sites where rearing fish were numerous based on knowledge of seasonal movements. Sampling frequency was reduced if efforts to catch 30 or more juveniles of a species in a grid of transects were unsuccessful. Backpack electrofishing units and 1/8" mesh beach seines were used to sample the entire cell for fish. Typically, beach seining was limited to turbid water samplings and electrofishing to clear water conditions. Electrofishing was the preferred sampling method, but was found to be ineffective in turbid water. Each captured fish was identified to species and measured in total length to the nearest millimeter. Those cells sampled for fisheries data were subsequently individually characterized by a set of habitat measurements even if no fish were captured.

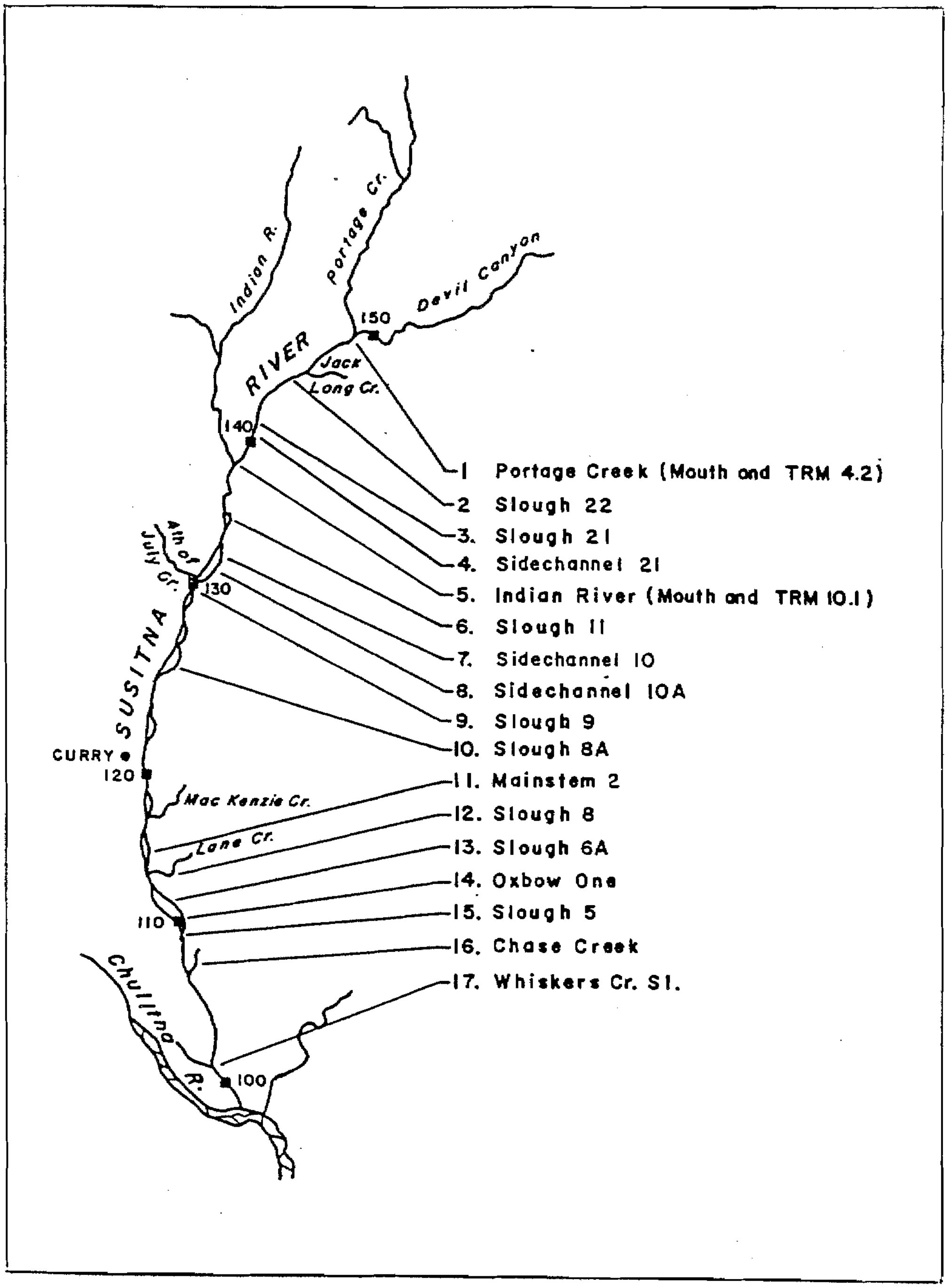

Figure 1. Location of the study sites sampled more than three times for juvenile salmon suitability criteria development, May through October, 1983.

2.2.2 Physical

We determined an average depth and velocity, and also estimated the total amount of available cover (expressed in percent areal coverage), and the dominant type of cover available for juvenile salmon in each cell. Codes for nine cover types and six categories of percent cover were developed (Table 1). Prior to the sampling season, a field trip was made to promote consistent ratings among the raters. Estimates of cover were made on the basis of cover specifically available to juvenile salmon for concealment or protection. Cells without objective cover (cover type group #1) will be referred to as "no cover" or "zero cover" cells.

Table 1. Percent cover and cover type categories.

Group #	% Cover	Group #	Cover Type
1	0-5%	1	No object cover
2	6-25%	2	Emergent vegetation
3	26-50%	3	Aquatic vegetation
4	51-75%	4	Debris or deadfall
5	76-96%	5	Overhanging riparian vegetation
6	96-100%	6	Undercut banks
		7	Gravel (1" to 3" diameter)
		8	Rubble (3" to 5" diameter)
		9	Cobble (larger than 5" diameter)

Water temperature, dissolved oxygen, pH, conductivity, and turbidity were measured at one point in the grid. If an obvious water quality gradient existed across the grid, another measurement of these parameters was taken. Detailed descriptions of the water chemistry measurement procedures are available in ADF&G (1984).

2.3 Data Analysis

Data were separated by gear type because both beach seining and electrofishing effectiveness are influenced by water quality and hydraulic attributes and because each gear was used selectively, dependent upon the sampling conditions. Since no resources were available for a major study of gear effectiveness, we did not attempt to quantify gear efficiency under various sampling conditions. Beach seines were used because backpack electrofishing is ineffective in highly turbid water. The bias inherent in both gear types influenced our pathway of analysis and affected our interpretation of results and subsequent conclusions. Figure 2 details the data analysis pathways and final products of criteria development as presented in the results section.

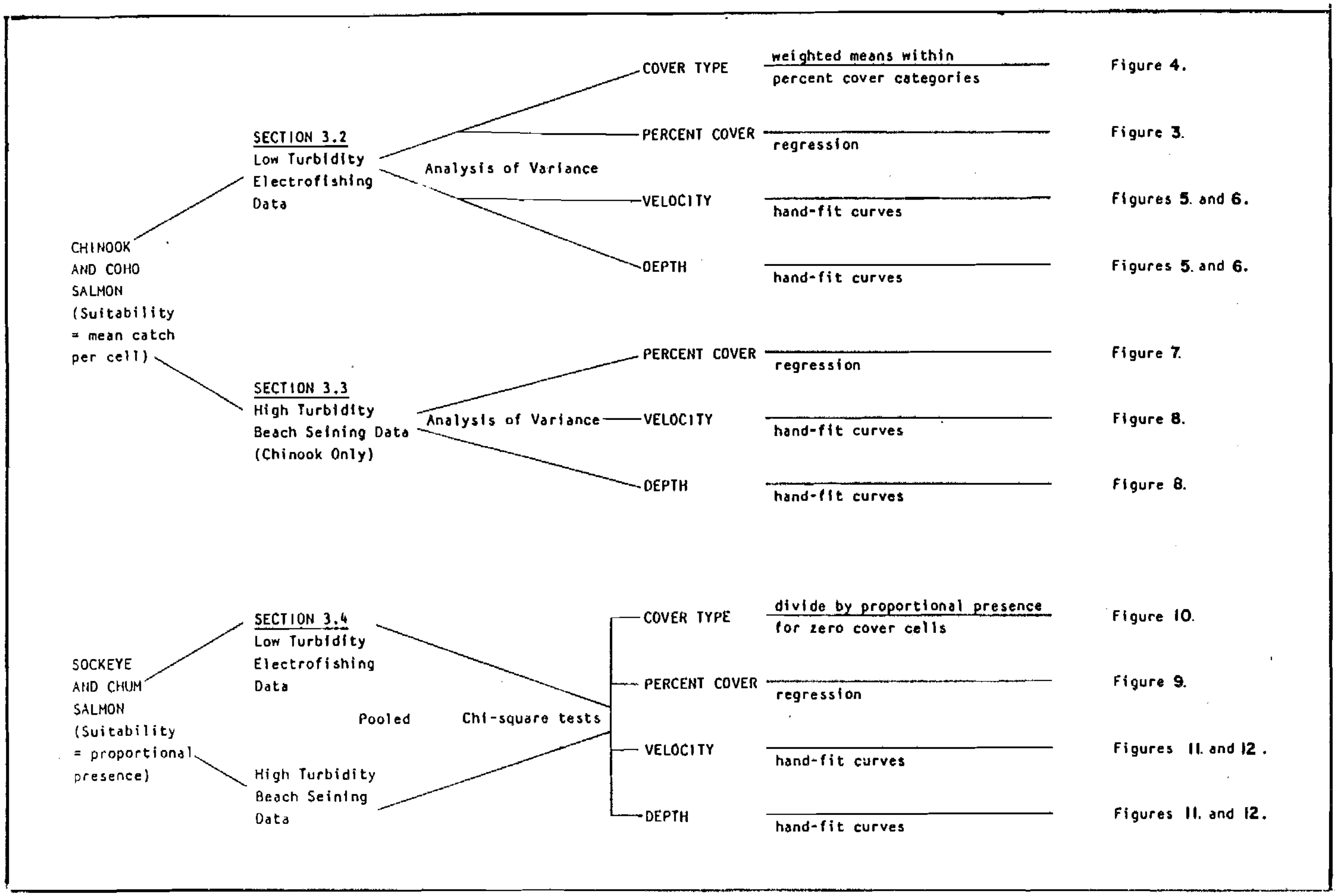

Figure 2. Outline of data analysis pathways for determination of juvenile salmon suitability criteria.

We used different types of analyses for chinook and coho salmon in comparison to sockeye and chum salmon. Chinook and coho salmon are territorial or at least exhibit some forms of agonistic behavior (Stein et al. 1972) and normally disperse themselves as individuals while sockeye and chum salmon are usually distributed in schools which move about as a cohesive social unit.

Suitability was derived for chinook and coho salmon by taking total fish catch for each value of attribute (utilization) and dividing by the number of cells fished having the same attribute value (effort). For example, if 50 chinook salmon fry were captured in 25 cells of 0.0 velocity sampled, mean catch per cell (suitability) was 50/25 = 2.0 for 0.0 velocity cells. Fish density was assumed to be a function of mean catch per cell. Differences in mean catch per cell by habitat attribute value were analyzed with analysis of variance and least squares regression.

Sockeye and chum salmon suitability was derived by taking the total number of cells with fish present by value of habitat attribute (utilization) and dividing by the number of cells fished (effort). For example, if chum salmon fry were captured in 10 of 50 cells of 0.0 velocity fished, then proportional presence (suitability) was 10/50 = 0.2 for 0.0 velocity cells. Suitability was derived differently for sockeye and chum salmon because these fish school normally and capture of a large school within a cell might disproportionately affect mean catch per cell as the habitat might be only as good as another cell nearby without any fish but the cell with fish would be ranked much higher than if rated on a proportional presence basis. Differences in proportional presence by habitat attribute value were analyzed with chi-square tests of association.

Data from all sites over the entire season were pooled by species for analysis. Data from tributary sites where no major runs of sockeye salmon are present were excluded from the sockeye suitability criteria development, as were data collected between May 1 and 15, when only a small percentage of sockeye had emerged. Since the vast majority of chum salmon outmigrate from the upper Susitna River prior to July 15 (ADF&G 1983b), only data collected before July 15 were used to develop suitability relationships for this species.

Statistical analyses used included analysis of variance, linear regression and chi-square tests of association. Most statistical analyses were conducted using the Statistical Package for the Social Sciences (SPSS) (Nie et al. 1975). Transformations by natural log (X+1) were used to help equalize variances and normalize catch per cell of chinook and coho salmon for analysis of variance (Dixon and Massey 1969). Chi-square tests of association were used to examine proportional presence data for differences in use of categories of habitat attributes by sockeye and chum salmon. Expected values in these tests were calculated with standard contingency table techniques. Kendall rank-order correlations were carried out between the habitat variables to check for intercorrelations. The particular procedure utilized in each analysis is presented within the appropriate results section.

Most of the analysis was geared toward a univariate analysis and development of suitability criteria but some multivariate comparisons were made. Multiway analyses of variance were conducted to find if interaction effects were significant. All velocity and depth criteria were fit to the data by hand using professional judgement to give the best fit. The rationale and judgements used for criteria development are discussed according to the individual relationship.

2.3.1 Cover analysis

Cover is an important factor influencing the distribution of juvenile salmon (Reiser and Bjornn 1979). Rocks, debris, and vegetation are types of object cover; turbidity is another form of cover. We examined the effects of both the type and amount of object cover on the distribution of juvenile salmon. Turbidity effects were inferred from differences in catch in cells without object cover over the range of turbidities sampled. We pooled percent object cover categories 76-95% and 96-100% for the analysis because of small sample sizes and then regressed percent cover categories against catch per cell for chinook and coho salmon. The proportion of cells with fish present were regressed against the percent cover categories for sockeye and chum salmon.

The relative importance of object cover type for chinook and coho salmon in clear water was addressed by examining mean catch per cell by cover type within each percent cover category. Each mean catch/cell for a cover type within a percent cover category was divided by the mean catch for that percent cover category for all cover types combined. These ratios were then pooled over all percent cover categories for a cover type by taking a weighted mean adjusted by the number of cells of that cover type within each percent cover category to give an average effect of cover type. The weighted mean was then used to rank cover types by suitability on a scale from 0 to 1. The equations used and an example are given in Appendix A. Cover type suitability differences were not addressed with the beach seine data since we believed seine effectiveness was strongly affected by cover type.

Because of the smaller sample sizes and use of proportional presence data, cover type suitability differences were calculated in a different way for chum and sockeye salmon. Sockeye and chum cover type suitability differences were addressed by pooling the incidence of catch by cover type over all percent cover categories and then dividing through by the proportional presence for cells without object cover. Sometimes, the proportional presence for some cover types was less than the proportional presence for zero cover cells. In these instances, cover type was assumed to have no effect on distribution and was ranked with the zero cover type in the suitability ratings. The equation used and an example are given in Appendix B.

2.3.2 Velocity and depth analysis

Velocity and depth were measured in intervals of 0.1 ft/sec and 0.1 ft, respectively. Since sample sizes were small and variances were high, these values were pooled into groups (Table 2). Baldridge and Amos (1983) listed a number of criteria of use in grouping data for criteria development but since we analyzed four species of salmon, one standard grouping interval was used for all criteria development.

Table 2. Velocity and depth groupings for suitability criteria development.

Group #	Velocity (ft/sec) Grouping	Group #	Depth (ft) Grouping
1	0	1	0.1 - 0.5
2	0.1 - 0.3	2	0.6 - 1.0
3	0.4 - 0.6	3	1.1 - 1.5
4	0.7 - 0.9	4	1.6 - 2.0
5	1.0 - 1.2	5	2.1 +
6	1.3 - 1.5		
7	1.6 +		

Mean catch/cell was again used as the measure of suitability for chinook and coho criteria development. Sockeye and chum suitability was measured using proportional presence.

2.3.3 Tests of data fit

In the PHABSIM system, univariate suitability indices are combined to provide a composite weighting factor which reflects the habitat potential of a cell at a given discharge (Bovee 1982). Suitability criteria are normally combined by multiplying suitability indices together to formulate these weighting factors but other combinations are possible (Milhous et al. 1981). Regardless of the composite weighting factor formulation used, one of the assumptions of the instream flow incremental methodology is that there is a positive linear relationship between weighted usable area and habitat use (Orth and Maughan 1982). We attempted to evaluate various combinations of univariate suitability indices by comparison with observed fish catches.

For chinook and coho salmon, we compared observed catches by cell with composite weighting factors calculated using suitability indices from various combinations of habitat attributes. Pearson correlation coefficients were calculated between various composite weighting factor indices and coho and chinook catch per cell. We again transformed catch per cell with natural log (X+1) to normalize the data. Since proportional presence was used as a measure of suitability for chum and sockeye salmon, correlation coefficients could not be used to test for data fit. Instead, we calculated several composite weighting factors using only a few combinations of univariate suitability indices and then divided the data into four groups of approximately equal size by value of composite weighting factor. Chi-square tests were then run to see if proportional presence was associated with the composite weighting factor value intervals.

3.0 RESULTS

3.1 Sampling Effort and Catch

Fish suitability criteria data were collected at a total of 1,260 cells over the entire season, with about 70 percent of the sampling done with backpack electrofishing gear and 30 percent with beach seines (Table 3). Some of the cells fished were subsequently eliminated from the sockeye and chum suitability criteria development because of seasonal and site factors discussed in the methods section.

Table 3. Sampling effort (number of cells fished) and catch by gear type.

	Electrofishing		Beach Seining		Total	
	Effort (cells fished)	Catch all age classes	Effort (cells fished	Catch all age classes	Effort	Catch
Chinook	871	3066	389	1329	1260	4395
Coho	871	1907	389	113	1260	2020
Sockeye	658	814	355	192	1013	1006
Chum	408	1152	106	5	514	1157

Field observations and examination of the catch data indicated that chinook salmon distribution was very different in turbid water than in clear water. Scatter plots of juvenile salmon catch by species in cells without object cover versus turbidity were examined. An inflection point at approximately 30 NTU was noted for juvenile chinook salmon. The catch rate at turbidities greater than 30 NTU was much higher than the catch rate below 30 NTU, indicating that turbidity is used for cover in lieu of object cover. Sample sizes for the other species were too small to indicate whether other inflection points were evident. Subsequently, mean catch/cell was examined for cells without object cover for each of the four species both above and below 30 NTU (Table 4). Catches of chinook were significantly higher in high turbidity cells without object cover than in similar cells with turbidities of less than 30 NTU. Chum salmon were caught in significantly higher numbers in clear water.

Table 4. Comparison of mean catch per cell for cells without object cover above and below 30 NTU turbidity.

	Total catch in zero cover cells	Total zero cover cells fished	Mean catch ≤30 NTU	Mean catch >30 NTU	t	Significance
Chinook	312	155	0.19(N=42)	2.69(N=113)	14.99	<0.001
Coho	5	155	0.00(N=42)	0.04(N=113)	1.35	0.25
Sockeye	64	144	0.23(N=35)	0.51(N=109)	0.76	0.39
Chum	52	57	1.81(N=21)	0.39(N=36)	5.15	0.03

Since the distribution of chinook is different in waters with turbidities greater than 30 NTU, when compared to clearer water, we grouped the data by both turbidity level and gear type (Table 5). The only data set deemed sufficient in size for suitability criteria development in high turbidity conditions was the chinook beach seine data. Although chum salmon may have a different distribution in turbid water, sample sizes were insufficient for suitability criteria development. Coho catches were very small in turbid water and no turbidity dependent suitability criteria could be generated from the data. The electrofishing data in clear water cells was ample for criteria development, and therefore the small amount of beach seine data were not pooled with the electrofishing data. Similarly, chinook electrofishing data from clear water were used exclusively for low turbidity criteria development.

Small sample sizes made it necessary for gear types and turbidity levels to be pooled for development of chum and sockeye suitability criteria development for two reasons. The amount of electrofishing data for sockeye and chum salmon was smaller than for chinook and coho salmon because some cells fished were eliminated due to season or spawning distribution as previously discussed in the methods. Also since proportional presence was used as the measure of suitability, sample sizes need to be large for good estimates of proportions. We therefore assumed that seining and electrofishing were equally effective at catching at least one fish in a cell if fish were present. Table 6 summarizes the data sets used for criteria development.

Table 5. Sampling effort and catch by gear type and turbidity level.

Clear (Turbidity ≤ 30 NTU)

	Electrofishing		Beach Seine	
	Effort	Catch	Effort	Catch
Chinook	813	2574	41	39
Coho	813	1699	41	62
Sockeye	611	757	24	84
Chum	366	1107	16	1

Turbid (Turbidity > 30 NTU)

	Electrofishing		Beach Seine	
	Effort	Catch	Effort	Catch
Chinook	44	61	320	1241
Coho	44	206	320	23
Sockeye	44	57	303	101
Chum	29	44	90	4

Note - Cells where turbidity was not recorded (14 electrofished cells and 28 beach seined cells) were excluded from this data set.

Table 6. Data sets used for suitability index development.

Species	Turbidity Level*	Gear Type	Suitability Measure	Number of cells Fished
Chinook	Clear Turbid	Electrofishing Beach Seine	Catch/cell Catch/cell	813 320
Coho	Clear	Electrofishing	Catch/cell	813
Sockeye	Both	Pooled	Proportion of cells with catch	1013
Chum	Both	Pooled	Proportion of cells with catch	514

* Clear - Turbidity ≤ 30 NTU
  Turbid - Turbidity > 30 NTU

Correlations among the values of habitat attributes and catch were examined for the data sets used in criteria development. The resulting Kendall rank-order correlation coefficients are listed in Table 7 for the low turbidity electrofishing data. There are a number of statistically significant correlations among the habitat attributes but none are greater in absolute value than 0.18. Correlations between the habitat attributes and fish catch are also small, none being over 0.22 in absolute value. Large correlations among the habitat variables would necessitate a multivariate approach or elimination of selected habitat attributes from consideration.

Table 7. Kendall correlation coefficients between habitat variables and chinook and coho catch by cell (N=813) in clear water for electrofishing data.

	Percent cover	Cover type	Velocity	Depth	Chinook
Percent cover	1.00				
Cover Type	0.11**	1.00			
Velocity	0.13**	0.18**	1.00		
Depth	0.03	-0.11**	-0.17**	1.00	
Chinook	0.21**	0.18**	0.20**	-0.04	1.00
Coho	0.22**	-0.18**	0.02	0.21**	0.20**

*Significantly different from 0 at $p < 0.05$
**Significantly different from 0 at $p < 0.01$

Kendall rank-order correlations among the high turbidity beach seine data were very similar to the electrofishing data (Table 8). The correlation between percent cover and cover type was fairly high (0.40) but small sample sizes and beach seine inefficiency in high object cover conditions caused the analysis of cover type in turbid water to be only qualitative.

Table 8. Kendall correlation coefficients between habitat variables and chinook catch in turbid water by cell (N=320) for beach seine data.

	Percent cover	Cover type	Velocity	Depth
Percent cover	1.00			
Cover Type	0.40**	1.00		
Velocity	0.12**	0.20**	1.00	
Depth	0.01	-0.05	0.08*	1.00
Chinook	0.12**	-0.02	-0.19**	0.12**

*Significantly different from 0 at $p < 0.05$
**Significantly different from 0 at $p < 0.01$

3.2 Analysis of Chinook and Coho Distribution in Low Turbidity Waters

3.2.1 Cover

Two-way analyses of variance (using the regression approach) were run on the catch/cell data to examine the effects of cover type and percent cover on the transformed chinook and coho catch/cell (Table 9). The effects of both cover type and percent cover were significant but the amount of explained variation was small.

Table 9. Analysis of variance in clear water between cover type, percent cover, and chinook or coho catch transformed by ln (x+1). Due to empty cells or a singular matrix, interactions could not be calculated.

Chinook Source of Variation	Sum of Squares	df	Mean Square	F	Significance of F
Main Effects	113.852	12	9.488	10.805	< 0.001
Cover type	45.871	8	5.734	6.530	< 0.001
Percent cover	54.897	4	13.724	15.630	< 0.001
Explained	113.852	12	9.488	10.805	< 0.001
Residual	702.482	800	0.878		
Total	816.334	812	1.005		

Coho Source of Variation	Sum of Squares	df	Mean Square	F	Significance of F
Main Effects	90.738	12	7.561	11.402	< 0.001
Cover type	56.793	8	7.099	10.705	< 0.001
Percent cover	35.058	4	8.765	13.216	< 0.001
Explained	90.738	12	7.561	11.402	< 0.001
Residual	530.550	800	0.663		
Total	621.288	812	0.765		

Least squares regressions were then run between chinook and coho catch per cell and the percent cover categories to quantify the relationship to cover categories where there is only a small amount of data. The fit of the regression to the actual mean catches and derived suitability indices by cover category is shown in Figure 3. The effects of cover type by species were then quantified by taking a weighted mean of the effect of cover type over all percent cover categories to derive a suitability index for cover type (Figure 4).

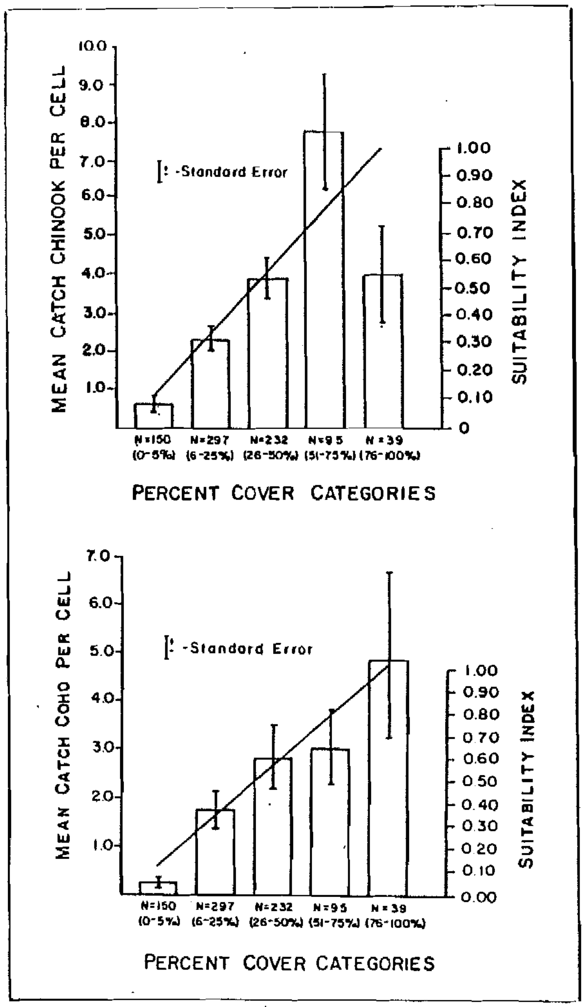

Figure 3. Mean catch of juvenile chinook and coho salmon per cell by percent cover category (bars) and fitted suitability index (lines) in low turbidity waters, Chulitna River to Devil Canyon reach of the Susitna River.

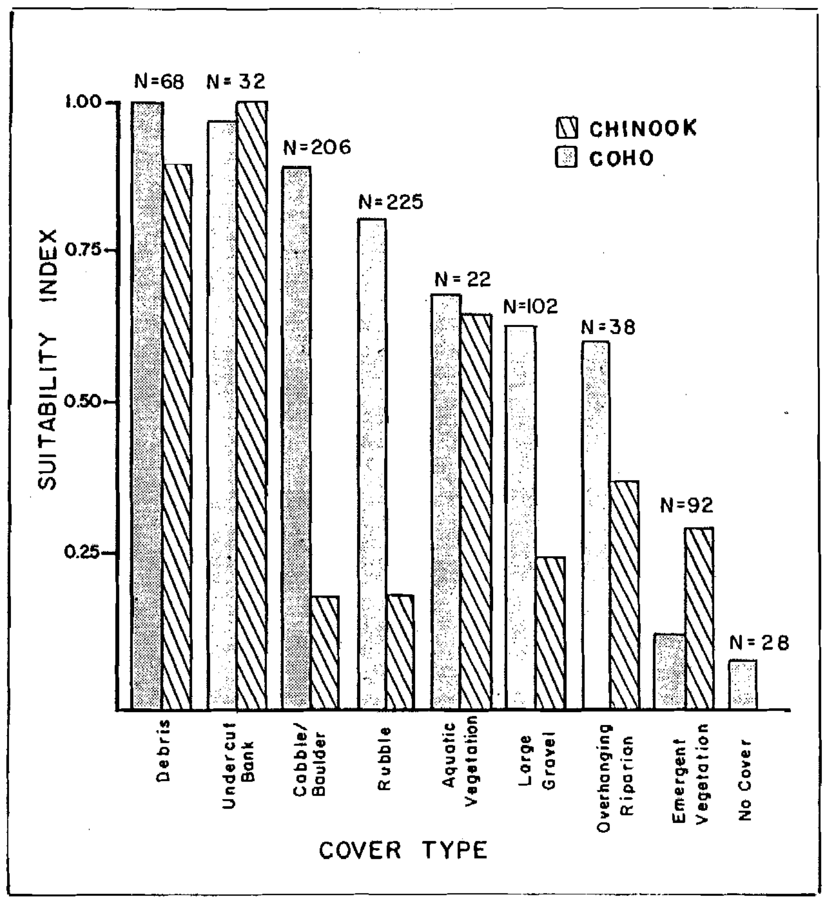

Figure 4. Comparison of cover type suitability indices for juvenile chinook and coho salmon in low turbidity waters, Chulitna River to Devil Canyon reach of the Susitna River.

3.2.2 Depth and velocity

Since depth and velocity were not expected to be linearly related to fish habitat suitability, depth and velocity effects were analyzed in a two-way analysis of variance for chinook and coho catch per cell (Table 10). Depth and velocity were singly not significant for chinook at the 0.05 significance level after adjusting for the effects of the other, but taken together, they were significant for chinook as was the interaction between depth and velocity. Depth, velocity, and the interaction between these two attributes were all significant for coho. The total amount of explained variation was again relatively small for both species.

Table 10. Analysis of variance in clear water between depth, velocity, and chinook or coho catch transformed by ln (x+1).

Chinook Source of Variation	Sum of Squares	df	Mean Square	F	Significance of F
Main Effects	27.426	10	2.743	2.990	< 0.001
Depth	8.099	4	2.025	2.207	0.067
Velocity	7.549	6	1.258	1.372	0.223
Interaction Effects	25.216	16	1.576	1.718	0.039
Explained	95.271	26	3.664	3.994	< 0.001
Residual	721.062	786	0.917		
Total	816.334	812	1.005		

Coho Source of Variation	Sum of Squares	df	Mean Square	F	Significance of F
Main Effects	35.505	10	3.551	5.242	< 0.001
Depth	8.318	4	2.079	3.070	0.016
Velocity	19.343	6	3.224	4.760	< 0.001
Interaction Effects	40.079	16	2.505	3.699	< 0.001
Explained	88.957	26	3.421	5.052	< 0.001
Residual	532.331	786	0.677		
Total	621.288	812	0.765		

Since the data base was not large enough, given the amount of variability in the data, to fit a multivariate function with any confidence, we examined depth and velocity only on a univariate basis. Professional judgement was used to fit a curve to the data by hand and suitability indices were normalized to the fitted data (Figures 5 and 6). The functions were fit so that they followed the means most closely over the intervals where sample sizes were greatest. On the depth curves, we

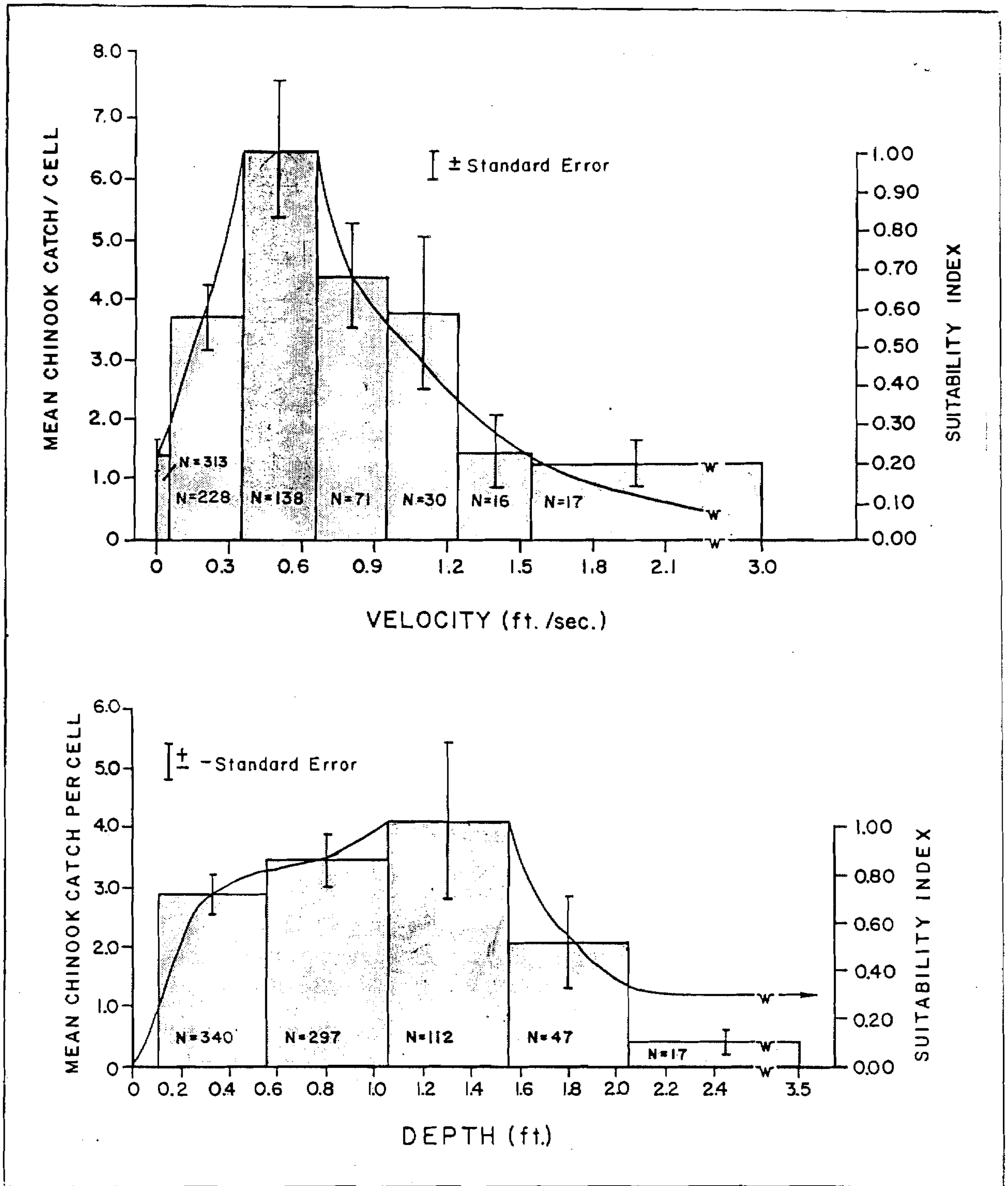

Figure 5. Mean catch of juvenile chinook salmon per cell by velocity and depth intervals (bars) in low turbidity waters, Chulitna River to Devil Canyon reach of the Susitna River. Suitability indices (lines) fitted by hand.

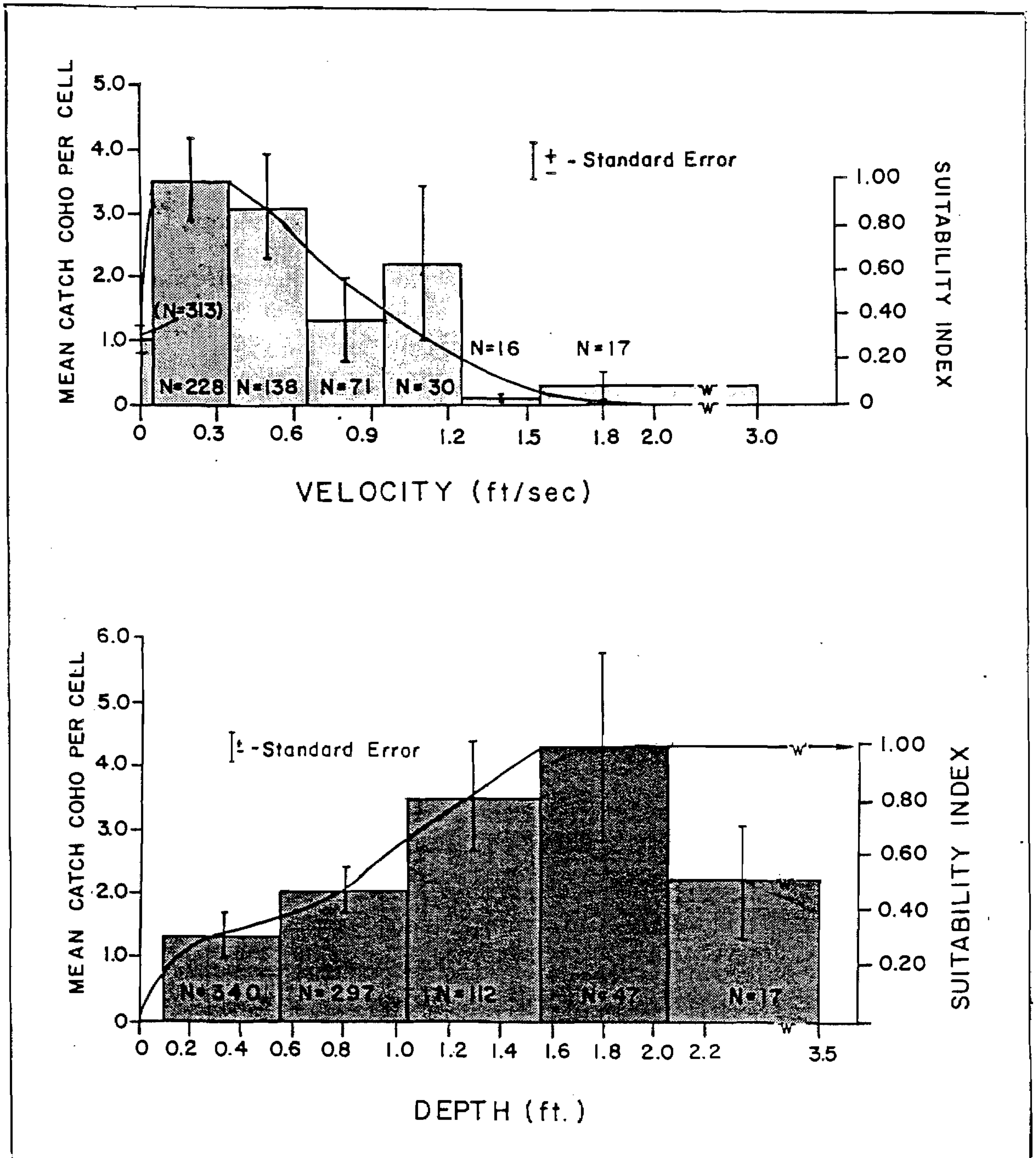

Figure 6. Mean catch of juvenile coho salmon per call by velocity and depth intervals (bars) in low turbidity waters, Chulitna River to Devil Canyon reach of the Susitna River. Suitability indices (lines) fitted by hand.

believed that gear inefficiency was becoming a factor at the greatest depths sampled and therefore the curves were drawn in at a higher suitability than a close fitting of the data would warrant. The depth curves did not drop off to zero at the high ranges because we thought depths did not limit juvenile distribution and we had no data for large depths.

3.3 Analysis of Chinook Salmon Distribution in High Turbidity Waters Using Beach Seine Data

3.3.1. Cover

Cover analysis of beach seine catch data is complicated by the fact that gear effectiveness is reduced by the amount and type of object cover. A least squares regression line was taken as a reasonable estimate of the relationship between suitability and percent cover, however, and a suitability index was normalized to the regression line (Figure 7). We did not try to analyze the effect of object cover type on suitability for chinook as it was obvious that the chinooks were using turbidity for cover and thus the type of object cover present was probably not as important.

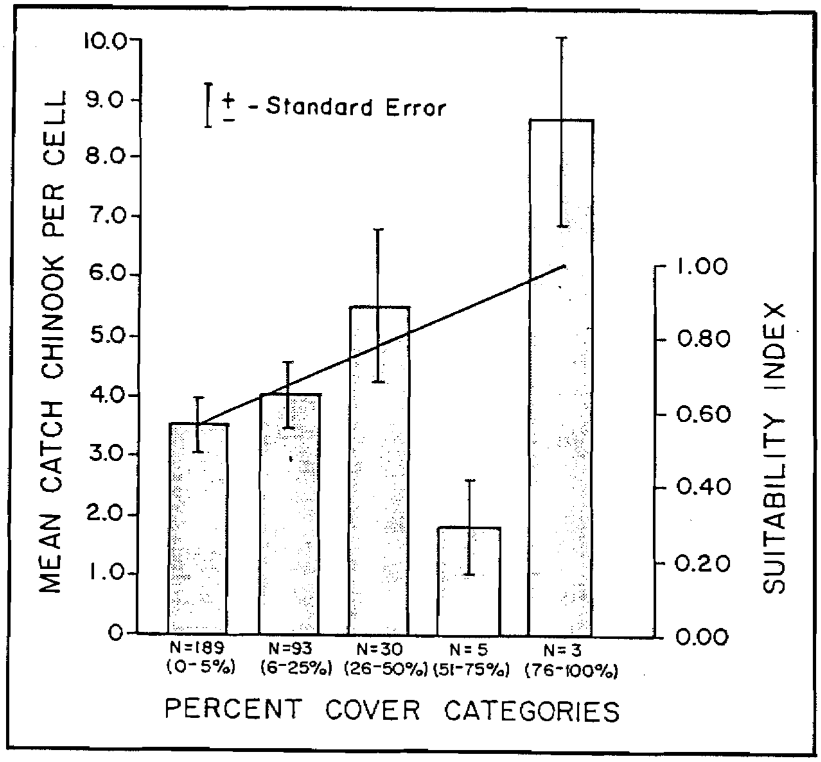

Figure 7. Mean catch of juvenile chinook salmon per cell by percent cover categories (bars) and fitted suitability index (line) in high turbidity waters, Chulitna River to Devil Canyon reach of the Susitna River.

3.3.2 Depth and velocity

Depth and velocity have much less effect on beach seine effectiveness than does the amount and type of cover within the range sampled and so analysis of depth and velocity was identical to that used for the electrofishing data. A two-way analysis of variance between depth, velocity and catch per cell showed velocity to be significant (Table 11). Depth was not significant by itself as an effect and interactions could not be assessed due to empty cells (in the analysis of variance table classification).

Table 11. Analysis of variance between depth, velocity, and chinook catch transformed by ln (x+1) in high turbidity water. Due to empty cells or a singular matrix, interactions could not be calculated.

Chinook Source of Variation	Sum of Squares	df	Mean Square	F	Significance of F
Main Effects	43.617	10	4.362	5.160	< 0.001
Depth	5.965	4	1.491	1.764	0.136
Velocity	35.617	6	5.936	7.022	< 0.001
Explained	43.617	10	4.362	5.160	< 0.001
Residual	261.212	309	0.845		
Total	304.828	319	0.956		

Even though depth was not statistically significant by itself, a curve was fit by hand to the data for depth using professional judgement because a trend was evident (Figure 8). A curve was also fit to the velocity data by hand using professional judgement and a suitability index derived (Figure 8). The data indicate that in turbid water, chinook use shallower and slower moving water than they do in clear water.

3.4 Analysis of Sockeye and Chum Salmon Proportional Presence Using Pooled Electrofishing and Beach Seining Data

3.4.1. Cover

Since proportional presence was used as a measure of suitability instead of catch per cell, standard analysis of variance techniques were not used. Instead, chi-square tests of association were used to test for differences in proportional presence among categories of percent cover and cover type (Table 12). All these tests were significant and suitability criteria were fit to the data. The five points of proportional

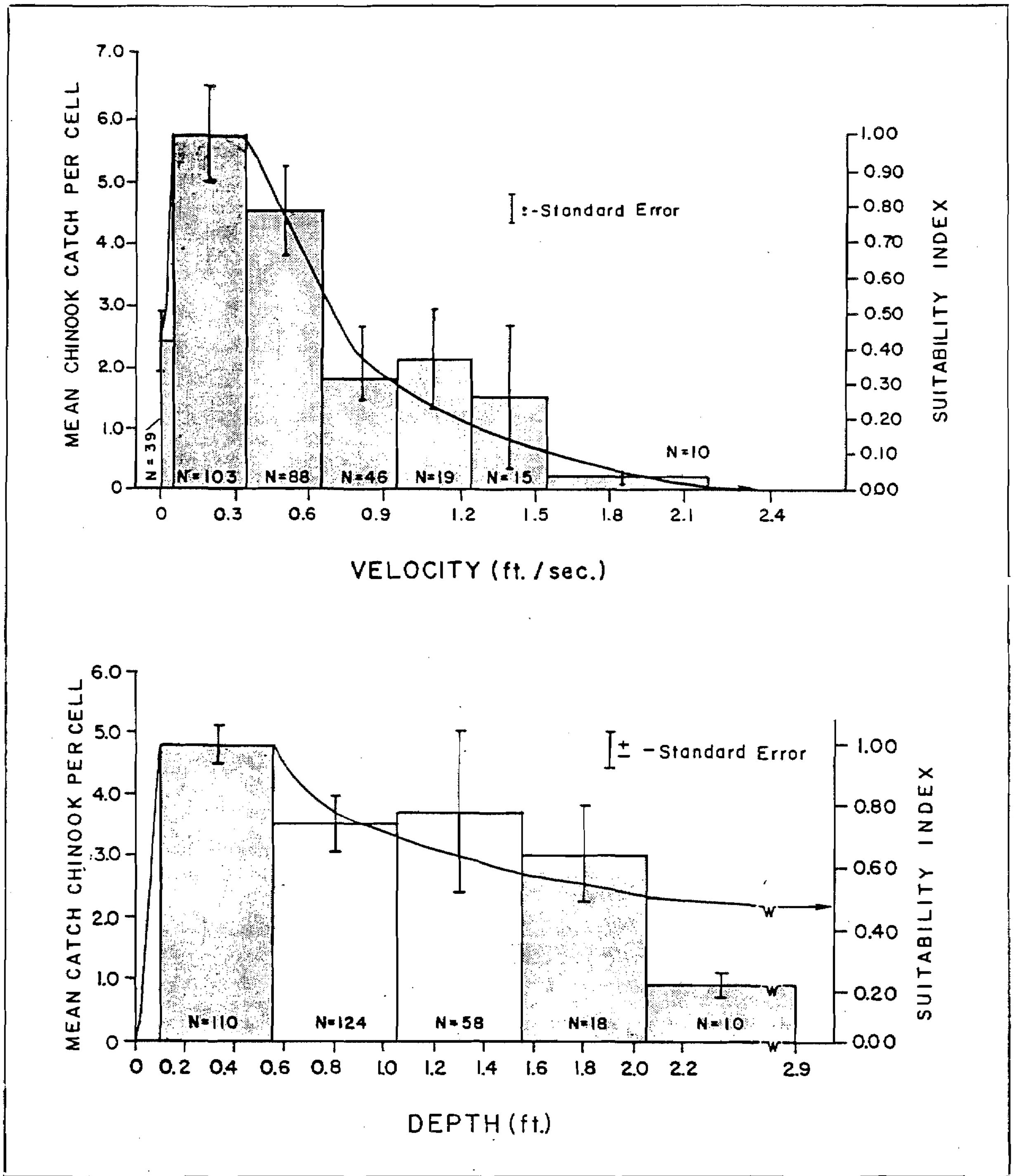

Figure 8. Mean catch of juvenile chinook salmon per cell by velocity and depth intervals (bars) in high turbidity waters, Chulitna River to Devil Canyon reach of the Susitna River. Suitability indices (lines) fitted by hand.

presence were regressed to the percent cover categories and the regression line was normalized to a suitability index (Figure 9). Cover type suitability criteria were formed by dividing through by the percent presence for zero cover cells and then normalizing (Figure 10). Some cover types were not any more suitable than the zero cover cells.

Table 12. Chi-square tests for differences in proportions of sockeye or chum presence between habitat attribute groupings of percent cover, cover type, velocity and depth.

Species	Habitat Attribute	df	Chi-square
Sockeye			
	Cover type	8	41.11**
	Percent cover	4	19.05**
	Velocity	6	28.68**
	Depth	4	15.73*
Chum			
	Cover type	8	21.18*
	Percent cover	4	23.65**
	Velocity	5	11.06*
	Depth	3	20.09**

*Significant at $p < 0.05$
**Significant at $p < 0.01$

3.4.2 Depth and velocity

Chi-square tests indicated that the depth and velocity group intervals were associated with both sockeye and chum proportional presence (Table 12). Curves were fit to the data by hand using professional judgement (Figures 11 and 12) and suitability indices normalized to the lines.

Velocity criteria were similar for both species but the depth criteria indicated that sockeye salmon found deeper water more suitable while chum used shallower water.

3.5 Tests of Fitted Habitat Values to Observed Fish Catches

3.5.1 Chinook and coho salmon

Once suitability indices were fitted to the data, various formulations of composite weighting factors were correlated with actual fish catches to evaluate their fit. Catches were transformed by ln (X+1) and Pearson correlations were then run between the transformed catch and various composite weighting factor combinations of habitat variables (Table 13).

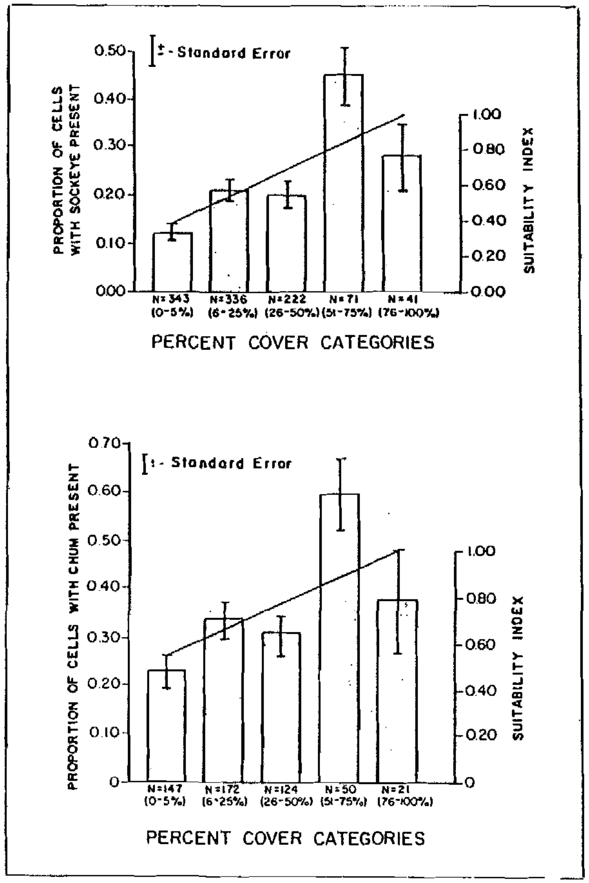

Figure 9. Proportion of cells with juvenile sockeye and chum salmon present by percent cover category (bars) and fitted suitability indices (lines), Chulitna River to Devil Canyon reach of the Susitna River.

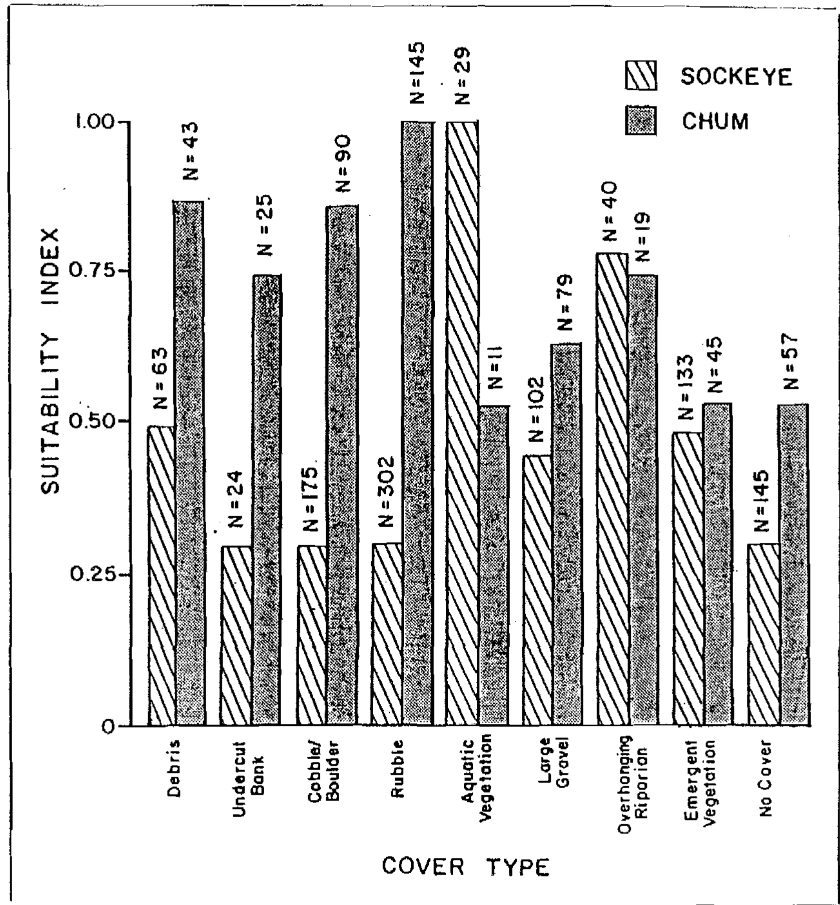

Figure 10. Comparison of cover type suitability indices for juvenile sockeye and chum salmon, Chulitna River to Devil Canyon reach of the Susitna River.

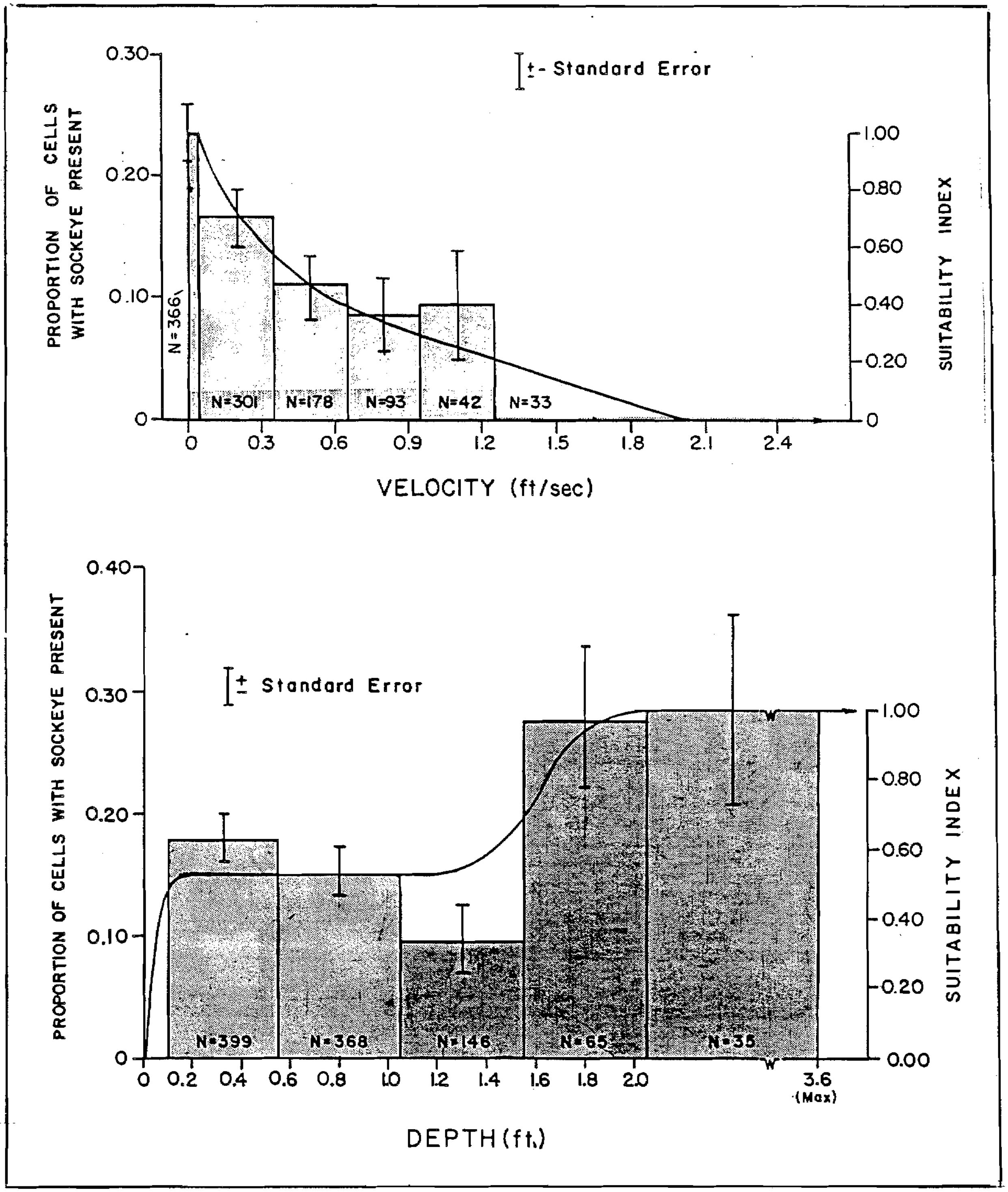

Figure 11. Proportion of cells with juvenile sockeye salmon present by velocity and depth intervals (bars), Chulitna River to Devil Canyon reach of the Susitna River. Suitability indices (lines) fitted by hand.

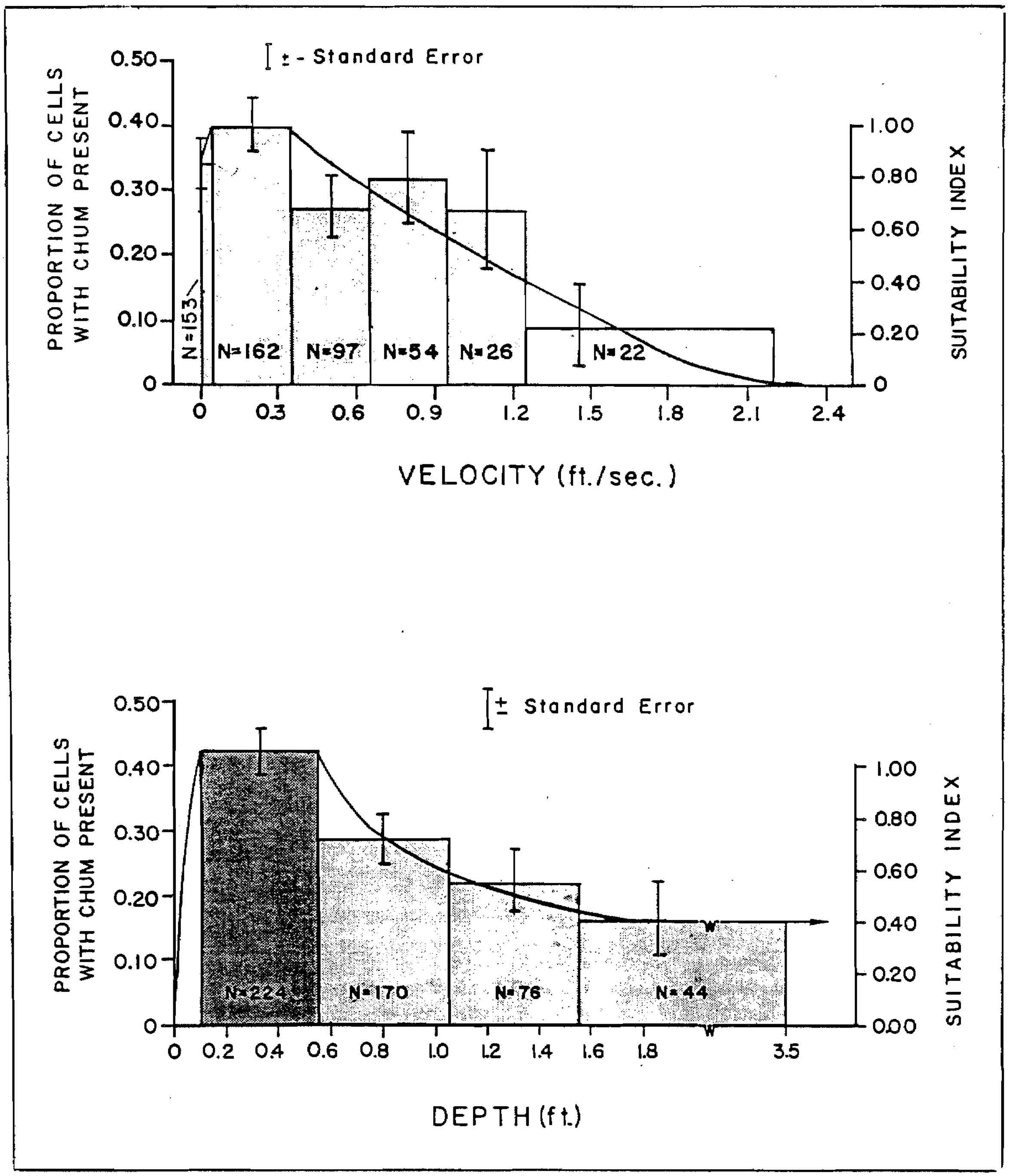

Figure 12. Proportion of cells with juvenile chum salmon present by velocity and depth intervals (bars), Chulitna River to Devil Canyon reach of the Susitna River. Suitability indices (lines) fitted by hand.

The correlations range from 0.16 to 0.42, and all were statistically greater than zero.

Table 13. Correlations between composite weighting factors generated using various combinations of suitability indices and transformed [ln (X+1)] chinook and coho catch.

Composite Weighting Factor Calculation	Pearson correlations (r)* Chinook (clear)	Coho (clear)	Chinook (turbid)
(Percent cover)x(cover type)x(velocity)x(depth)	0.42	0.36	0.31
(Percent cover)x(cover type)x(velocity)	0.41	0.38	0.30
(Percent cover)x(cover type)	0.35	0.37	0.16
(Velocity)x(depth)	0.28	0.30	0.28
Limiting factor (minimum of (percent cover x cover type), (velocity), or (depth) taken as weighting factor)	0.43	0.39	0.32
	N=813	N=813	N=813

* All correlations significantly greater than zero at the 0.01 significance level.

Combinations of habitat variables with the highest correlations are the most likely candidates for applications in habitat modelling studies. The low correlations are due to the fact that actual fish numbers are influenced greatly by other factors such as season and site.

3.5.2 Sockeye and chum salmon

Sockeye and chum salmon proportional presence increased significantly with increased magnitude of several composite weighting factor intervals (Table 14). The largest composite weighting factor interval had an associated proportional presence which was three to seven times the proportional presence associated with the lowest composite weighting factor interval.

Table 14. Proportional presence of sockeye and chum salmon fry associated with several composite weighting factors.

Species	Composite Weighting Factor Calculation	Composite Weighting Factor Interval	Total No. of cells	Proportion with Fish Present	Chi-Square
Sockeye	Minimum factor of (percent cover x cover type), (velocity) or (depth)	0.0-0.12	269	0.12	62.9*
		0.12-0.20	321	0.08	df=3
		0.20-0.33	312	0.22	
		0.33+	111	0.38	
Sockeye	(Percent cover) x (cover type) x (velocity) x (depth)	0.0-0.04	312	0.09	49.6*
		0.04-0.08	260	0.13	df=3
		0.08-0.17	330	0.20	
		0.17 +	111	0.36	
Sockeye	(Percent cover) x (cover type) x (velocity)	0.0-0.08	341	0.09	50.8*
		0.08-0.14	253	0.12	df=3
		0.14-0.30	308	0.22	
		0.31 +	111	0.35	
Chum	Minimum factor of (percent cover x cover type) (velocity), or (depth)	0.0-0.33	79	0.18	32.6*
		0.33-0.50	177	0.25	df=3
		0.50-0.67	178	0.37	
		0.67+	80	0.55	
Chum	(Percent cover) x (cover type) x (velocity) x (depth)	0.0-0.17	77	0.09	49.6*
		0.17-0.31	171	0.26	df=3
		0.31-0.53	177	0.37	
		0.53 +	89	0.56	
Chum	(Percent cover) x (cover type) x (velocity)	0.0-0.26	71	0.14	32.7*
		0.26-0.44	183	0.27	df=3
		0.44-0.64	175	0.36	
		0.64 +	85	0.54	

* All significant at $p < 0.001$

4.0 DISCUSSION

Suitability criteria for juvenile salmon in the Susitna River have been developed by integrating statistical methods with professional judgement. Somewhat novel design and analysis methods were used to overcome problems that prevented the use of traditional applications in the Susitna River system. Bovee (1982) reviewed the popular methods of describing preference curve construction. The methods range from the binary criteria used by Collings et al. (1972) to multivariate suitability techniques explored by Voos (1981) and Prewitt (1982). Perhaps the most widely used methods have been the probability-of-use curves construction techniques described by Bovee and Cochnauer (1977).

Baldrige and Amos (1983) have expanded Bovee and Cochnauer's approach to produce univariate suitability descriptions which minimize environmental and sampling bias. Our techniques merge these authors' concepts of environmental suitability, availability, and usability with an infrequently applied approach. Usability descriptions (defined as suitability times availability) are commonly derived from collecting point specific habitat measurements at locations where fish are observed. These data are the probability of observing a value for an environmental attribute (E), given fish (F), which is P[E/F] (Bovee 1982). This practice cannot be easily implemented for juvenile salmon in large turbid glacial systems. Instead, we have compiled the description P[N/E], the probability of one or more fish (N), given a set of environmental attribute values. This method, has the benefit of collecting fish and physical habitat data in a manner that can be used to subsequently verify model outputs. This was accomplished by establishing the grid and cell sampling scheme over important rearing areas in the reach. Bovee notes that two assumptions are made when P[N/E] distributions are calculated directly: systematic random sampling is employed and that the entire population is sampled. We view our experimental design as stratified random sampling of selected areas of the most important macrohabitats available in the reach above the Chulitna confluence. While we did not observe the whole population we believe that representative data have been collected.

4.1 Limitations of the Suitability Criteria

Not all the factors which could have a major effect on the distribution of juvenile fish were addressed in this study. We evaluated cover, depth, and velocity but such factors as water quality and food production also influence juvenile salmonid distribution (Reiser and Bjornn 1979). We may have addressed food production indirectly as Reiser and Bjornn reported that velocity, depth, and substrates are correlated with food supply. The water quality suitability differences within and between sites are probably minimal with the exception of turbidity as measured water quality attributes of dissolved oxygen and temperature normally do not vary greatly from optimum ranges presented by Reiser and Bjornn (1979).

These criteria are also specific to the Susitna River reach studied and if used outside that reach they might not be valid. The suitability criteria developed are also limited to the open-water time period from

May to mid-October. Winter rearing habitat preferences are probably different as feeding and activity of the fish are reduced. Bjornn (1971) reported that juvenile salmon enter large rubble substrate when stream temperatures drop below 4-6°C and will leave the area if this cover type is not present.

The criteria are also limited by the values of the habitat attributes which could be effectively sampled by the methods used. Velocities over three feet per second and depths over two to three feet could not be effectively sampled, for example. A preliminary experiment described in Part 2 of this report suggested that sampling efficiency also decreased slightly in cells with large amounts of cover.

Single habitat measurements used to describe a cell with diverse values of habitat attributes like depth and velocity are often inadequate descriptions. Since the curves are univariate, they also do not account for interactions between variables such as depth and velocity.

Criteria also were not developed specifically by age class; however, over 99% of the fish captured were 0+ fish and 1+ fish were pooled with these to increase sample sizes. Suitability criteria might also shift as a function of within year life history: larger fish of a given species may prefer different habitat conditions as food sources and behaviors change. (Chapman and Bjornn 1969; Everest and Chapman 1972).

4.2 Chinook and Coho Salmon

Chinook and coho salmon low turbidity suitability indices were developed from the same data set. Electrofishing is perhaps the best method for collecting juvenile fish in clear water as seining efficiency is affected strongly by cover. Because the backpack electroshocker is most effective in shallow water, the depth curves were drawn so that the suitability in deep water was actually higher than indicated by the data. Wiley and Tsai (1983) concluded that the electroshocker (and also beach seine) was more effective and consistent than seines for estimating fish populations. Dauble and Gray (1980) concluded that electrofishing was better than beach seining for sampling irregular substrates and higher velocities.

4.2.1 Chinook salmon

Chinook salmon were the only species for which enough data were collected to generate suitability indices for both clear and turbid conditions. Some shifts in preferences for habitat conditions are apparent. Lower velocity waters are preferred under turbid conditions than under clear conditions, as are shallower depths (Figures 5 and 8). Juvenile chinook salmon possibly prefer lower velocities in turbid water because when using the turbid water as cover, they have no velocity breaks to hide or rest behind. Cover might still be useful, however, as a break from velocity. A shift in depth preference may be due to the fish reacting to high suspended solid concentrations by staying near the surface (Wallen 1951 as cited in Beauchamp et al. 1983).

The preference for object cover appears stronger in clear water than in turbid water for chinook salmon because of the higher suitability for low cover cells and lesser slope of the cover regression line in turbid than in clear water. This limited preference for object cover in turbid water is partly due to gear bias as beach seining is quite ineffective where large amounts of object cover are present. However, the distribution of chinook salmon is clearly different in clear than in turbid water. In turbid waters, such factors as depth and velocity most limit and influence distribution while in clear water, object cover seems more important. MacCrimmon (1954) noted Atlantic salmon fry use of turbid water for cover.

The velocity probability-of-use curves for juvenile chinook salmon presented in Bovee (1978) and Burger et al. (1982) are almost identical with the curve developed for chinooks in clear water of the Susitna River with the peaks at approximately 0.2 to 0.6 ft /sec. Minnow trap chinook catch data from the Little Susitna River also suggest the optimum velocity for chinook salmon to be approximately 0.3 to 0.6 ft /sec with little use of velocities greater than 1.8 ft /sec (Delaney and Wadman 1979).

Depth criteria developed in other systems for juvenile chinook salmon vary significantly from those presented here, where optimum depths were 1.0 to 1.5 ft in clear water and less than 0.5 ft in turbid water. A depth probability-of-use curve presented in Bovee (1978) for chinook salmon shows an optimum range from 1.2 ft up to at least 3.0 ft in depth, while data presented in Delaney and Wadman's (1979) data suggest an optimum of 2.5 to 3.2 ft Burger et al. (1982) observed chinook fry in pools to ten feet in depth and thought depths of less than 0.2 ft were avoided. Correlations of depth with other important distributional factors which may vary from river to river probably cause much of this variation in the form of the depth suitability functions.

4.2.2 Coho salmon

In contrast to chinook salmon, coho salmon do not appear to use turbid water as cover. Bisson and Bilby (1982) reported that coho salmon avoided turbidities of 70 to 100 NTU under experimental conditions and Sigler et al. (1984) found, in a laboratory study, that more juvenile coho salmon emigrated from channels with a turbidity level of 25-50 NTU than from clear water channels. These turbidity levels are frequently exceeded during the ice free months in side channels of the Susitna River. Catches of coho salmon were very low in turbid side channels (see Part 2 of this volume). Cover types preferred by coho, i.e. debris and undercut banks, are also very scarce at these sites, however, and almost impossible to sample effectively with beach seines. It may be that coho usually leave a site when turbidities exceed a certain level.

The distribution of coho salmon fry may be limited greatly within a clear water area by the lack of suitable cover type, as very strong preferences for a few cover types were noted (Figure 4). In contrast to chinook salmon, substrate was little used as cover while preferred velocities and depths were also somewhat different. Bustard and Narver (1975) also noted that coho preferred bank cover in the form of undercut banks rather than instream cover. Social interactions between the two species could cause these differences (Stein et al. 1972) but intraspecific interactions and microhabitat preferences might be most important (Allee 1981).

Bovee (1978) presented a velocity suitability curve for coho fry very similar to that presented in this report with a slightly higher optimum of 0.5 ft /sec. and a minimum at 2.3 ft /sec. Burger et al. (1982) presented utilization curves with optimums at 0.0 ft /sec , but which then quickly dropped to very low suitabilities at velocities greater than 0.2 ft /sec. Habitat suitability criteria from the Terror and Kizhuyak Rivers for coho salmon juveniles also presented optimum velocities at 0.0 to 0.4 ft /sec (Baldridge 1981) as do those suggested by Delaney and Wadmans' (1979) data. Optimum velocities for coho derived in this report are therefore very similar to velocity criteria developed for coho in other streams.

Depth criteria, on the other hand, vary greatly from stream to stream. On the Terror and Kizhuyak rivers, optimum depths for coho fry ranged from near 0.0 ft to 1.0 ft and then declined rapidly to zero at 2.5 ft (Baldrige 1981). Data presented in Bovee (1978), however, indicate very little use until 1.0 ft in depth with an optimum at 2.0 ft and a gradual decline to zero use at 5.0 ft. In the Susitna River, the optimum suitability appeared to occur at approximately 1.6 to 2.0 ft with limited data above this depth. These conflicting data show that depth suitability may vary greatly from river to river for unknown reasons, although correlations of depth with other important factors influencing distribution are probable.

4.3 Sockeye and Chum Salmon

The sockeye and chum suitability indices are less reliable than for chinook and coho as the numbers, distribution, and seasonal use of habitat is smaller for these species. The seasonally reduced sampling and need for large sample sizes also made it necessary to pool gear types to adequately address the range of habitat conditions encountered during the study. The schooling behavior of these species also caused us to put catch on a presence-absence basis for purposes of analysis.

4.3.1 Sockeye salmon

Sockeye salmon were apparently much less dependent on cover than were chinook or coho salmon because they occur in schools and use the schooling as a means of predator avoidance. Schools of sockeye were observed ranging throughout areas which varied from heavy cover to no cover at all. Depth and velocity, therefore, could have a much larger effect on their distribution. However, from the analysis, the distribution of junvenile sockeye salmon did appear to be related with cover. The suitability curves for depth and velocity both indicate a fish that rears in a lacustrine environment. The effect of turbidity on sockeye salmon distribution is unknown. A limited review of the literature indicated that suitability criteria for stream rearing sockeye populations have not been developed. Burger et al. (1982) presented a velocity probability-of-use curve for sockeye in the Kenai River with an optimum at 0.0 ft /sec and very little use at velocities greater than 0.6 ft /sec.

Sockeye salmon have a limited distribution in the upper Susitna River basin. Most of the rearing appears to be limited to sites along the mainstem Susitna which offer lacustrine environments. However, we had no means of effectively sampling these types of habitat areas in this study.

4.3.2 Chum salmon

Of the four species of salmon which rear in the middle Susitna River, chum salmon rear for the shortest period of time (ADF&G 1983b). Little is known about the rearing requirements of chum salmon but they have been reported to use substrate as cover initially (Neave 1955) and then after schooling, use the protection of the schools (Hoar 1956). Both these behaviors of chum salmon fry were observed in the Susitna River and the suitability indices reflect a larger relative use of large substrate for cover by chum salmon than for sockeye salmon. As the amount of cover increased greatly, however, the change in use by juvenile chum salmon was very similar to sockeye salmon. Shallow depths and low velocity water were found most suitable for chum salmon fry in this study. Mean catches of juvenile chum salmon were less in cells without object cover in turbid water which suggests avoidance of turbid conditions. On the other hand, this may also have been an artifact of the influences of natal areas on distribution with clear water near emergence areas affecting the results.

4.4 Recommended Applications for the Suitability Criteria

The suitability criteria for juvenile salmon in the Susitna River reach between the Chulitna River confluence and Devil Canyon which are recommended for use in calculating weighted usable area are listed in Appendix Table C-1.

Suitability criteria, in conjunction with hydraulic models, are one means of calculating changes in habitat with changes in flow. Typically, weighted usable areas (WUA's) are calculated for a series of discharges and these are taken as representing changes in the desirability of habitat. There are several standard methods for calculating WUA's by multiplying area with composite weighting factors which are combinations of suitability indices of factors believed to have major effects on distribution. Suitability indices can be multiplied together, the geometric mean can be taken, or the lowest suitability index for attributes of importance can be used as the composite weighting factor (Milhous et al. 1981).

We have calculated composite weighting factors for various combinations of habitat attributes and compared the composite weighting factor to observed fish catch (Tables 13 & 14). The geometric mean was not used for integrating suitability indices as this implies a compensatory effect that does not seem biologically reasonable for juvenile salmonids. The correlations are very similar for various combinations and are consistently low. Other formulations of composite weighting factors are possible and these could produce better correlations, but time constraints prevented further testing.

Effects of depth on the distribution of juvenile salmon are probably limited as depth typically by itself would not limit the distribution of fish. Correlations with other factors like site, season, or velocity may make depth seem more important than it is. When depth was eliminated from calculations of the composite weighting factor, little reduction in the correlations of catch with weighting factors was noted. By including depth in the calculations, however, equal weight is given to depth with cover and velocity and this weighting can drive changes in WUA with discharge as was noted in trial runs with models discussed in Part 4 of this report. Since depth is not as limiting in a behavioral or physical sense as cover and velocity are, its applicability to habitat modelling as equally weighted with velocity or cover is dubious. Analyses of variance, however, suggested that depth and velocity interactions were sometimes significant and that fish were not selecting habitat on the basis of velocity independent of depth (Table 10). Interactions of depth and velocity have been shown in at least one other study (Orth and Maughan 1982) to affect WUA's when depth and velocity were multiplied together to generate composite weighting factors.

Because the inclusion of depth in the composite weighting factors did not improve the correlation with fish density, we decided to discount the effect of depth at depths greater than 0.15 ft in the composite weighting factors which were used in projecting weighted usable area in Part 4 and Part 7 of this report. This was done by setting the suitability index to 1.0 for all depths greater than or equal to 0.15 ft. and represents a departure from the depth suitability indices presented in the results section. The 0.15 point is somewhat arbitrary, but there is little data to go on. Burger et. al (1982) as previously suggested that chinook salmon avoided depths of less than 0.2 ft. Obviously, a depth of 0.0 ft. has a suitability index of 0.0.

If turbidity is used as cover, then depth suitability is not independent of turbidity. At shallower depths, water of a given turbidity may not provide cover, while deeper waters may provide excellent cover. Secchi disc transparencies measured in Eklutna Lake decreased from 3.0 to 1.4 ft. over a turbidity range of 18 to 36 NTU (R & M Consultants, 1982). Cover for fish would be provided at shallower depths than indicated by Secchi disc readings due to their cryptic coloration. The relationship of turbidity to light penetration, water depth, and related cover value has not been quantified in the Susitna River.

The minimum factor approach which implies that the habitat is no better than the most limiting attribute is biologically reasonable. The calculated fit with the observed data was as good as the other approaches used. When the minimum factor was used as the composite weighting factor, cover was often the minimum factor for chinook and coho salmon in clear water, velocity was secondarily important, and depth was only occasionally the minimum factor. Reiser and Bjornn (1979) reviewed the importance of cover in the literature and found that salmonid abundance declined and increased as cover was removed or added to streams in a number of instances. Burger et al. (1982) reported that velocity was perhaps the most limiting factor for juvenile chinook in the Kenai River but that the fry also moved from areas where suitable cover types in the form of steep vegetated banks no longer existed. Depth was not mentioned in these studies as having much of an influence on distribution, and therefore probably should not be weighted the same as cover or velocity. If cover and velocity are weighted with equal importance and depth suitability is held constant, determinations of WUA's for juvenile salmon will perhaps be most valid.

The suitability criteria which have been developed in this paper represent a compendium of the data from the 1983 field study and three years of experience in observing and sampling these populations. Although there are limitations to the suitability criteria technique, we are confident that the curves presented are reasonably accurate for this reach of river and will lead to weighted usable area projections which are of value in predicting effects of changes in flow on juvenile salmon habitat.

5.0 CONTRIBUTORS

Field sampling was conducted by Paul Suchanek, Larry Dugan, Robert Marshall, and David Sterritt. Carol Kerkvliet drafted the figures. Allen Bingham provided assistance with the data analysis. Donna Buchholz keypunched the data and Gail Heineman organized the database. Larry Bartlett, Allen Bingham, and Kathrin Zosel reviewed the manuscript.

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APPENDIX A

Calculations of Suitability of Cover Type for Chinook and Coho Salmon in Clear Water

Calculations of suitability of cover type for chinook and coho salmon in clear water.

$$\text{Weighted mean effect of cover type } j = \frac{\sum_{i=1}^{x} \left(\frac{N_{i,j}}{K_i} \right)}{\sum_{i=1}^{x} C_{i,j}}$$

$N_{i,j}$ = Number of fish captured in percent cover category i and cover type category j

$C_{i,j}$ = Number of cells sampled in percent cover category i and cover type category j

i = Percent cover category

j = Cover type category

x = Number of percent cover categories = 5

$$K_i = \sum_{j=1}^{y} N_{i,j} \Big/ \sum_{j=1}^{y} C_{i,j}$$ = Mean catch for all cover types pooled in percent cover category i

y = Number of cover types = 9

Hypothetical example:

1. Sample data

Percent Cover Category	Primary Cover Type	Chinook Captured ($N_{i,j}$)	Cells Sampled ($C_{i,j}$)
1) 0-5%	1) Emergent vegetation	1	5
	2) Undercut banks	5	10
	3) Boulders	4	5

$$K_1 = \sum_{j=1}^{3} N_{1,j} \Big/ \sum_{j=1}^{3} C_{1,j} = 10 / 20 = 0.5$$

Percent Cover Category	Primary Cover Type	Chinook Captured ($N_{i,j}$)	Cells Sampled ($C_{i,j}$)
2) 6-25%	1) Emergent vegetation	5	10
	2) Undercut banks	10	10
	3) Boulders	15	10

$$K_2 = \sum_{j=1}^{3} N_{2,j} \Big/ \sum_{j=1}^{3} C_{2,j} = 30 / 30 = 1.0$$

2. Calculations of average effect of cover types on chinook distribution

Weighted mean effect of emergent vegetation =

$$\frac{\sum_{i=1}^{2} \left(\frac{N_{i,1}}{K_i}\right)}{\sum_{i=1}^{2} C_{i,1}} = \frac{\frac{1}{0.5} + \frac{5}{1.0}}{5 + 10} = 0.47$$

Weighted mean effect of undercut banks =

$$\frac{\sum_{i=1}^{2} \left(\frac{N_{i,2}}{K_i}\right)}{\sum_{i=1}^{2} C_{i,2}} = \frac{\frac{5}{0.5} + \frac{10}{1.0}}{10 + 10} = 1.00$$

Weighted mean effect of boulders $= \dfrac{\sum_{i=1}^{2} \left(\dfrac{N_{i,3}}{K_i}\right)}{\sum_{i=1}^{2} C_{i,3}} = \dfrac{\dfrac{4}{0.5} + \dfrac{15}{1.0}}{5 + 10} = 1.53$

3. Normalize to 1.0 by dividing each effect by the largest effect

	Weighted Mean Effect	Suitability
Emergent Vegetation	0.47	0.47/1.53 = 0.31
Undercut banks	1.00	1.00/1.53 = 0.65
Boulders	1.53	1.53/1.53 = 1.00

APPENDIX B

Calculations of Effect of Cover Type on Distributions of Sockeye and Chum Salmon

Calculations of effect of cover type on distributions of sockeye and chum salmon.

Effect of cover type j = $E_j = \dfrac{P_j / C_j}{R}$

If less than 1.0 then $E_j = 1.0$ = effect of no cover

P_j = Number of cells of cover type j sampled with fish present
C_j = Number of cells of cover type j sampled
$R = N_1/C_1$ = Proportional presence of fish in cells without object cover

---

Hypothetical example:

1. Sample data

Primary Cover Type	Cells Sampled (C_j)	Number of Cells Sampled with Sockeye Present (N_j)
1) No object cover	15	5
2) Emergent vegetation	20	5
3) Undercut banks	20	8
4) Boulders	50	25

2. Calculations of average effect of cover type on sockeye distribution.

$R = P_1/C_1 = 5/15 = 0.33$

Effect of emergent vegetation $= \dfrac{P_2 / C_2}{R} = \dfrac{5 / 20}{0.33} = 0.76$

Since less than 1.0 change to equal 1.0.

Effect of undercut banks $= \dfrac{P_3 / C_3}{R} = \dfrac{8 / 20}{0.33} = 1.21$

Effect of boulders $= \dfrac{P_4 / C_4}{R} = \dfrac{25 / 50}{0.33} = 1.52$

3. Normalize to 1.0 by dividing each effect by the largest effect

	Effect	Suitability
No cover	1.00	1.00/1.52 = 0.66
Emergent vegetation	1.00	1.00/1.52 = 0.66
Undercut banks	1.21	1.21/1.52 = 0.80
Boulders	1.52	1.52/1.52 = 1.00

APPENDIX C

Suitability indices for juvenile salmon for cover, velocity, and depth

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Appendix Table C-1. Suitability indices for juvenile salmon for cover, velocity, and depth.

		Cover Suitability					
Cover type	% Cover[1]	PHABSIM Code	Chinook (high turbidity)	Chinook (low turbidity)	Coho	Sockeye	Chum
No cover	0-5%	1.1	0.45	0.01	0.00	0.11	0.29
Emergent vegetation	0-5%	2.1	0.57	0.01	0.03	0.18	0.29
	76-100%	2.5	1.00	0.12	0.29	0.47	0.53
Aquatic vegetation	0-5%	3.1	0.57	0.07	0.07	0.39	0.29
	76-100%	3.5	1.00	0.68	0.65	1.00	0.53
Debris/deadfall	0-5%	4.1	0.57	0.11	0.10	0.19	0.47
	76-100%	4.5	1.00	1.00	0.90	0.49	0.87
Overhanging riparian vegetation	0-5%	5.1	0.57	0.06	0.04	0.30	0.40
	76-100%	5.5	1.00	0.61	0.38	0.78	0.74
Undercut banks	0-5%	6.1	0.57	0.10	0.12	0.11	0.40
	76-100%	6.5	1.00	0.97	1.00	0.29	0.74
Large gravel (1-3")	0-5%	7.1	0.57	0.07	0.03	0.17	0.37
	76-100%	7.5	1.00	0.63	0.24	0.44	0.68
Rubble (3-5")	0-5%	8.1	0.57	0.09	0.02	0.12	0.54
	76-100%	8.5	1.00	0.81	0.18	0.30	1.00
Cobble or boulder (> 5")	0-5%	9.1	0.57	0.09	0.02	0.11	0.46
	76-100%	9.5	1.00	0.89	0.18	0.29	0.86

[1] With the exception of the "no cover" cover type, there are three other precent cover categories for each cover type between the 0-5% and 76-100% categories. Suitability values for these cover types are linearly interpolated from the two endpoints given. PHABSIM codes for the

Appendix Table C-1 (continued)

VELOCITY

Chinook (turbid)		Chinook (clear)		Coho		Sockeye		Chum	
Velocity (ft/sec)	Suitability	Velocity (ft/sec)	Suitability	Velocity (ft/sec)	Suitability	Velocity (ft/sec)	Suitability	Velocity (ft/sec)	Suitability
0.00	0.42	0.00	0.18	0.00	0.29	0.00	1.00	0.00	0.86
0.05	1.00	0.20	0.57	0.05	1.00	0.05	1.00	0.05	1.00
0.35	1.00	0.35	1.00	0.35	1.00	0.20	0.71	0.35	1.00
0.50	0.80	0.65	1.00	0.50	0.88	0.50	0.48	0.50	0.87
0.80	0.38	0.80	0.68	0.80	0.55	0.80	0.36	0.80	0.70
1.10	0.25	1.10	0.44	1.10	0.32	1.10	0.27	1.10	0.56
1.40	0.15	1.40	0.25	1.40	0.12	1.40	0.17	1.40	0.37
1.70	0.07	1.70	0.18	1.70	0.04	1.70	0.09	1.70	0.15
2.00	0.02	2.00	0.12	2.00	0.01	2.00	0.02	2.00	0.03
2.30	0.01	2.30	0.06	2.10	0.00	2.10	0.00	2.10	0.00
2.60	0.00	2.60	0.00						

DEPTH (All Species)

Depth (ft)	Suitability
0.00	0.00
0.14	0.00
0.15	1.00
10.00	1.00

PART 4

Juvenile Salmon Rearing Habitat Models

JUVENILE SALMON REARING HABITAT MODELS

1984 Report No. 2, Part 4

by Robert P. Marshall, Paul M. Suchanek, and Dana C. Schmidt

Alaska Department of Fish and Game
Susitna Hydro Aquatic Studies
2207 Spenard Road
Anchorage, Alaska 99503

ABSTRACT

The effects of mainstem discharge on rearing habitat of juvenile salmon in the Susitna River reach between the Chulitna River confluence and Devil Canyon were quantified by use of habitat models. Six slough and side channel sites were sampled at four to seven different levels of mainstem discharge during the 1983 open water season. Data were collected on hydraulic characteristics, cover, water quality, water surface area, and fish density. Suitability criteria were integrated with the habitat data to calculate weighting factors for cover and velocity for selected species at each site. These weighting factors, which were calculated for both shoreline and mid-channel areas, were then combined with area to produce weighted usable areas for the site. A habitat index was then calculated for site comparisons. Peaks in habitat indices for chinook salmon occurred when slough or side channel heads were overtopped. Upland slough habitat indices steadily increased with mainstem discharge. Lack of cover may limit juvenile salmon use of many of the sites.

JUVENILE SALMON REARING HABITAT MODELS

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1.0 INTRODUCTION

Five species of Pacific salmon spawn in the Susitna River between the Chulitna River confluence and Devil Canyon. This reach of river provides rearing habitat for chinook, coho, sockeye, and chum salmon during the juvenile portion of their life cycle. Pink salmon outmigrate immediately after emergence. The proposed hydroelectric project on the Susitna River will create turbidity, temperature, discharge, and other physical-chemical conditions which are substantially different from preproject conditions (Acres, 1982). This is one of three interrelated studies attempting to determine the effects of lowered flows on the capability of this reach of the Susitna River to support juvenile salmon rearing during the ice-free season.

Studies during 1981 and 1982 (ADF&G 1981; 1983a) demonstrated large scale distribution and habitat utilization patterns of these species. Other studies (ADF&G 1983b, appendices E, F and G) investigated the response of selected macrohabitat areas to mainstem discharge using "hydraulic zones" to characterize sections of the slough and tributary mouth areas. The surface area of these zones, as a function of mainstem discharge, were compared to the relative use of the zones by each species. The result of the analysis was an index of habitat availability for each species as a function of mainstem discharge. During the course of that study we noticed that microhabitat parameters within the zones were responding to discharge changes at rates higher than the zone surface areas being evaluated. These microhabitat factors included cover and turbidity.

The present study incorporates these microhabitat parameters into simulations of mainstem Susitna River discharge effects on juvenile salmon rearing habitat. Our experimental design emphasizes the measurement of cover at sites that are characteristic of the macrohabitats utilized by juvenile salmon. Otherwise, the methodology is similar to, but less data intensive than Instream Flow Group (IFG) hydraulic methods (Bovee 1982) of calculating the amount of optimum habitat called weighted usable area. Each site/discharge description is developed from parameters measured in shoreline and mid-channel area cells specified by a fixed sampling grid. Our experimental design evolved because it enabled us to develop models at several sites encompassing the full range of macrohabitat types. The intensive effort required to develop IFG models would have limited the number of sampling sites.

Concurrent with the collection of habitat modelling data, fisheries data were collected at less rigidly specified grids at 29 additional sites. The two data bases were used to develop estimates of: 1) abundance of cover type and percent cover, turbidity, velocity and depth versus mainstem discharge at the six sites, and 2) univariate suitability functions for velocity, depth, cover type, and percent cover for sampling cells at all sites. The suitability function study is reported separately (Part 3 of this volume). In this report, the environmental descriptions are combined with the suitability functions to yield weighted usable rearing areas for the species as a function of mainstem discharge at the six sites. The weighted usable areas for each species, site, and mainstem discharge were then divided by the surface area of the site at a typical midsummer mainstem discharge of 23,000 cfs to produce habitat indices. The index values are plotted as a function of mainstem discharge by species so that the weighted usable areas can be compared independently of each site's surface area at a fixed mainstem flow.

The results of these calculations have application to two concurrent projects. The results from juvenile habitat simulation studies using IFG hydraulic models (Part 7 of this volume) will be integrated with those presented here to produce best estimates of habitat indices for the juvenile salmon species at the macrohabitat types identified in the Susitna River reach between the Chulitna River confluence and Devil Canyon.

Secondly, incremental estimates of total usable rearing area in the Chulitna River confluence to Devil Canyon reach impacted by mainstem flows will be made from the product of the integrated indices and macrohabitat abundance as a function of mainstem Susitna River discharge. To accomplish this, the area of each macrohabitat type is being mapped from aerial photographs taken at different mainstem flows. The total area of each macrohabitat type in the reach as a function of mainstem discharge will be provided by E. Woody Trihey and Associates.

2.0 METHODS

2.1 Field Sampling Design

2.1.1 Study site location and selection criteria

Much of the juvenile salmon studies program has been directed towards collection of CPUE data over widely ranging spatial and temporal habitats of the species (ADF&G, 1982; 1983c). A product of these studies has been the identification of critical juvenile rearing "macrohabitat" types affected to varying degrees by variation in mainstem flow. These areas of the riverine environment, depending on the mainstem stage, are characterized as side channels, side sloughs or upland sloughs. For this study, six study sites representative of these three macrohabitat types were chosen to complement the IFG hydraulic modelling sites. All these macrohabitats are affected by mainstem stage and flow and contain significant numbers of rearing juvenile salmon. Side Channel 10A was chosen because it possessed potential habitat for rearing juvenile chinook salmon and represented side channel macrohabitats strongly affected by mainstem discharge. Two upland slough sites, Slough 5 and Slough 6A, were chosen because juvenile sockeye salmon rear in these areas and because they are representative of sites that do not have mainstem discharge passing through; the predominant influence of the mainstem on these sites is the backwater created by mainstem stage at the mouth of the site. Three sites, Slough 8, Slough 22, and Whiskers Slough, which progressed from side sloughs to side channels at high mainstem flows, were also modelled (Figure 1). A side slough is considered a side channel when turbid mainstem water flows through (overtops) the head of the site. These six sites represented a cross section of three morphological habitat types present in this reach which are known to support significant rearing of juvenile salmon.

2.1.2 Sampling grid design

Habitat data at the modelling sites was collected at a grid of fixed transect markers. The locations of the transects at each site are illustrated on aerial photographs in Plates 1 through 6. The grids at each site were placed to maintain a relatively uniform water chemistry condition and to maximize the diversity of cover, depth, and velocity parameters to be sampled in the area.

The eight or nine pairs of the transect markers spanning the selected reach (typically 1,000 ft) of the site were installed during the first visit to the sampling site. The location of up to three cells (6 ft by 50 ft) per transect were specified for each subsequent sampling. (Figure 2). Two shoreline and one mid-channel area cells were always specified if the wetted area at the transect crossing was 18 or more ft in width. When the site was between 12 and 18 ft in width, two shoreline cells were specified; for widths under 12 ft, one shoreline cell was specified.

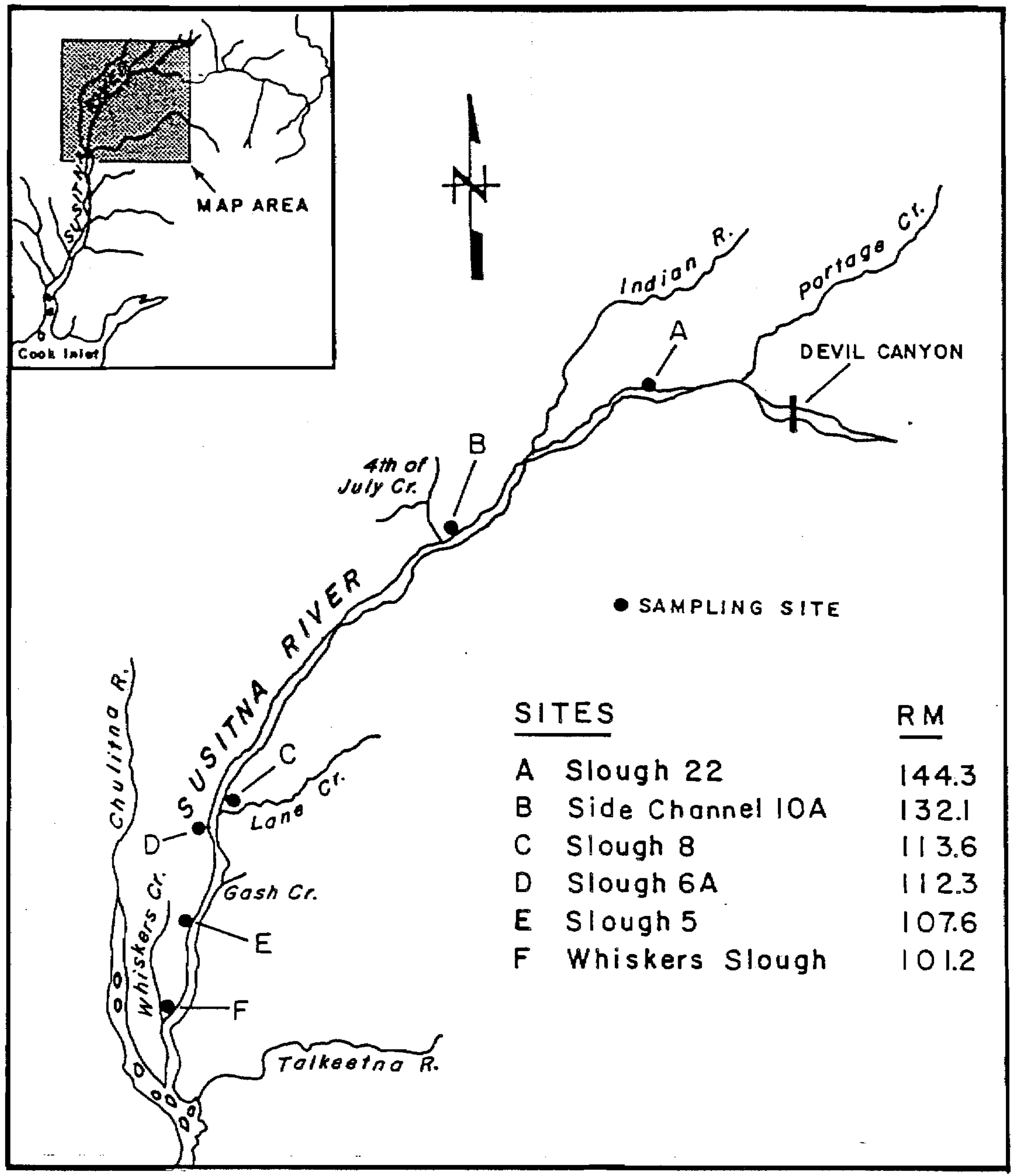

Figure 1. River mile and relative location of the juvenile salmon rearing habitat model study sites.

Plate 1. Aerial photograph of Side Channel 10A (RM 132.1), September 1983. The pool between transects 1-5 and the island was excluded from the study area.

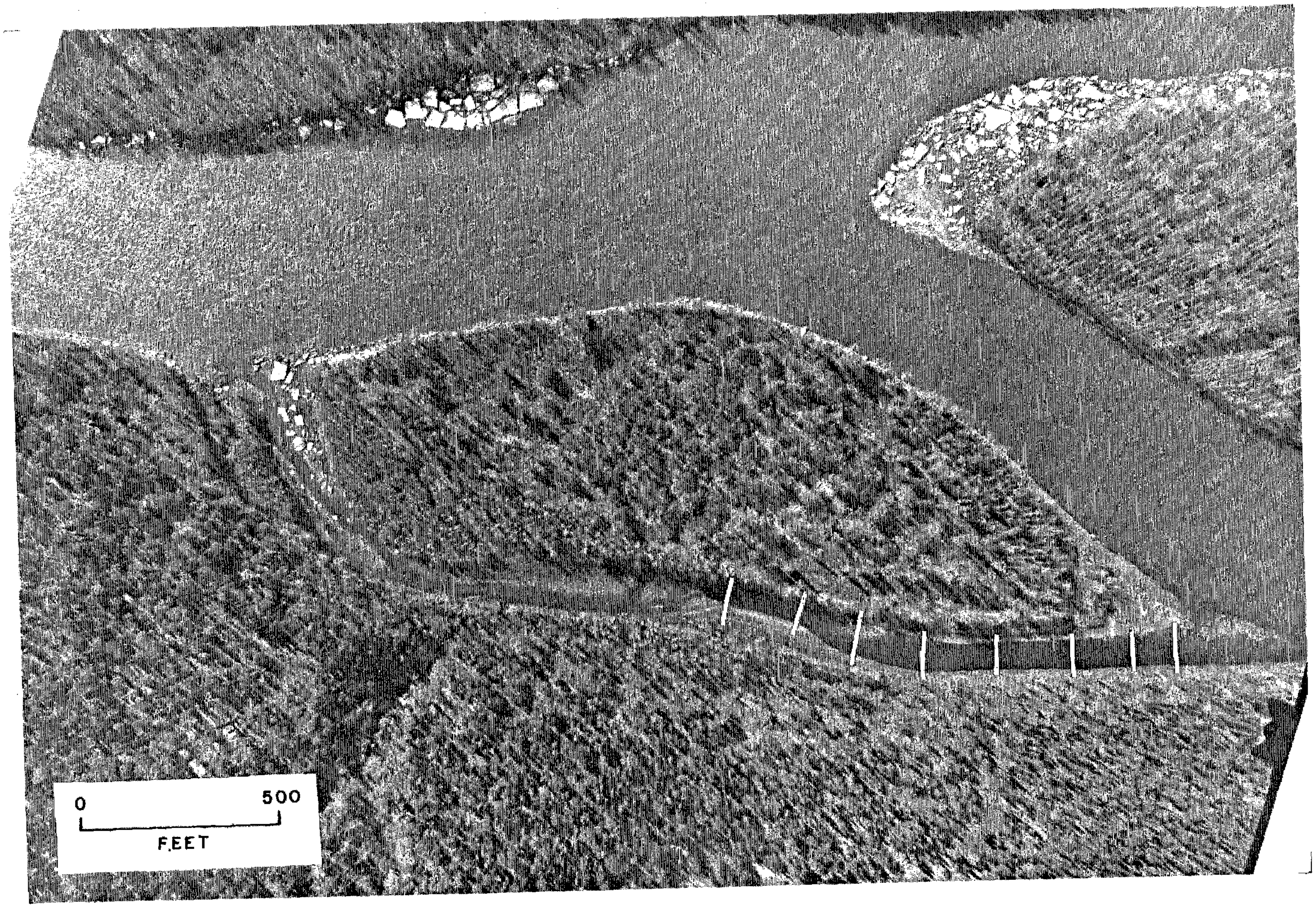

Plate 2. Aerial photograph of Slough 22 (RM 144.3), May 1982.

Plate 3. Aerial photograph of Whiskers Creek Slough (RM 101.2), September 1983.

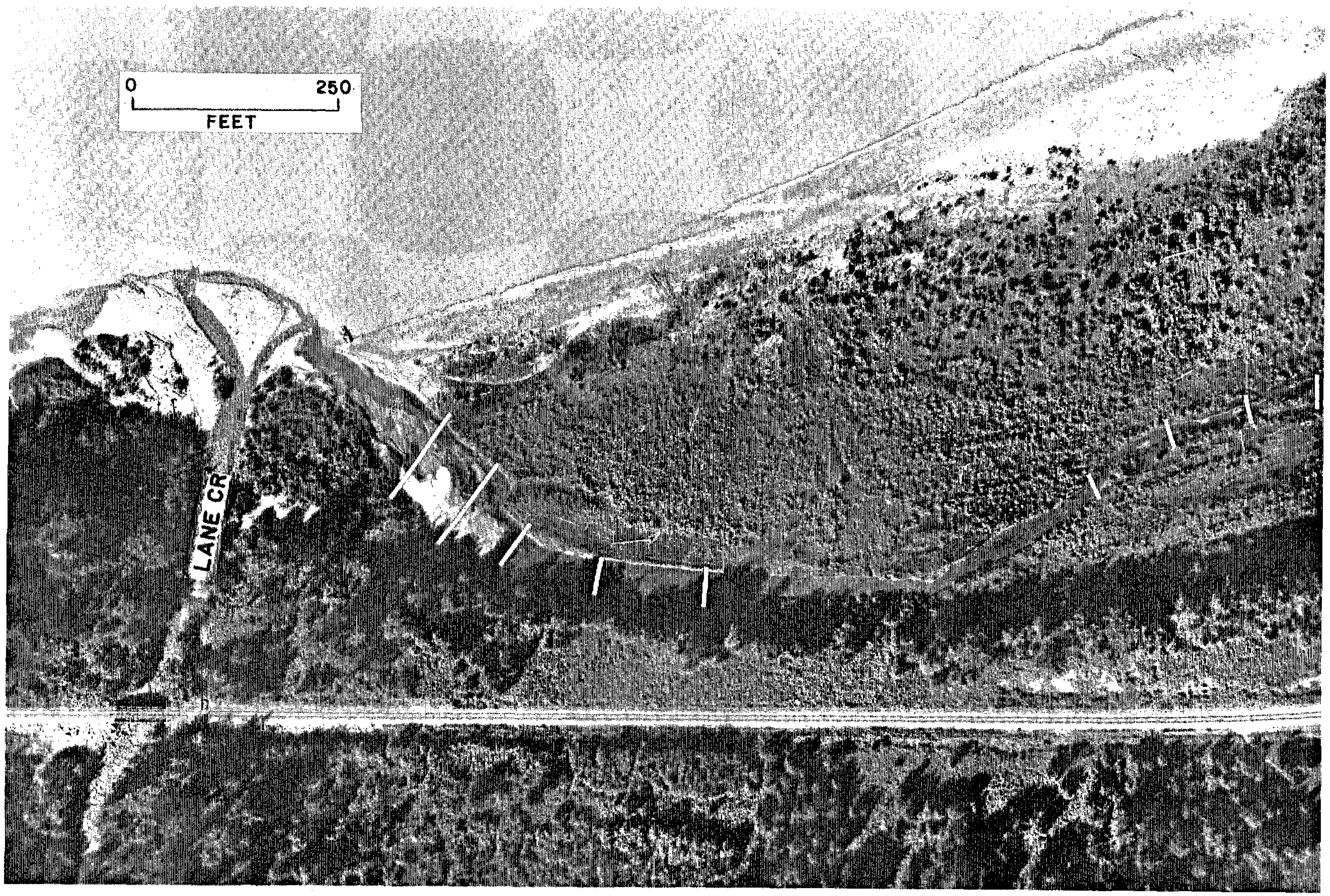

Plate 4. Aerial photograph of Slough 8 (RM 113.6), August 1982.

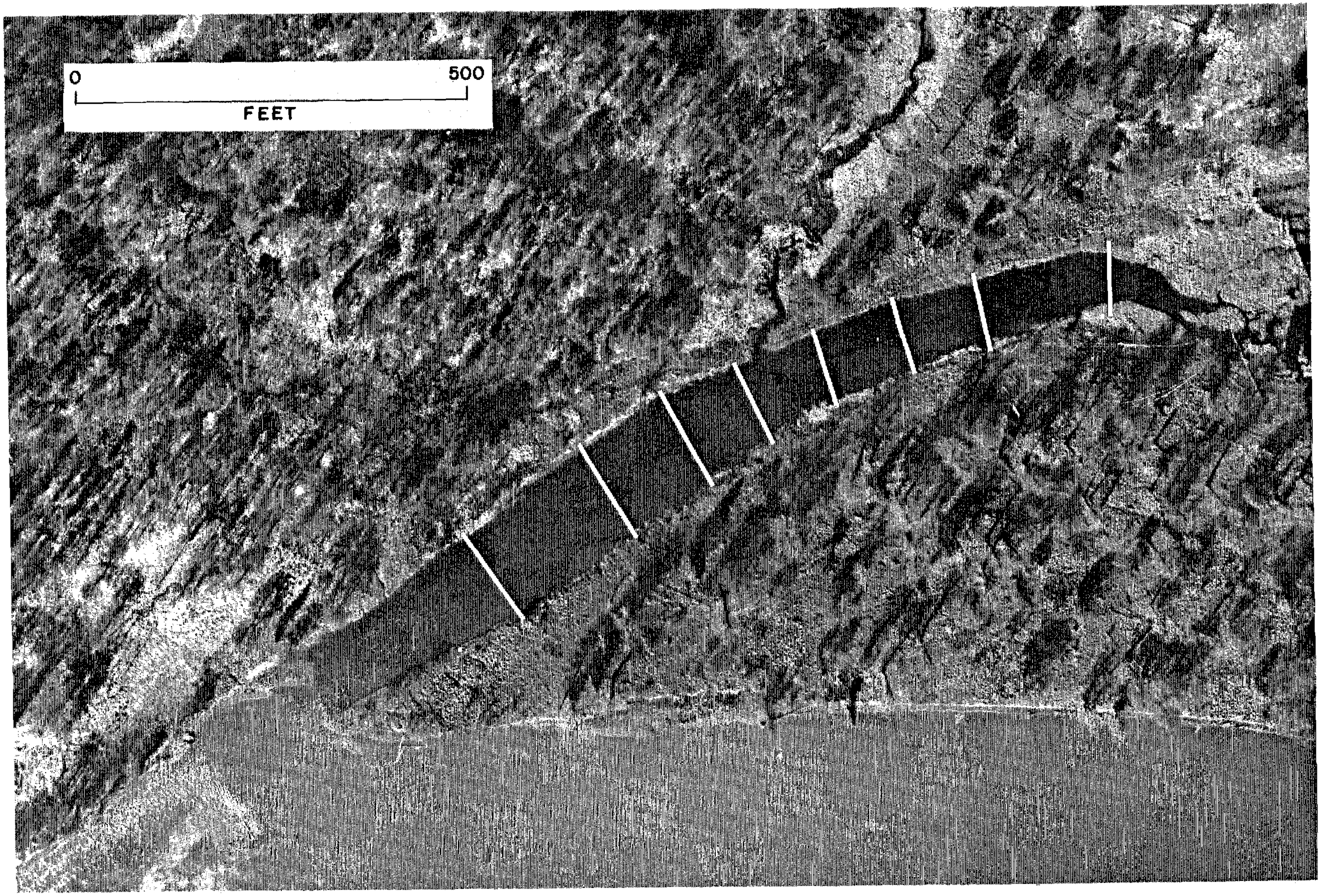

Plate 5. Aerial photograph of Slough 6A (RM 112.3), May 1982.

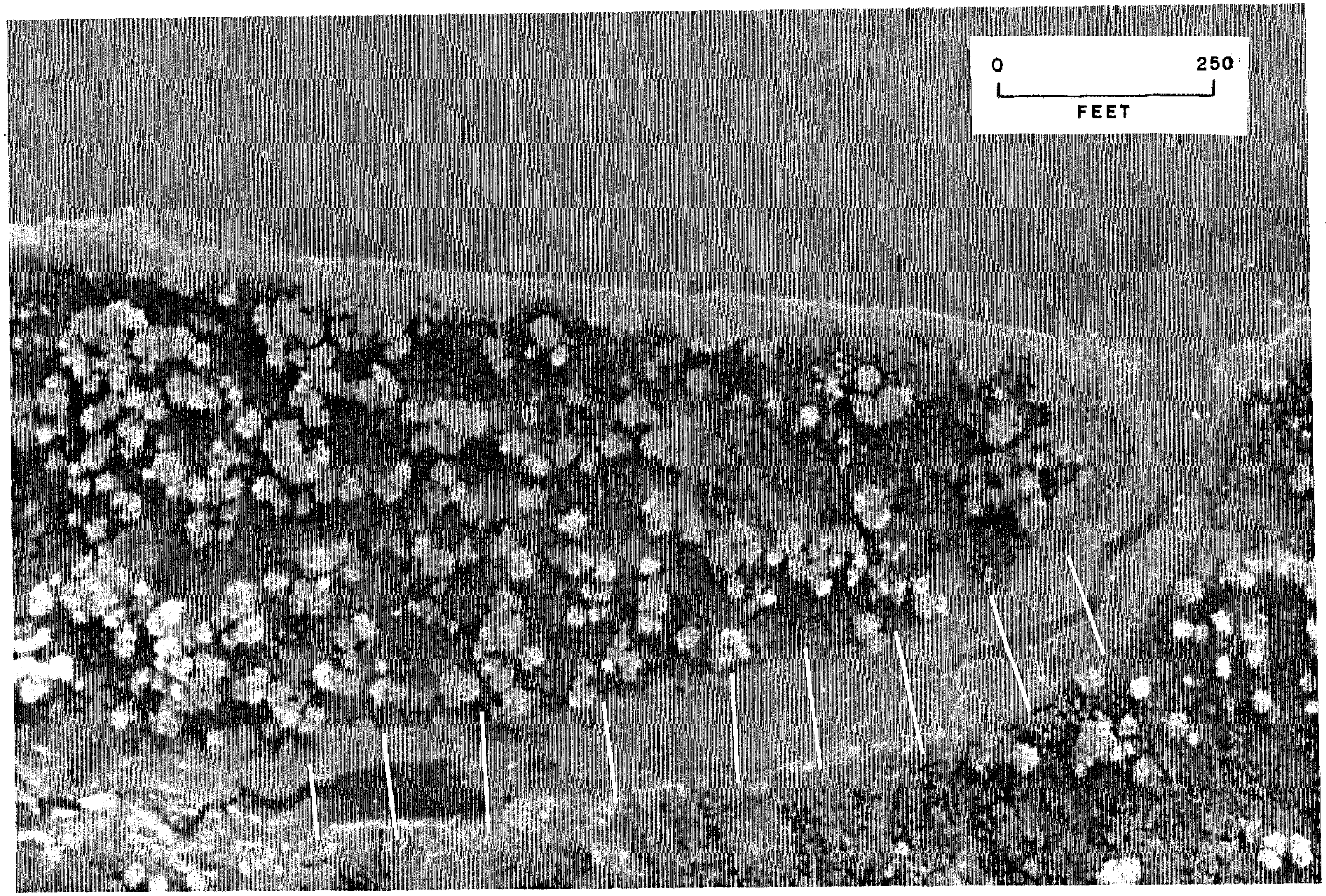

Plate 6. Aerial photograph of Slough 5 (RM 107.6), September 1983.

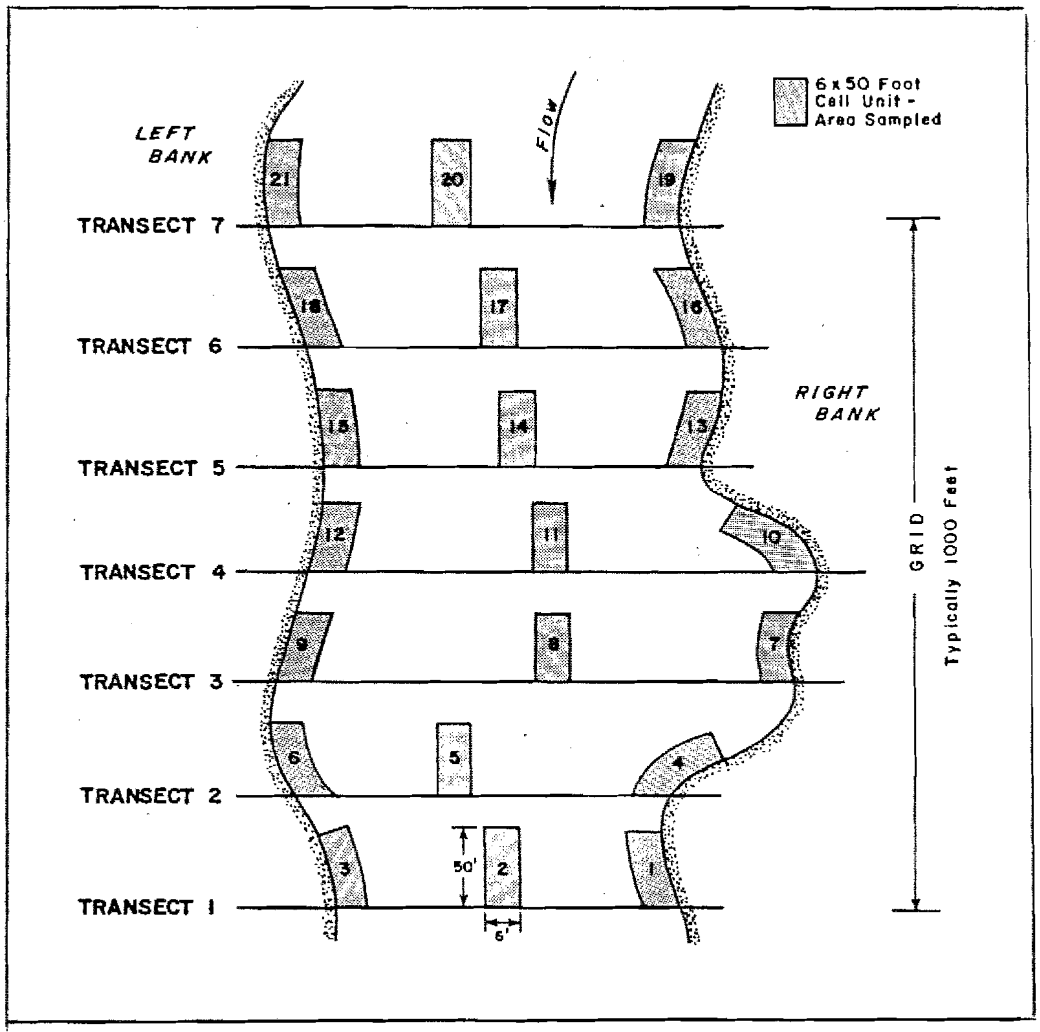

Figure 2. Illustration of the grid and cell sampling scheme employed at habitat modelling study sites.

Characterization of the physical parameters of each site by the cell measurements was made over as wide a range of mainstem discharge as was practically possible. Relative water surface elevations at each study site were recorded from staff gages at each sampling. Mainstem Susitna River discharges for each sampling were taken from USGS provisional records of flows measured at the Gold Creek gaging station, 15292000.

2.1.3 Cell measurements

Eight or nine mid-channel cells and 16 to 18 shoreline cells were created by the grid of transects established at each site. During each sampling, average depth, and mean water column velocity was measured in each cell and total percent cover, and the dominant cover type was estimated. In nearly all cases, cells in a grid were assigned a common water chemistry measurement of temperature, turbidity, pH, dissolved oxygen, and conductivity. If obvious water quality differences existed across the grid, two or more groupings of the cells were made by water quality parameters. In one case (Slough 8), two grids of transects were used to sample regions having similar water quality but very different morphological characteristics.

The mean depth of a cell was estimated from several measurements taken with a graduated wading rod midway along the length of the cell. Cell velocity was determined using a Price Model AA velocity meter at one to three characteristic mid-cell locations. The total percent of object cover available to juvenile fish was visually estimated, as was the primary object cover type. Nine cover types and six categories of percent cover (Table 1) were developed. Prior to the sampling season, a field trip was made to promote consistent ratings among the four raters. Percent cover in this study is defined as the ratio of horizontal or obliquely viewed concealing, hiding or protecting area potentially available to a (30-100 mm) juvenile fish, relative to the surface area of the cell. To reduce variances introduced by raters, rating categories were kept broad and the training introduced common concepts of how to rate percent cover. The percent cover rating is thus an estimate of the square feet of cover per cell (300 ft²).

Table 1. Percent cover and cover type categories

Percent Cover	Cover Type
0-5%	No object cover
6-25%	Emergent vegetation
26-50%	Aquatic vegetation
51-75%	Debris/deadfall
76-95%	Overhanging riparian vegetation
96-100%	Undercut banks
	Gravel 1" to 3" (in diameter)
	Rubble 3" to 5"
	Cobble or boulders > 5"

Water temperature, pH, dissolved oxygen, and conductivity were measured at mid-site with a Hydrolab model 4001 multiparameter meter. Polypropylene bottles stored grab samples for turbidity measurements using an HF model DRT-15 turbidometer calibrated over a 0 to 200 NTU range.

The procedures and techniques used to collect the fisheries data have been described in detail in ADF&G (1984) and also are summarized in Part 2 of this report.

2.2 Data Analysis

An overview of the data analysis performed in this study is shown in Figure 3. Field procedures and recording forms specified in ADF&G (1984) were used throughout. The field data were initially input to a mainframe computer data base management system and reformatted for examination.

Following completion of the field season, the catch per unit effort data for the juvenile salmon species at the six model sites were examined to determine which sites should be integrated with the species suitability data for weighted usable area (WUA) projections (Table 2). All sites with species catches greater than mean catch per cell for all six sites combined were selected for modelling. Mean catch at these six sites was very similar to mean catch at all sites sampled during 1983 even though very high mean catches were recorded at tributary sites. Slough 5 was modelled for coho and sockeye as these two species were most abundant at this site. Whiskers Creek Slough, Slough 8, and Slough 22 were modelled during both their side slough and side channel states (clear and turbid conditions).

2.2.1 Surface areas

Surface areas were calculated from the distance between each transect bench marker and the wetted edge of the water measured during each field sampling (during one visit to each habitat site the distances and compass bearings between transect bench markers were measured). These data were input to a computer program which calculated the wetted surface area of the study site on each occasion. The "mid-channel" area present between six feet wide "shoreline area" strips was also calculated and by subtracting this area from the total surface area for each sampling, the wetted shoreline area was computed.

Total surface areas of each of the study sites for mainstem flows outside the range of conditions observed during the 1983 open water season were estimated using a variety of techniques. The methods used at each study site are noted on figures presented in the results section. Since a wide range of mainstem discharges was desired for the incremental analysis (6,000 to 45,000 cfs), an extrapolation of the measured surface area curve shapes based on a knowledge of general study site morphology was required in some cases. Surface area projections at high mainstem flows were not made for the Slough 8 site.

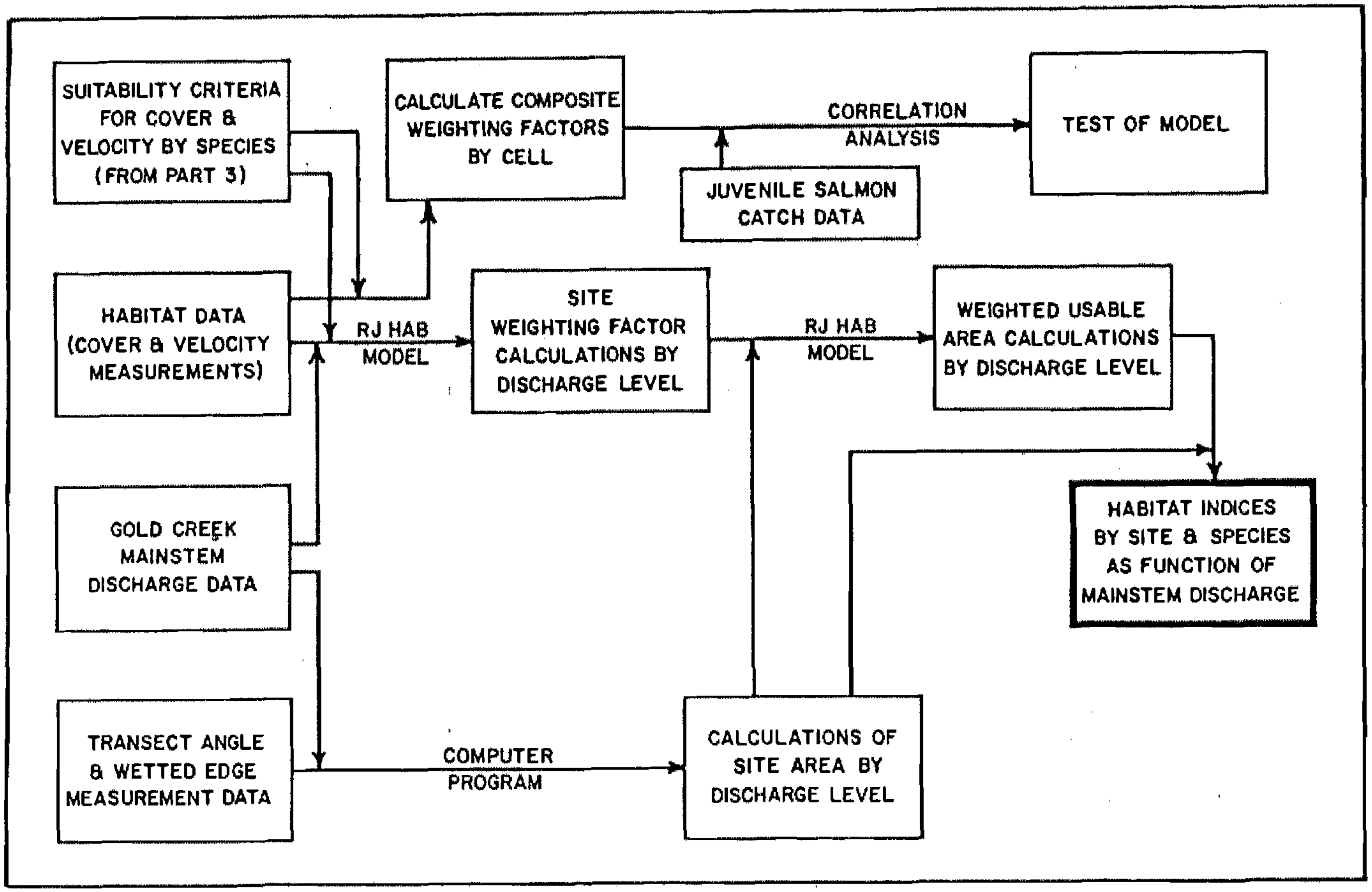

Figure 3. Data analysis flow chart for juvenile salmon rearing habitat models.

Table 2. Catch, catch per cell, and delineation of site and species combinations modelled.

Site	No of cells fished (effort)	Catch (catch per cell)			
		Chinook	Coho	Sockeye	Chum
Whiskers Creek Slough	67	<u>260(3.9)</u>[a]	<u>291(4.3)</u>	24(0.4)	5(0.1)
Slough 5	50	20(0.4)	<u>88(1.8)</u>	<u>27(0.5)</u>	0(0.0)
Slough 6A	77	108(1.4)	<u>286(3.7)</u>	<u>169(2.2)</u>	11(0.1)
Slough 8	72	65(0.9)	<u>198(2.8)</u>	<u>131(1.8)</u>	<u>73(1.0)</u>
Side Channel 10A	64	<u>406(6.3)</u>	0(0.0)	1(0.0)	0(0.0)
Slough 22	52	<u>260(5.0)</u>	5(0.1)	0(0.0)	1(0.0)
Total (model sites)	382	1119(2.9)	868(2.3)	352(0.9)	90(0.2)
Total of all cells sampled during 1983[b]	1260	4395(3.5)	2020(1.6)	1006(0.8)	1157(0.9)

[a] If underlined, the species response to mainstem discharge was modelled at the site.

[b] Taken from Part 3 of this report.

2.2.2 Resident Juvenile Habitat (RJHAB) Model

The Resident Juvenile Habitat (RJHAB) model presented here is a simplified method for calculating weighted usable area (WUA) without using hydraulic models. Our method divides the modelling site into shoreline and mid-channel areas and then calculates a WUA for both of these portions of the site. The site WUA is the sum of the shoreline and mid-channel WUA. The WUA for a shoreline or mid-channel portion of the site (i) having area (A) at Susitna River discharge (q) for rearing species (s) is calculated as follows:

$$(1)\ WUA_{i,s,q} = WF(c) \times WF(v) \times WF(d) \times A$$

The weighting factors WF(c), WF(v) and WF(d) are shoreline or mid-channel overall suitability values for cover (both amount and type integrated), velocity, and depth for any given i, s, and q. The depth weighting factor was set to 1.0 because data from part 3 of this report indicated it had little effect on fish distribution in comparison to velocity and cover. Examples of the calculations required to obtain the weighting factors for cover and velocity are described in text and equations 2 and 3 below. The factors i, s, and q are held constant in the following equations.

The weighting factor for cover (WF(c)) can be calculated in the form:

$$(2)\ WF(c) = \frac{\sum_{j=1}^{n} (C_j \times S(a)_j \times S(t)_j)}{\sum_{j=1}^{n} C_j}$$

Where:

$S(a)_j$ = Value of the habitat suitability function for value of percent cover in cell #j.

$S(t)_j$ = Value of the habitat suitability function for measured value of cover type t in cell #j

C_j = surface area of cell #j.

n = number of cells sampled in either shoreline or mid-channel portions

Since there were nine cover types (t) and five present cover categories (a), a total of 45 percent cover by cover type combinations were possible.

The weighting factor for velocity was calculated by expressing the velocity data as proportional frequencies of occurrence after measured values were grouped into 0.3 ft/sec categories (intervals) with 0.0

remaining a unique data point. The weighting factor for velocity (WF(v)) is calculated as follows:

$$(4)\quad WF(v) = \sum_{k=1}^{m} (P_k \times S(v)_k)$$

Where:

m = number of velocity categories

k = velocity category code

$S(v)_k$ = value of the habitat suitability function for velocity in interval k

$$P_k = \sum_{l=1}^{r} C_l \Big/ \sum_{j=1}^{n} C_j$$ = proportion of cells within velocity interval k

r = number of cells in velocity interval k

n = number of cells in either shoreline or mid-channel portions

These computations were carried out on a microcomputer using commercial spreadsheet software. The calculated weighting factors WF(c) and WF(v) were output as graphs for each site and species for both shoreline and mid-channel areas of the site as a function of mainstem discharge. For chinook salmon juveniles, the weighting factors were also plotted for both low and high turbidity mainstem conditions. These plots were interpreted with respect to the changing environmental conditions and data scatter and a line was fit to the data by hand. This interpretation required that the frequency distribution of each attribute's values (in the shoreline and mid-channel areas of the site), at each discharge be viewed with respect to the suitability curve for the attribute. The analysis of the weighting factor plots enabled some conclusions to be drawn from the data which were not obvious from the plots. Following slough breaching for example, chinook salmon mid-channel area velocity weighting factors at two similar discharges may have been about the same value. The two velocity frequency distributions, however, occasionally had median points falling on opposite sides of the peak in the velocity suitability function plot; hence, the implication of peak suitability between the two points and falling suitability (with increasing velocities) after. Similarly, the slight displacement of maximum suitabilities for high and low turbidity chinook salmon velocity values occasionally inferred refinements between the plots. For example, a downwards trend of the weighting factors (with increasing discharge) in a low turbidity plot could be used to project the slope of a downwards trend in the high turbidity plot at higher velocities where no data were available. Based on the shape of the composite weighting factor (f(c) x f(v)) plot, WUA curves were drawn to fit the data.

Weighting factors for flows well beyond those observed were estimated from the trends occurring in the cover and velocity data and from the shape of the suitability criteria curves. Accumulated field experience at the site, and comparisons to other sites where similar conditions existed were additional criteria used to make the projections. The velocity weighting factors extrapolated for side channels at high mainstem discharges are the most uncertain of these projections.

The last step in the data analysis was to calculate "habitat indices" for the species. Habitat indices were calculated as the WUA divided by the surface area present in the study site sampling grid at a mainstem discharge of 23,000 cfs. The 23,000 cfs figure was chosen because it is a representative summer streamflow and it also may be integrated with macrohabitat abundance information provided by E. Woody Trihey and Associates from aerial photographs of the upper Susitna reach at this discharge.

The individual cell measurements and weighting factor plots are not presented in this report. Bound volumes of the data can be obtained for inspection at the Susitna Hydro Aquatic Studies office.

During the analytical process the data base was screened for errors and inconsistencies. Some data collected at closely related mainstem flows were averaged to eliminate scatter not related to mainstem discharges. The largest single change made to the raw data was to substitute a representative mean cell cover value for the individual (instantaneous) mid-channel cell readings. The desirability for this change arose because of the considerable difficulty with consistently determining substrate cover values in deep, rapid or turbid water mid-channel cell areas. Roughly 750 habitat cells were characterized for the analysis. Several field observations were changed because we believed they were recorded erroneously.

2.2.3 Model verification

Data on fish abundance and distribution were collected at the sites to validate WUA projections. However, time constraints prevented an intensive sampling effort. A composite weighting factor was calculated for each cell sampled for fish and this factor was correlated with fish catch in the cell. If cells with high composite weighting factors are associated with higher densities of fish as expressed in the catch, then it can be assumed that if changes in mainstem discharge raise or lower an entire site's composite weighting factor, the associated potential for fish use will also be raised or lowered.

In order to test for a relationship between cell composite weighting factors and fish catch, the following procedures were carried out. The composite weighting factor in each cell was calculated by multiplying suitability values for cover and velocity together. Coho and chinook catches were transformed by natural log (X+1) in an attempt to normalize variances. Pearson correlation coefficients were then calculated between the composite weighting factor and coho and chinook catch by cell. For chum and sockeye, chi-square contingency tables were run between proportional presence and composite weighting factor value intervals (to test for associations between these two factors). Sampling occasions when less than three fish were captured in all the cells within a site (in a day of sampling) were deleted from analysis. This was done because low densities of fish are often due to seasonal movements rather than to within site habitat conditions. If fish sampling data from sites without fish were used in a correlation analysis, the correlations might become statistically insignificant even if the correlations between composite weighting factor and fish catch were large.

3.0 RESULTS

3.1 Surface Areas

The total wetted surface areas at each site are plotted as a function of mainstem Susitna River discharge on Figures 4 through 10. These figures also contain schematic notes concerning important changes which occurred over the range of flows which were observed. The range of surface areas calculated from observational data are highlighted with solid lines. Extrapolated data are noted with dotted lines.

The total weighted usable areas (WUA's) calculated for the species at sites where fisheries data support projecting habitat use are presented in Section 3.2 through 3.7. The total weighted usable areas projected for each site and species at mainstem discharge increments of 3,000 cfs are also tabulated in Appendix A.

3.2 Side Channel 10A

Chinook salmon were the only juvenile species captured in abundance at this site. Because suitability functions for cover, velocity, and depth at turbidities above and below 30 NTU were different for this species of juvenile salmon, WUA projections for high and low turbidity mainstem flows are calculated (Figure 11). All WUA units are in square feet. The solid line labelled "calibrated range" in the WUA plots is the estimated WUA at observed flows. The dotted line labelled "extrapolated range" is the extrapolated WUA at flows which were not observed during the open water season of 1983. The total weighted usable area in each plot is the sum of the WUA's calculated for the shoreline and mid-channel areas of the study site. At any mainstem discharge, the WUA for the shoreline or mid-channel area is the product of the weighting factors WF(c) and WF(v) and the surface area for the shoreline or mid-channel area at that mainstem discharge. The weighting factor plots calculated for this species and site under high and low turbidity mainstem flow conditions are included here (Figures 12 and 13) as an example. Weighting factor plots for the other sites are available at the Su Hydro Aquatic Studies office.

The difference between the WUA's projected for high and low turbidity conditions reflects the differences in suitability for the cover and velocity values measured at the study site over the range of observed and extrapolated mainstem flows. Especially noticeable are the effects of suitability for cover: under the low turbidity condition the weighting factors (and thus the WUA's) are greatly reduced. Similarly, the difference in the shape of the velocity weighting factor curves for the two turbidity conditions explains much of the differences between the shapes of the two plots.

3.3 Slough 22

Chinook salmon were the only juvenile species captured in abundance at this site. Weighted usable area projections for juvenile chinook salmon were calculated for both high and low mainstem turbidities (Figure 14). At mainstem flows above 20,200 cfs, the head of this slough is

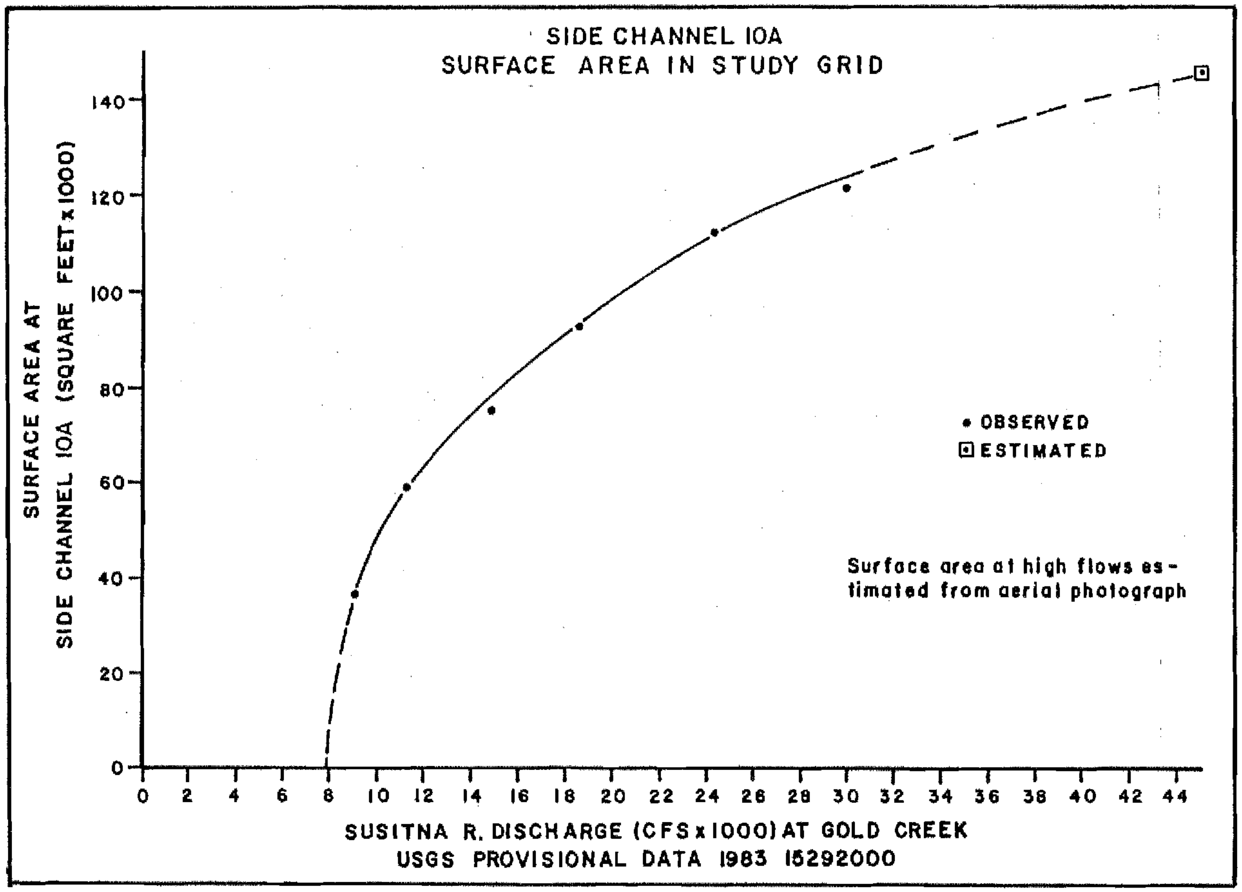

Figure 4. Total wetted surface areas measured and extrapolated in the Side Channel 10A habitat model study site.

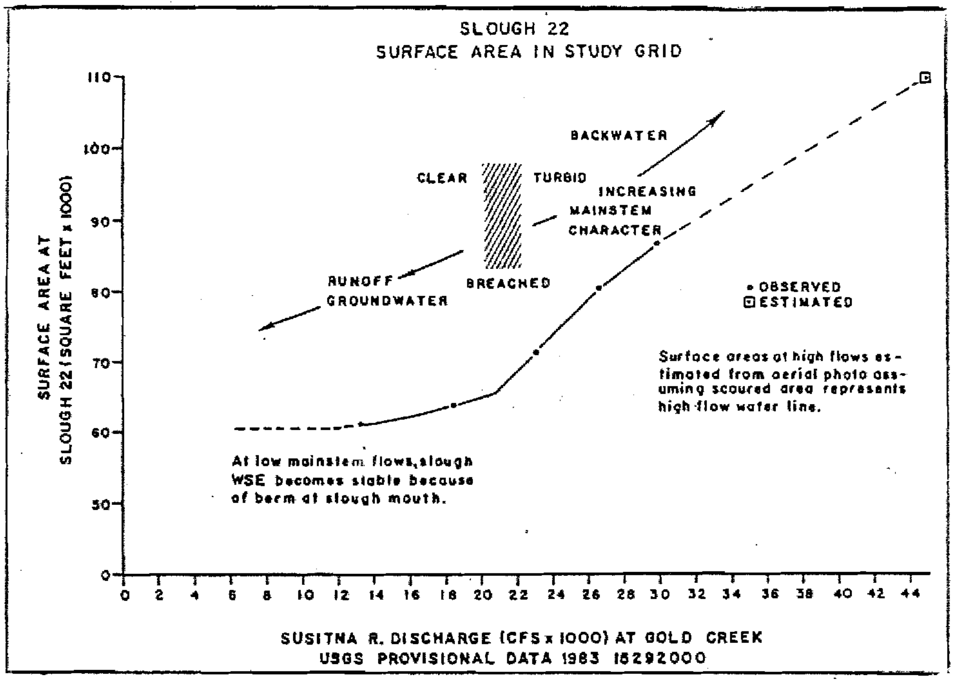

Figure 5. Total wetted surface areas measured and extrapolated in the Slough 22 habitat model study sites.

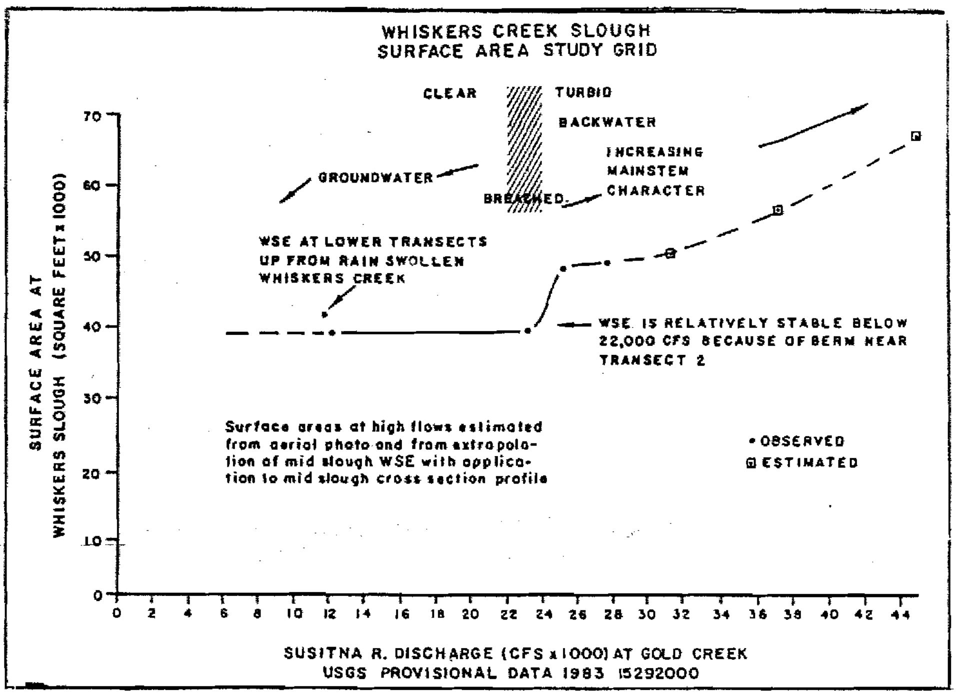

Figure 6. Total wetted surface areas measured and extrapolated in the Whiskers Creek Slough habitat model study site.

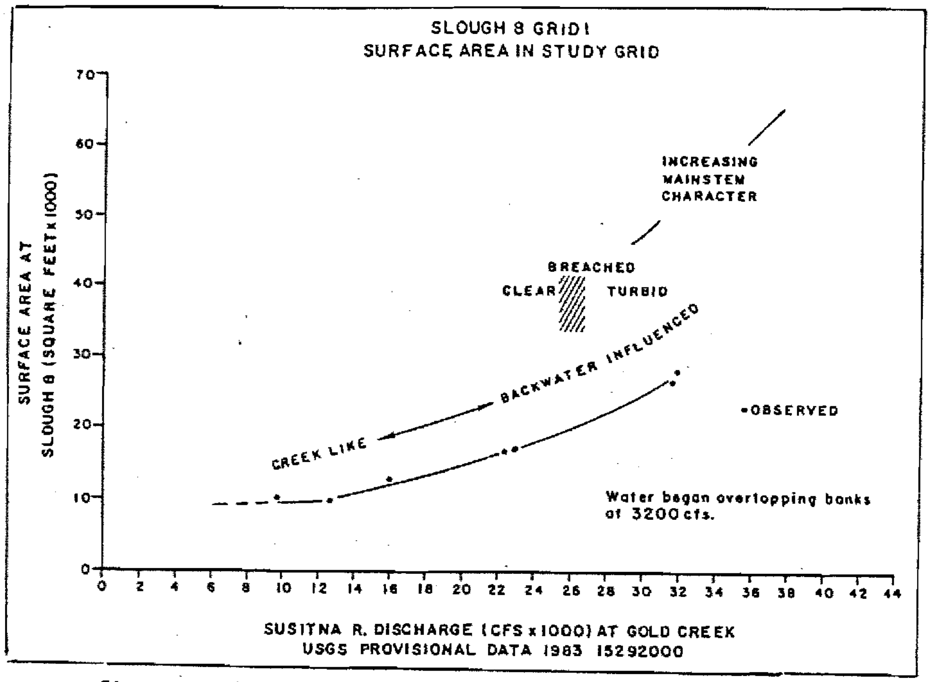

Figure 7. Total wetted surface areas measured and extrapolated in the Slough 8 grid 1 habitat model study site.

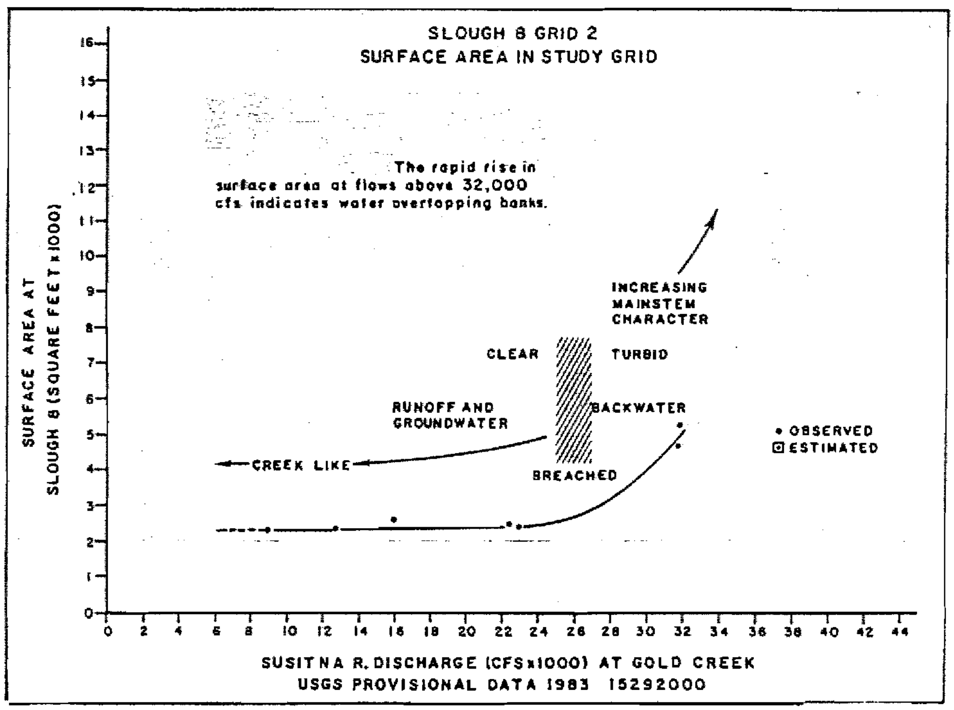

Figure 8. Total wetted surface areas measured and extrapolated in the Slough 8 grid 2 habitat model study site.

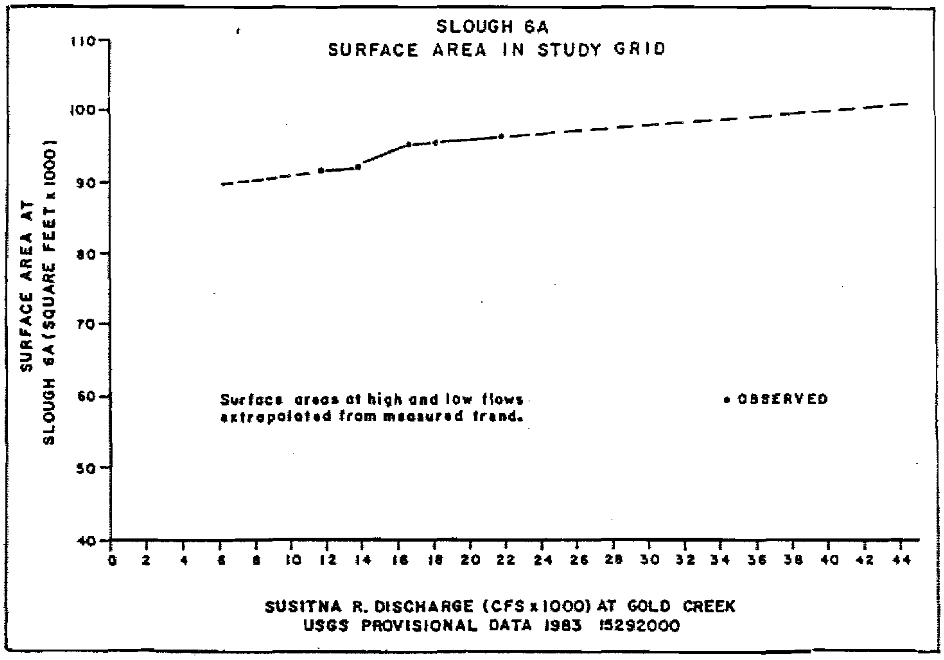

Figure 9. Total wetted surface areas measured and extrapolated in the Slough 6A habitat model study site.

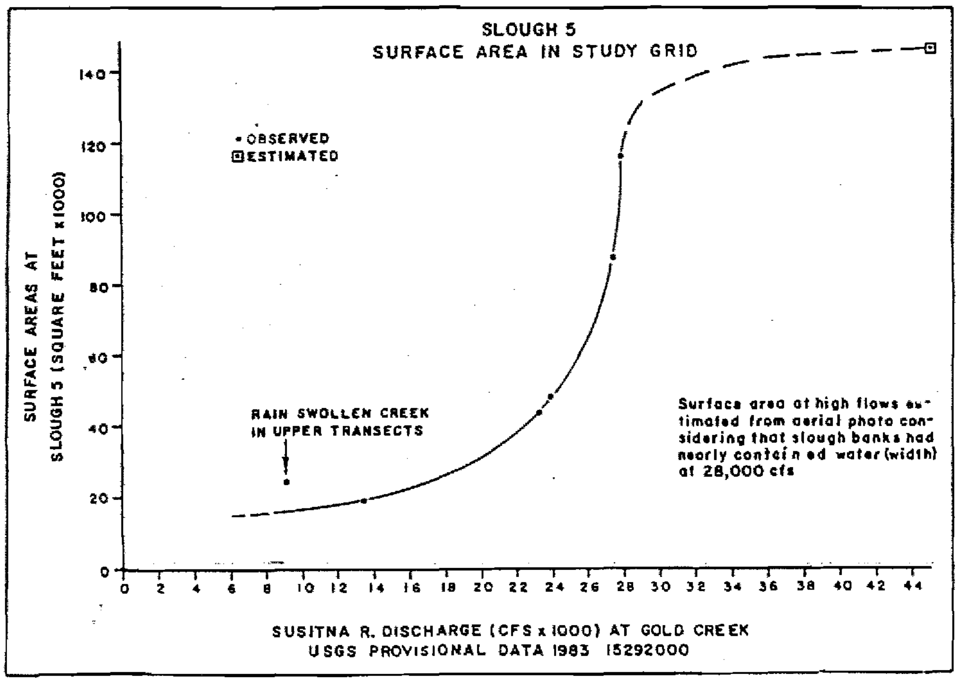

Figure 10. Total wetted surface areas measured and extrapolated in the Slough 5 habitat model study site.

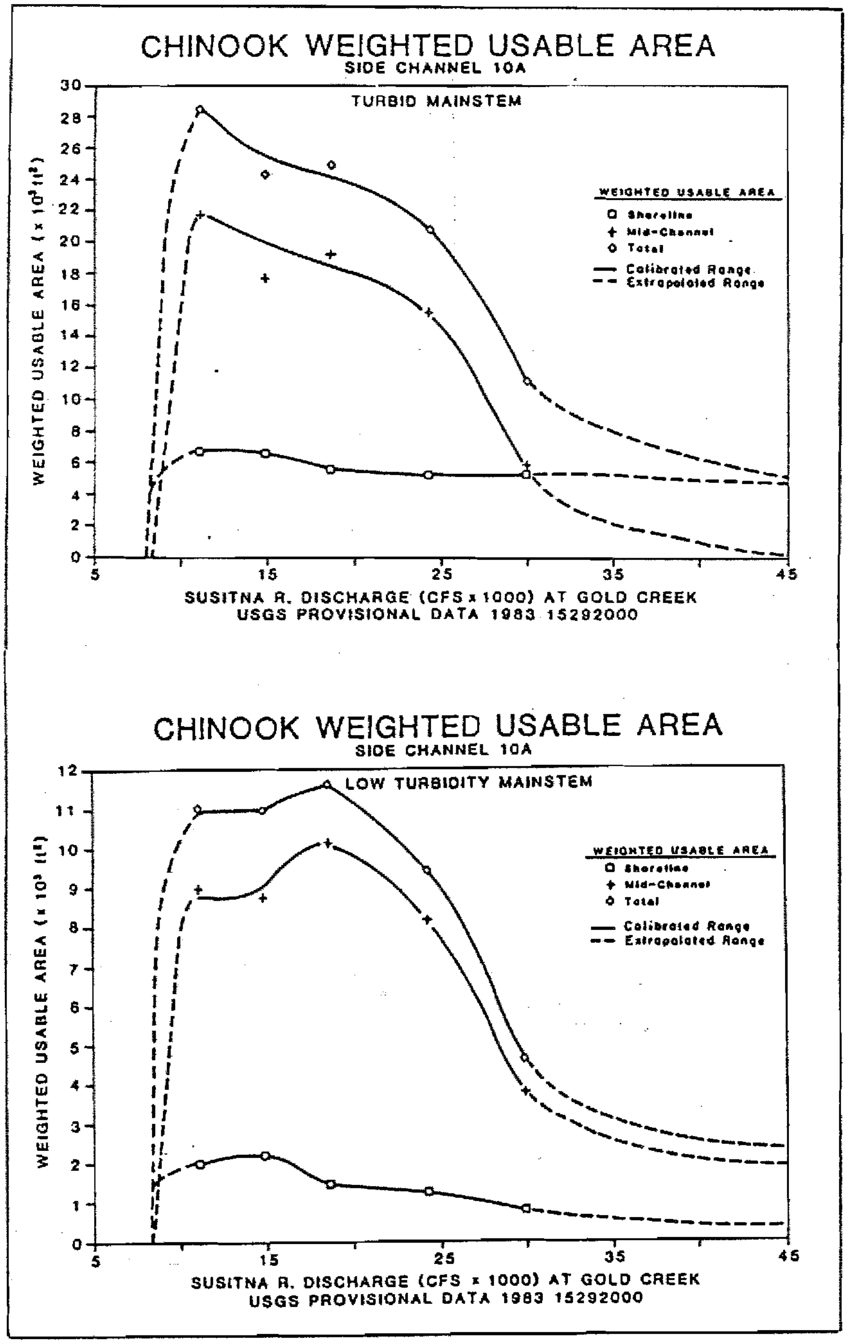

Figure 11. Weighted usable area projections for juvenile chinook salmon at the Side Channel 10A modelling site.

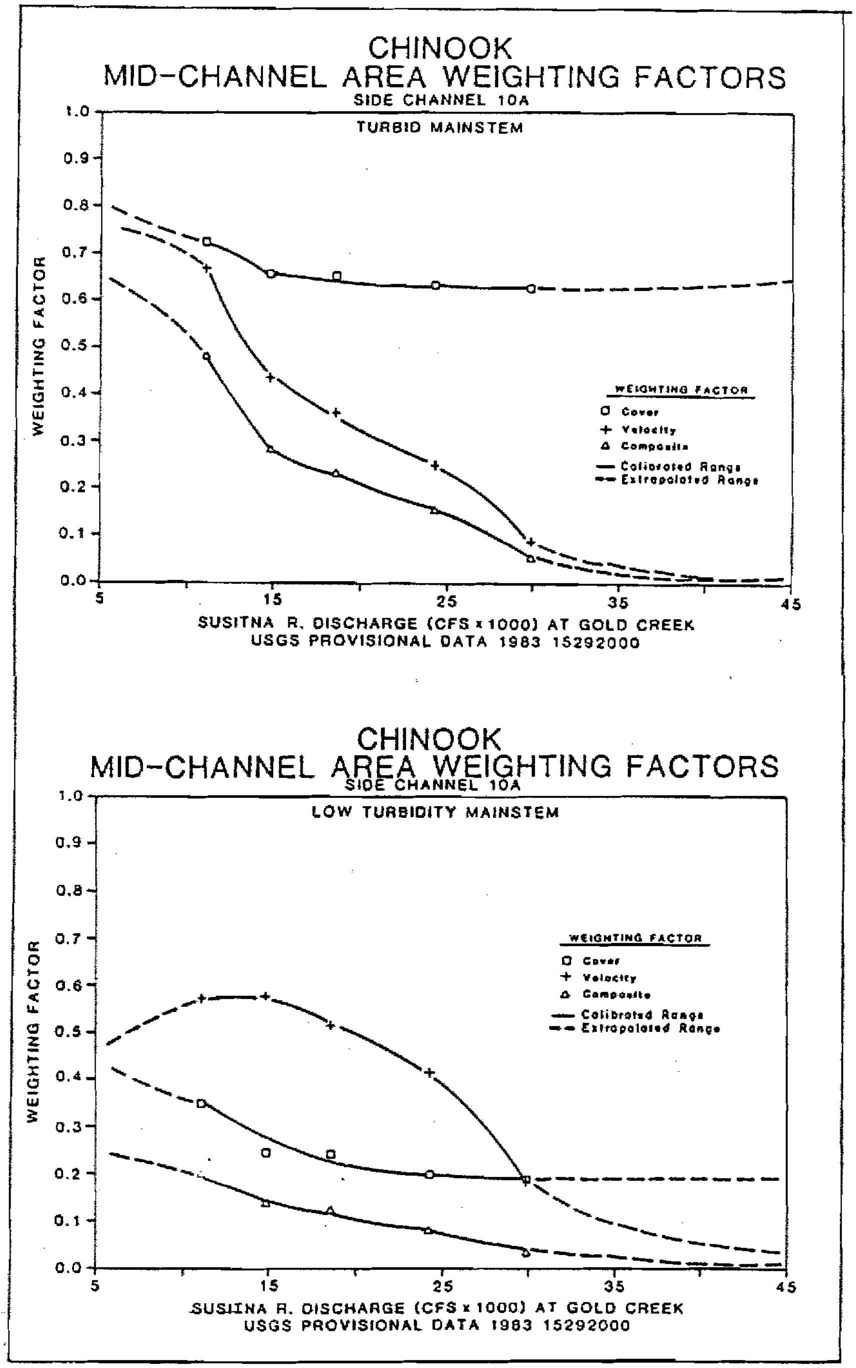

Figure 12. Mid-channel area weighting factors for juvenile chinook salmon at the Side Channel 10A modelling site.

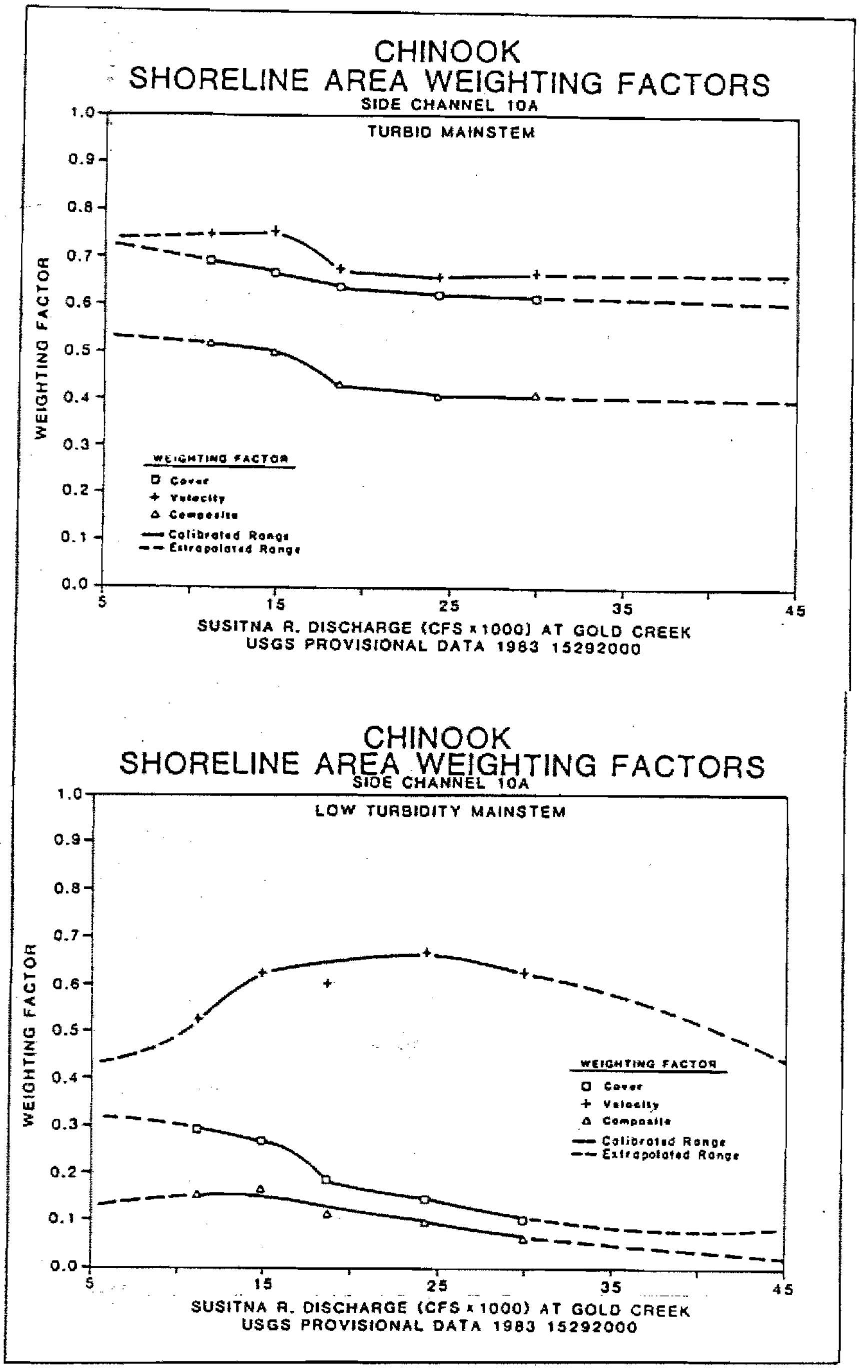

Figure 13. Shoreline area weighting factors for juvenile chinook salmon at the Side Channel 10A modelling site.

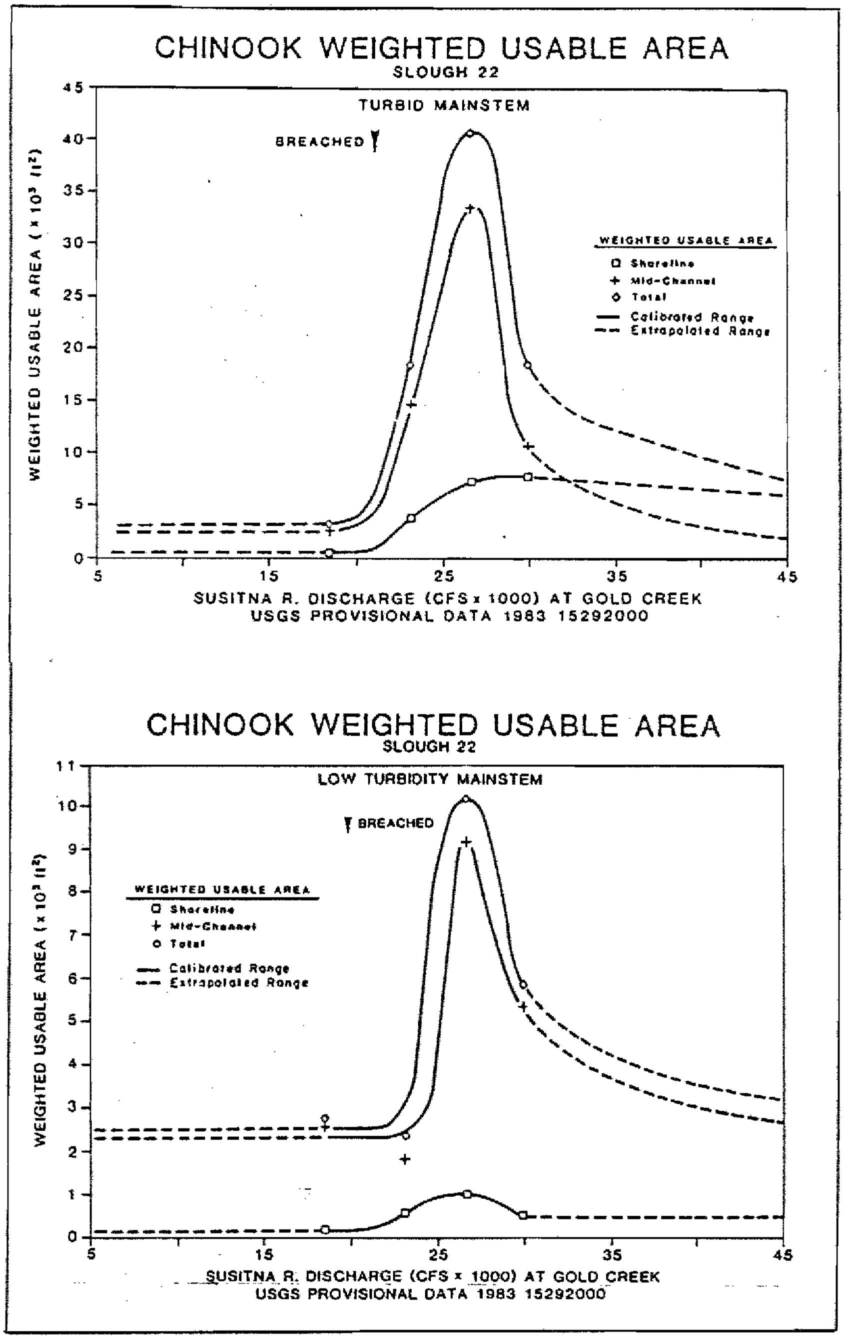

Figure 14. Weighted usable area projections for juvenile chinook salmon at the Slough 22 modelling site.

overtopped, and in both the low and high turbidity models WUA is affected by the changing velocity conditions. A greatly increased suitability for cover at the higher turbidity is again manifest in the projected WUA's.

3.4 Whiskers Creek Slough

The shapes of the weighted usable area plots projected for chinook salmon juveniles at this site (Figure 15) are very similar to those for the Slough 22 site. The Whiskers Slough site has more cover and hydraulically approaches mainstem conditions at a faster rate following the breaching event than does the site at Slough 22.

Weighted usable areas were also projected for coho salmon at this site (Figure 16). Preferences for different turbidity conditions for juvenile coho salmon were not demonstrated because of the lack of occurrence of juvenile coho at turbid sites. The WUA plots for this species do not reflect use of turbid conditions. Compared to chinook WUA's for the site, cohos WUA's are roughly 25% smaller under low turbidity slough conditions, and 50 to 80% smaller during either low or high turbidity side channel conditions.

3.5 Slough 8

Juvenile coho, sockeye, and chum salmon were captured in abundance at this site. Seventy-five percent of the chums were captured during the one sampling in May, so the seasonal mean catch/cell data presented in Table 2 for chum salmon are somewhat misleading. Modelling at mainstem discharges above the calibrated range was dropped for lack of supporting fisheries data and because projections for surface areas at high mainstem discharges were so uncertain that robust predictions for WUA's were impossible.

Weighted usable areas for coho, sockeye, and chum salmon in both study grids were calculated up to a mainstem discharge of 31,900 cfs (Figures 17 through 19). The shapes of these plots largely reflect velocity changes as backwater moved into and nearly covered the site before the head breached. The cover weighting factors however, are responsible for the very large differences in the WUA's calculated for each species. Weighted usable areas around 4,400 ft^2 for chum salmon are associated with mean cover weighting factors of 0.44 and 0.34 for the shoreline and mid-channel areas of the site, respectively. Weighted usable areas around 1,400 ft^2 for sockeye salmon are associated with mean cover factors of 0.27 and 0.12 for the shoreline and mid-channel areas of the site. The site is least suitable to coho. WUA's for that species are around 380 ft^2 with mean cover factors of 0.14 and 0.02 for the shoreline and mid-channel areas.

3.6 Slough 5

Slough 5 is an upland slough which is not normally connected with the mainstem Susitna River except at its mouth. Juvenile coho and sockeye salmon were captured in moderate abundance at this site. At mainstem

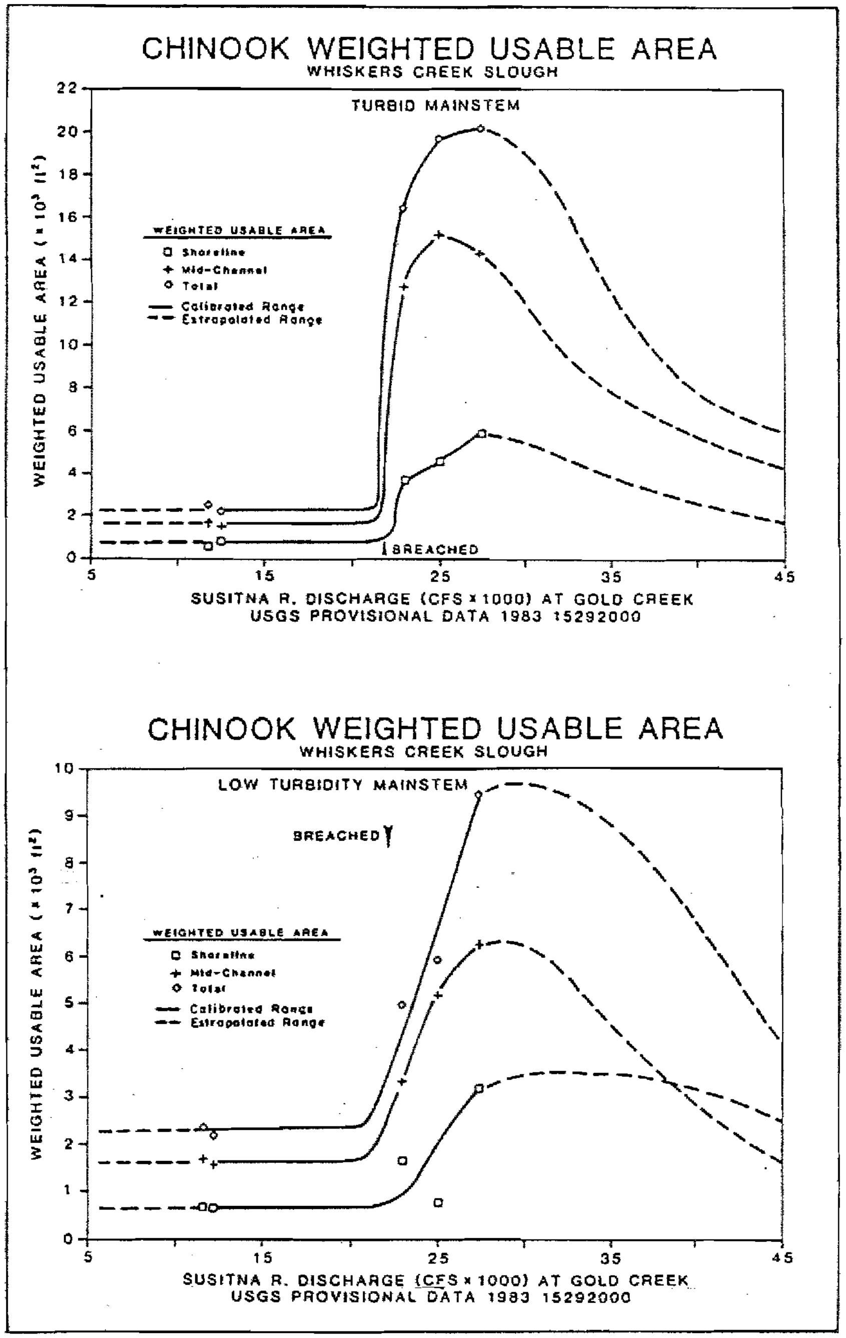

Figure 15. Weighted usable area projections for juvenile chinook salmon at the Whiskers Creek Slough modelling site.

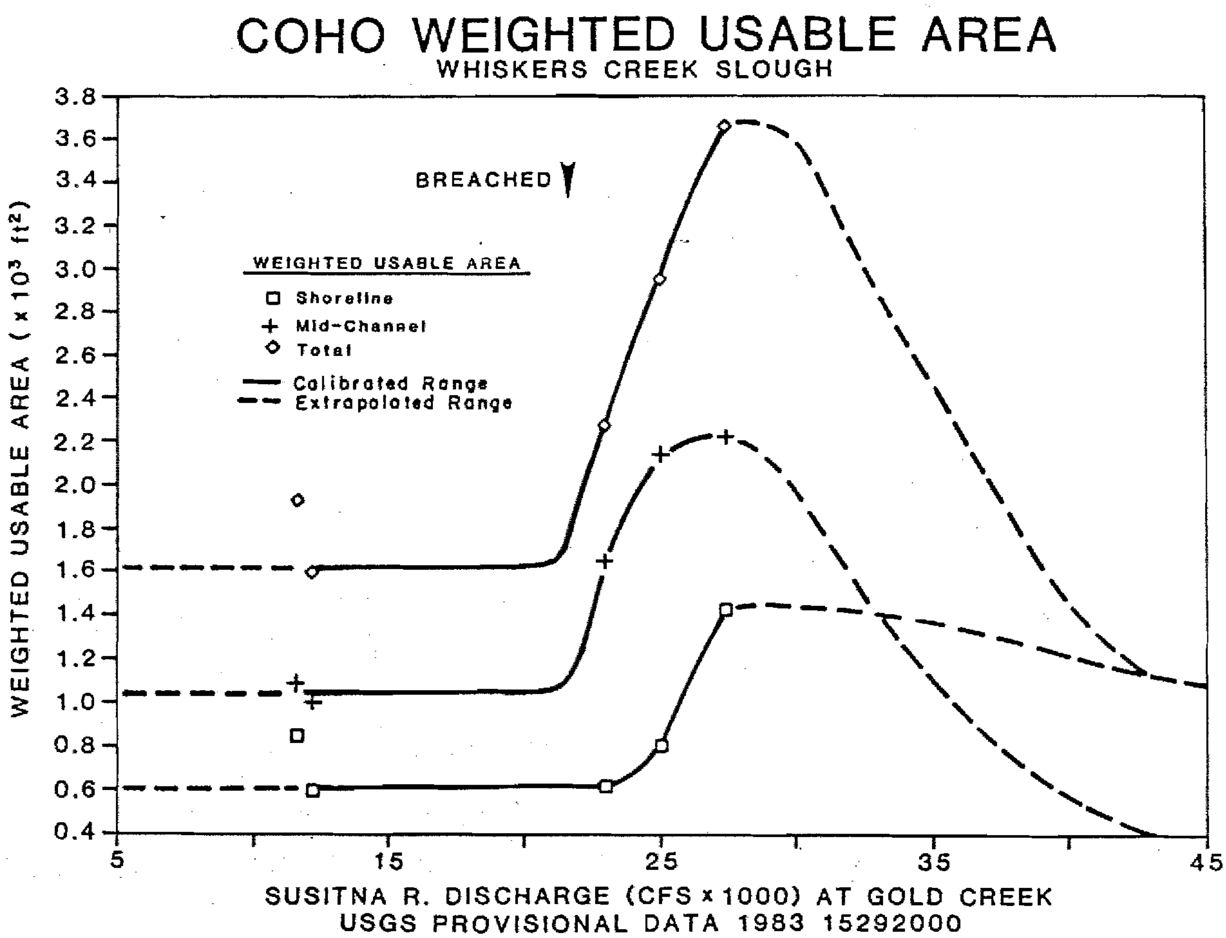

Figure 16. Weighted usable area projections for juvenile coho salmon at the Whiskers Creek Slough modelling site.

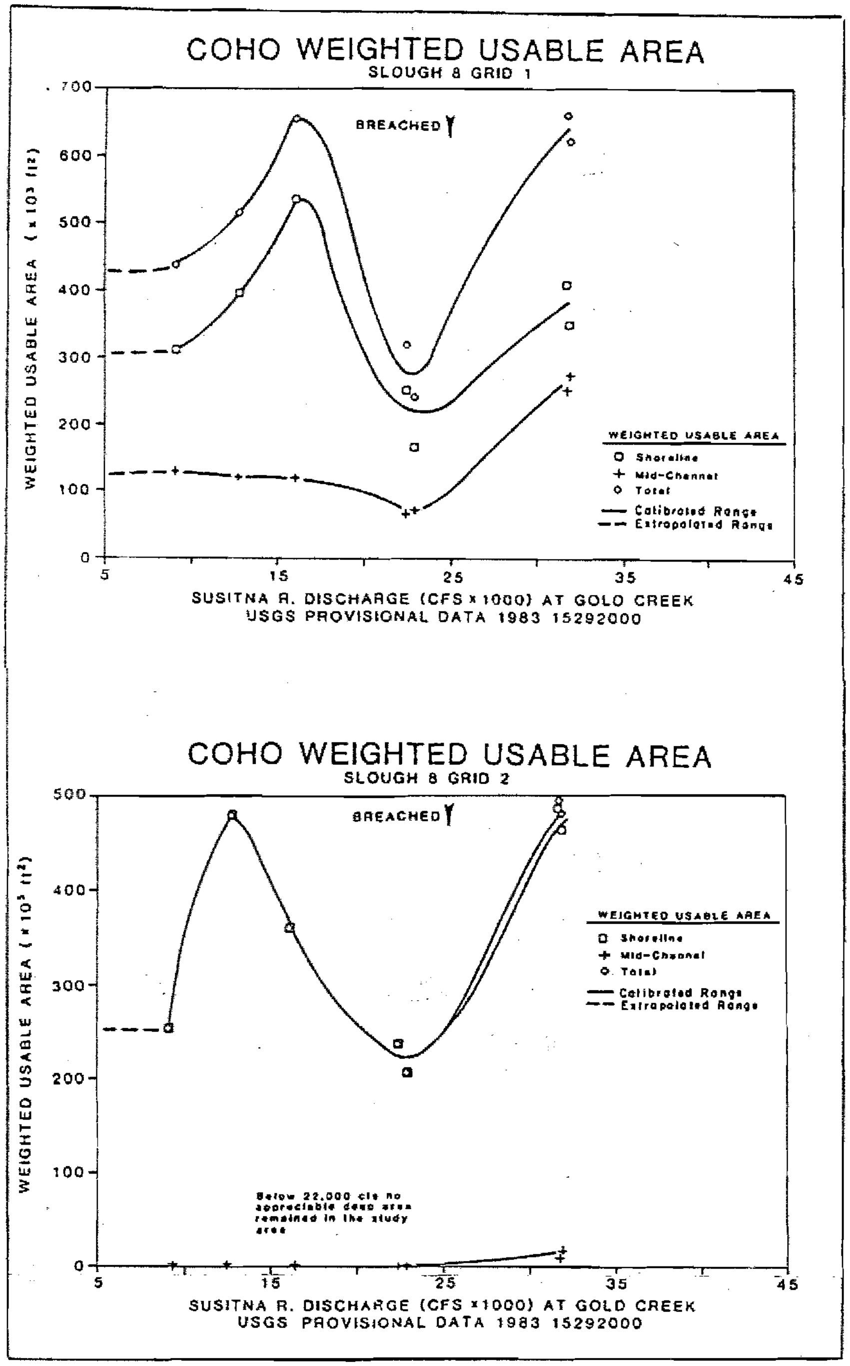

Figure 17. Weighted usable area projections for juvenile coho salmon at the Slough 8 modelling site.

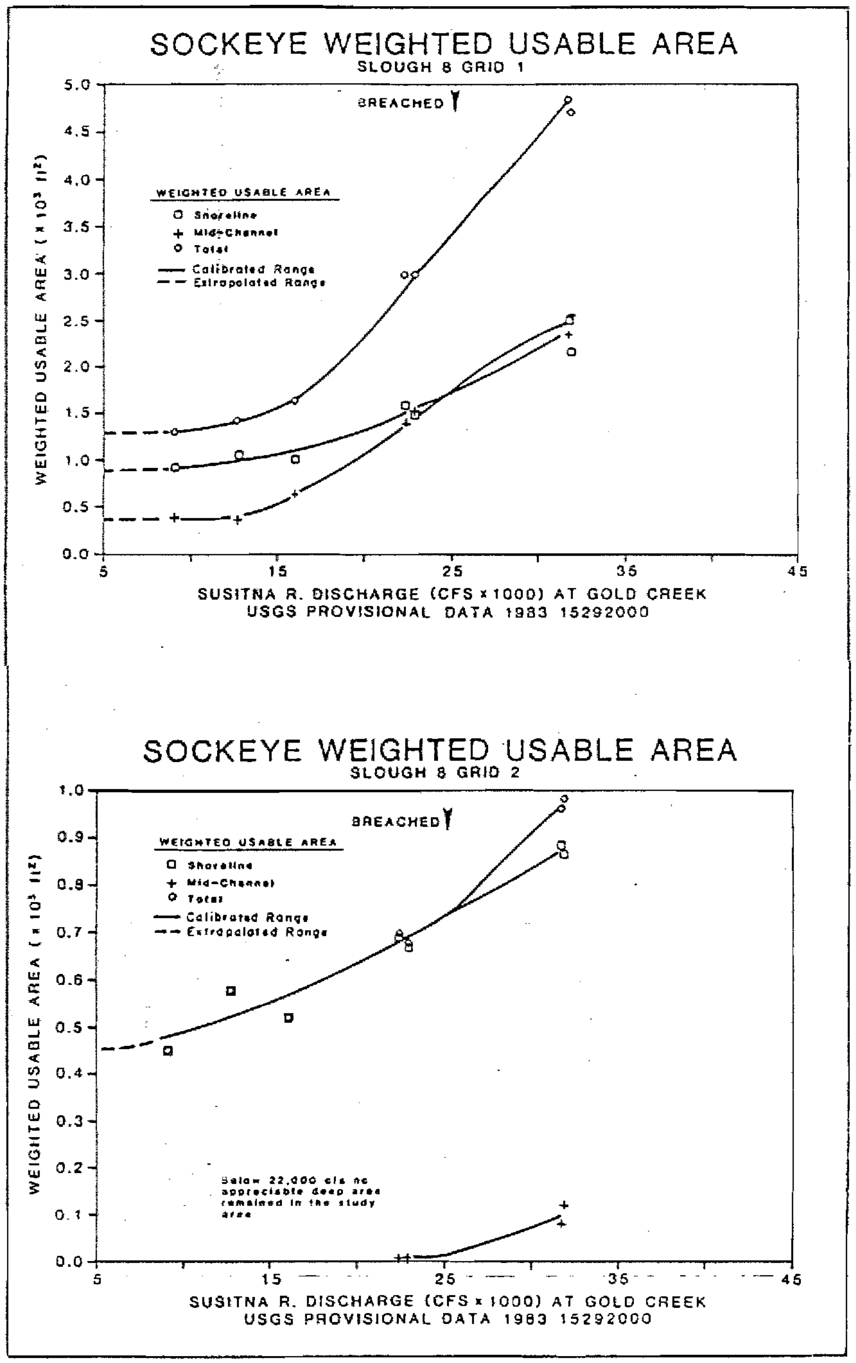

Figure 18. Weighted usable area projections for juvenile sockeye salmon at the Slough 8 modelling site.

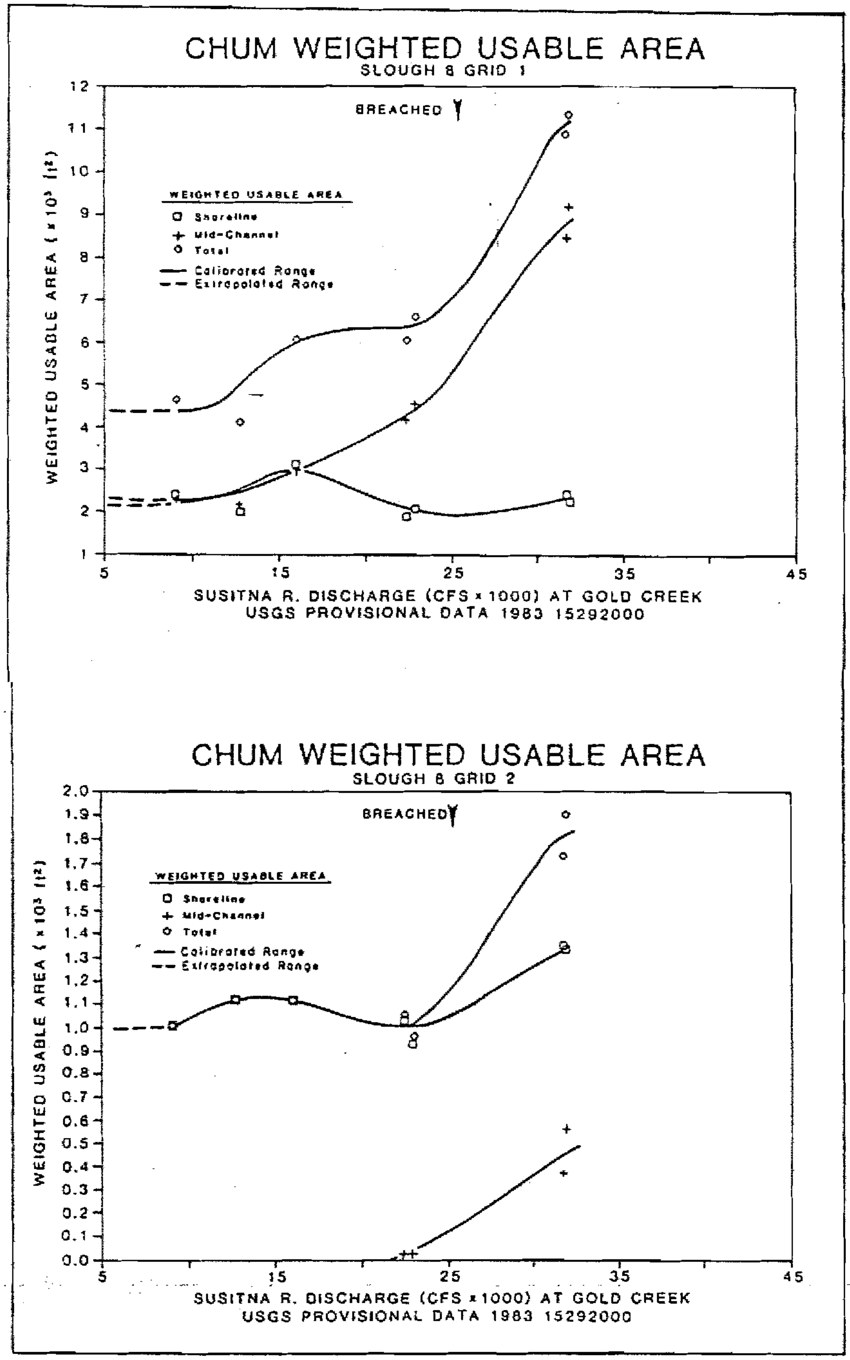

Figure 19. Weighted usable area projections for juvenile chum salmon at the Slough 8 modelling site.

discharges under about 15,000 cfs, the majority of Slough 5's wetted surface is divided between a steep-sided channel at the mouth and a shallow meandering stream, often only a few feet in width. At higher discharges, rising backwater progressively floods large areas of the study site. The increase in WUA for both species, with increasing mainstem stage, was projected to be lower than the physical measurements indicated (Figure 20). The downwards adjustment of WUA's was made to reflect less than optimal conditions which existed following the initial flooding event when submerged vegetation was so dense that it restricted juvenile movements and caused the water to stagnate. Because increasing water depths improved habitat conditions in the flooded areas, the weighted usable areas indicated by the physical data at mainstem discharges around 28,000 cfs were used for the species at 45,000 cfs. This adjustment is reflected in the projected cover indices at discharges greater than 25,000 cfs. Relatively lower velocity and cover weighting factors are responsible for the lower WUA's calculated for cohos than those calculated for sockeye at this site.

3.7 Slough 6A

Slough 6A is an upland slough with steep banks which prevent large changes in surface areas from occurring over the range of mainstem discharges observed. All species of juvenile salmon except pink salmon were captured at the site, although only coho and sockeye juveniles were captured in abundance relative to catches at other sites.

Smaller WUA's for both species (Figure 21) at mainstem discharges below 25,000 cfs reflect loss of cover in the shoreline areas of the site. Differences in the magnitude of the cover and velocity weighting factors in all areas of the site are responsible for the much lower overall suitabilities calculated for coho juveniles.

3.8 Model Verification

Strong positive (i.e., significantly greater than 0.0) correlations between coho and chinook catch and combined weighting factors by cell were found for most sites modelled (Table 3). Correlations between chinook catch and combined weighting factors in low turbidity waters ranged from 0.61 to 0.81. In high turbidity water, the correlations were much lower in absolute value and sometimes not significant by site at the 0.05 level although the correlation coefficient for the sites pooled was highly significant. Coho salmon catches were significantly correlated with combined weighting factors at all sites, and ranged from 0.48 to 0.63.

Sockeye proportional presence was strongly associated with large values of the combined weighting factor (Table 4). Chum salmon were not significantly associated with the combined weighting factors but the sampling effort was very small.

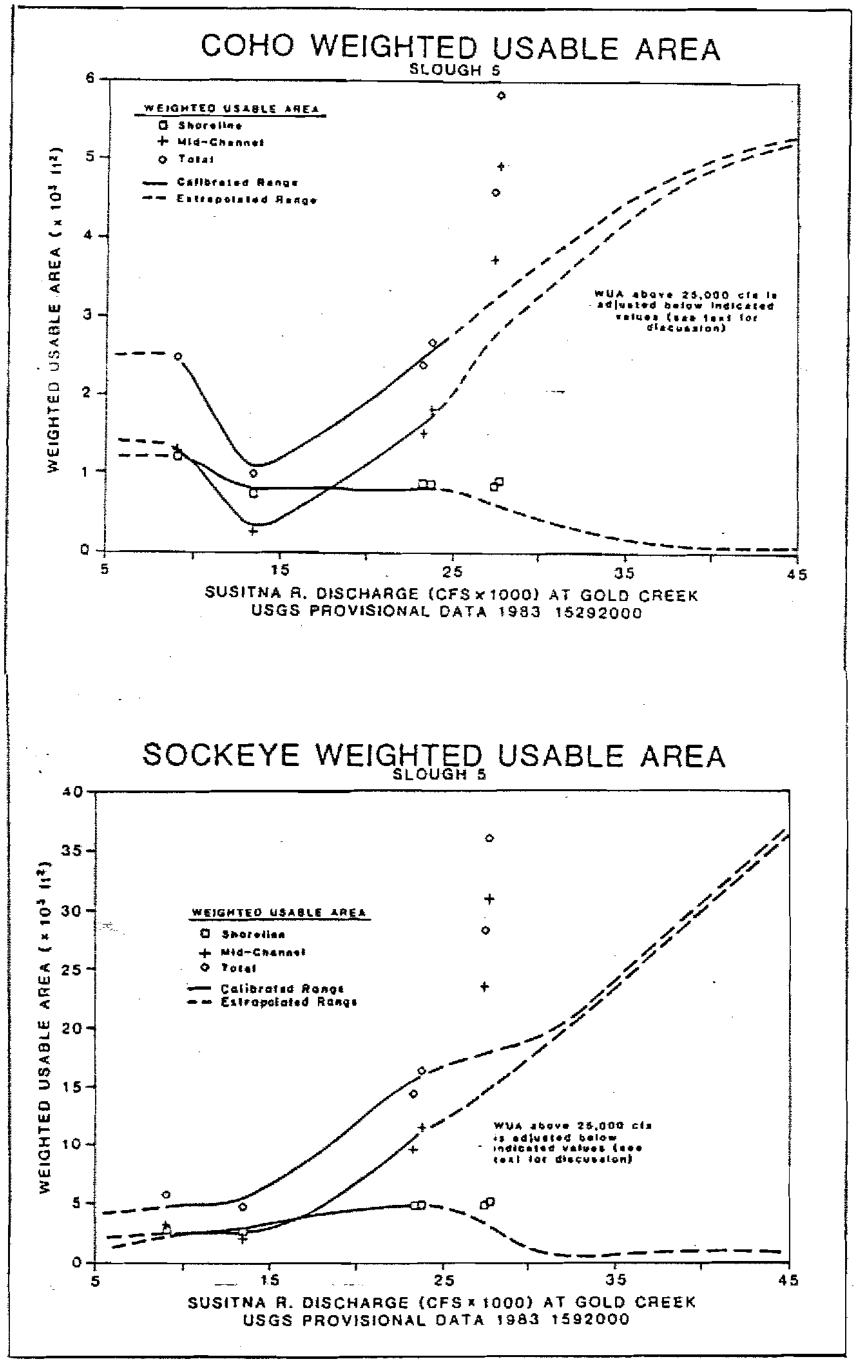

Figure 20. Weighted usable area projections for juvenile coho and sockeye salmon at the Slough 5 modelling site.

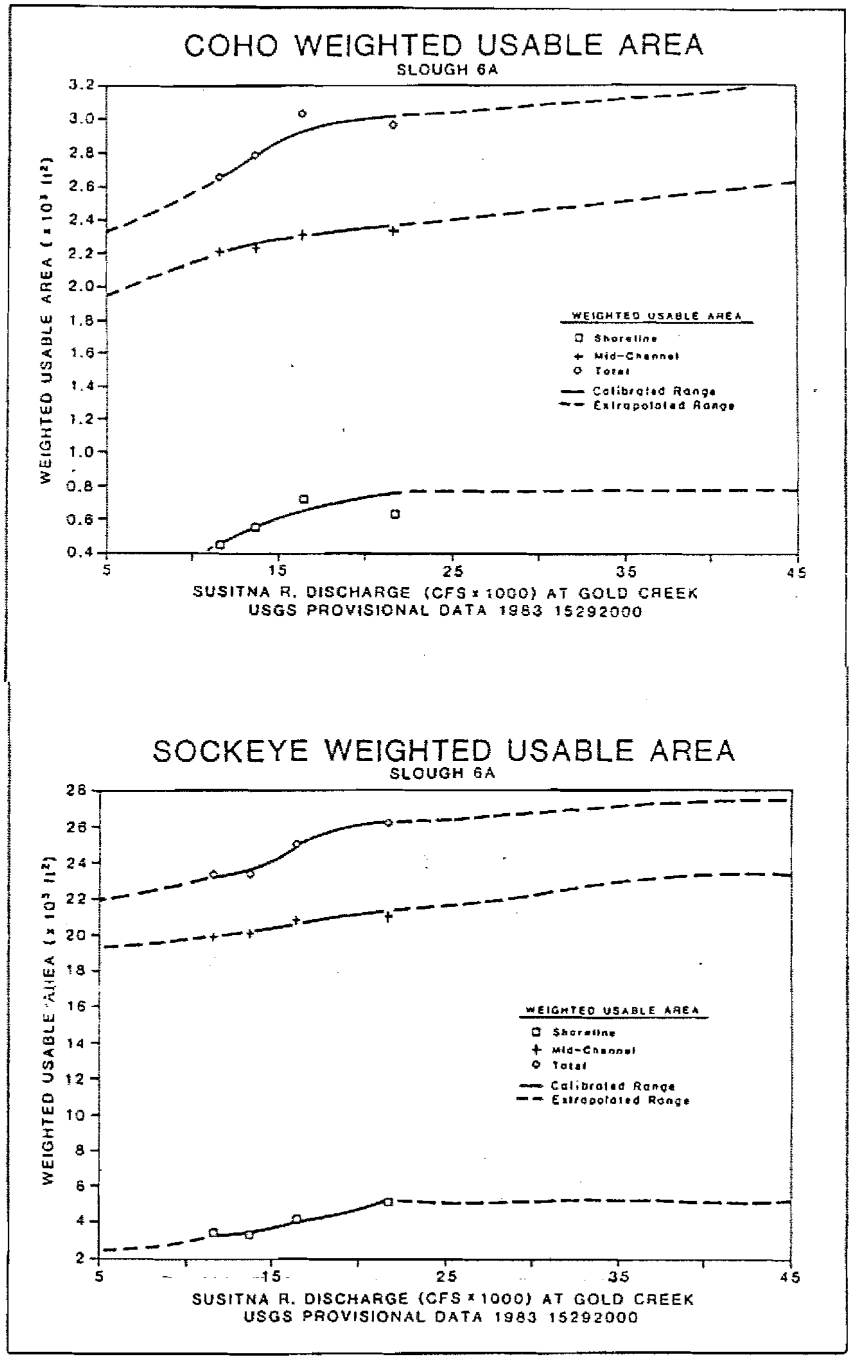

Figure 21. Weighted usable area projections for juvenile coho and sockeye salmon at the Slough 6A modelling site.

Table 3. Correlations between composite weighting factors and catch transformed by natural log (X+1) for juvenile coho and chinook salmon by site and by all sites pooled.

	Chinook					
	Low Turbidity (≤ 30 NTU)			High Turbidity (> 30 NTU)		
	n	r	Sig[a]	n	r	Sig
Whiskers Creek Slough	30	0.61	0.001	37	0.40	0.066
Slough 22	35	0.81	0.001	17	0.73	0.001
Side Channel 10A	14	0.77	0.001	50	0.19	0.065
Pooled	79	0.72	0.001	104	0.29	0.009

	Coho		
	n	r	Sig
Whiskers Creek Slough	67	0.48	0.001
Slough 6A	62	0.50	0.001
Slough 8	51	0.63	0.001
Slough 5	39	0.58	0.001
Pooled	219	0.45	0.001

[a] Significance level for rejection of hypothesis that there is a positive correlation between composite weighting factors and catch.

Table 4. Chi-square contingency tests of juvenile sockeye and chum salmon proportional presence by composite weighting factor intervals.

Sockeye (Data from Sloughs 8, 6A, and 5 pooled)

Combined weighting factor interval	No. of cells Present	Absent	Total	Proportion Present
0.03-0.12	6	30	36	0.17
0.13-0.22	12	25	37	0.32
0.23-1.00	24	15	39	0.62

$X^2 = 16.7$ df = 2
Significant at $P < 0.001$

Chum (Data from Slough 8)

Combined weighting factor interval	No. of cells Present	Absent	Total	Proportion Present
0.24-0.34	4	4	8	0.50
0.41-0.66	5	5	10	0.50

$X^2 = 0.0$ df = 1
Not significant at 0.05 level

4.0 DISCUSSION

The weighted usable area models for juvenile salmon at critical upland slough, side slough, and side channel habitat locations indicate that both species-specific and site-specific trends exist. The trends reflect fish suitability for hydraulic conditions, including changes in surface area. Significantly, most of the weighted usable area estimates are affected strongly by the availability of suitable cover. In the environments modelled, suitable cover for juvenile chinook salmon includes turbidity. In all three side channel habitats, peaking of the weighted usable area function occurs in a narrow range of flows which occur following the overtopping event. In side and upland slough habitats, the changes in WUA values for all juvenile salmon species are related to mainstem backwater effects.

Habitat indices were calculated from the smoothed WUA projections (Appendix A). In this calculation, the weighted usable areas interpolated at 3,000 cfs increments of mainstem discharge are expressed as the fraction of the total area available at the site when mainstem discharge was 23,000 cfs. Plotting these normalized values as a function of mainstem discharge results in habitat indices by macrohabitat type for each juvenile salmon species. Habitat index values are compared with the IFG modelling results in Part 7 of this report.

4.1 Chinook Salmon

Juvenile chinook habitat was modelled at three study sites for turbidity levels above and below 30 NTU (Figure 22). The difference in habitat index values for the two turbidity conditions largely reflects the differences in suitability for cover at the sites. Slough 22 appears roughly as usable as Whiskers Creek Slough under turbid conditions but is much less usable with low turbidity flows. This reflects the relatively cover-poor environment at Slough 22. The shape of all three side channel plots shows that the available habitat becomes less suitable for juvenile chinooks as velocity increases at large mainstem discharges. Since each side channel habitat is breached by mainstem water at slightly different mainstem discharges, a larger sampling of side channels which are breached by mainstem water at different discharges is required to formulate average index values for a particular mainstem discharge.

4.2 Coho Salmon

Habitat indices for coho salmon at four sites are plotted in Figure 23. The habitat indices are much lower than those for chinook and reflect generally poor rearing habitat for coho in mainstem influenced environments of the Susitna River. The index for Slough 5 increases primarily because of a large increase in surface area of the site. These low indices in generally are primarily the result of a lack of suitable cover for coho.

The Whiskers Creek Slough site was unusual among the sites sampled because coho were captured there when turbid water was present. This was related to the proximity of the slough to a natal area, Whiskers Creek.

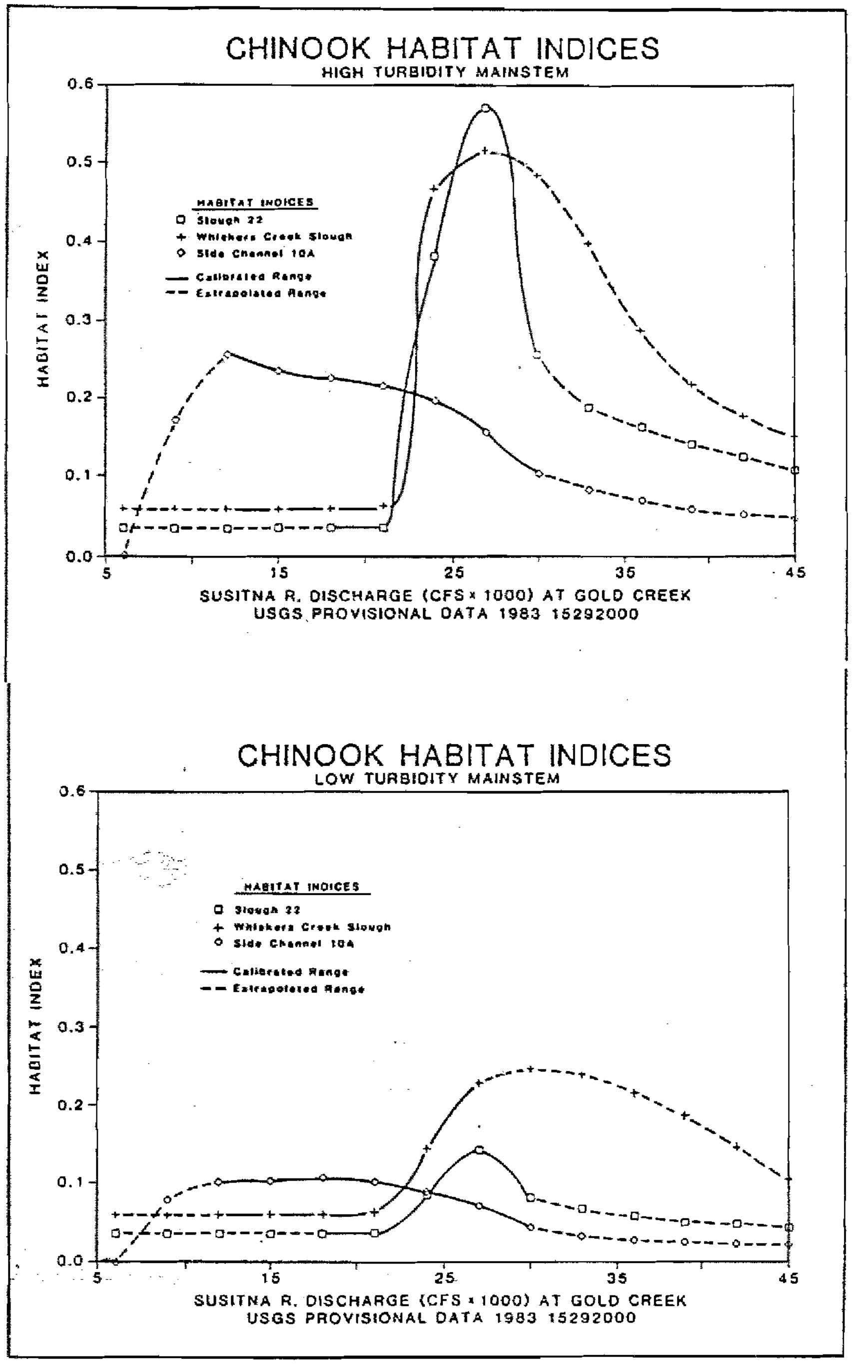

Figure 22. Habitat indices for juvenile chinook salmon.

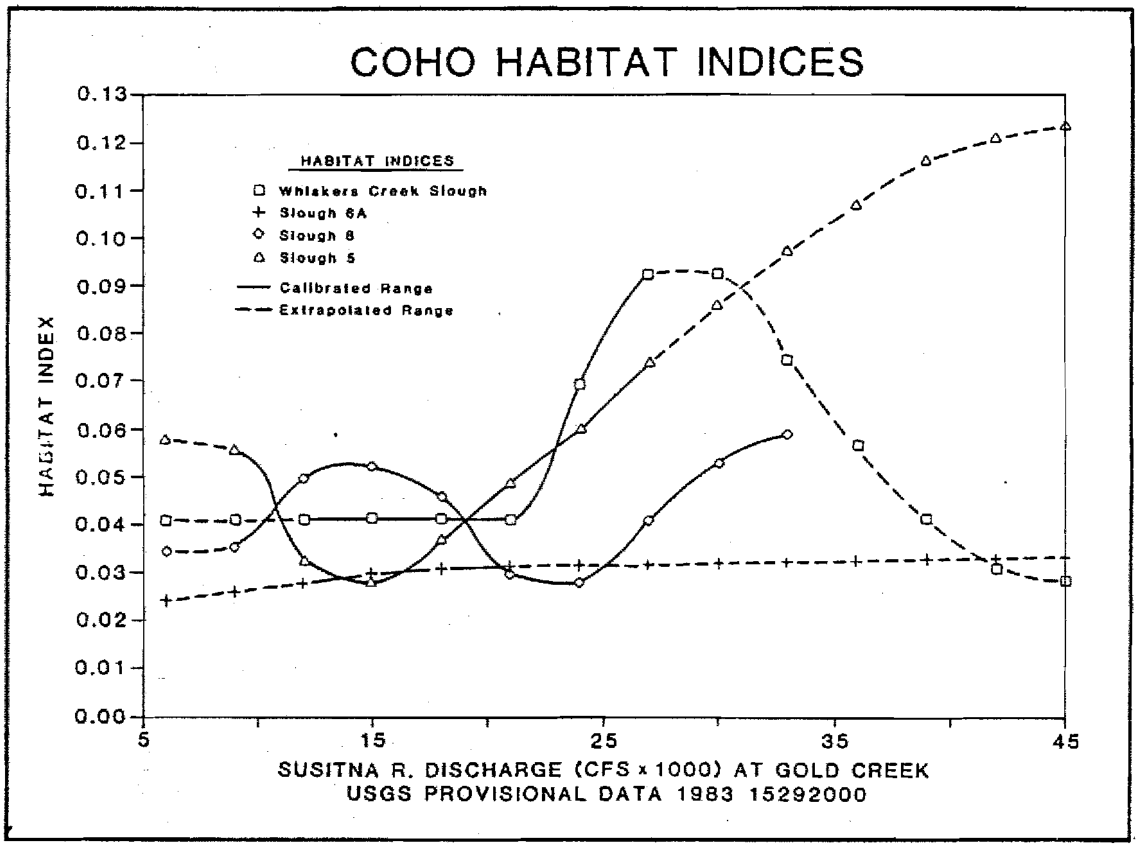

Figure 23. Habitat indices for juvenile coho salmon.

4.3 Sockeye and Chum Salmon

Sockeye salmon habitat indices increased with discharge over the modelled range (Figure 24). Upland sloughs (Slough 6A and 5) become increasingly important habitats for juvenile sockeye salmon as mainstem discharge increases due to the backwater effects. These two sloughs represent the extremes in changes of conditions possible for this type of habitat; Slough 6A has a steep banked, well defined channel and Slough 5 has very low gradient banks which are quickly overtopped by backwater. Only Slough 8 was modelled for chum salmon and the habitat index increased with mainstem discharge (Figure 25). With further increases in mainstem discharge, however, the indices for both chum and sockeye at Slough 8 would decline due to velocity becoming important in limiting distribution.

4.4 Limitations of the Models Regarding Methodology

The methods employed in this study were intended to provide a rapid and quantitative estimation of the overall effects of mainstem Susitna River discharge on the suitability of selected rearing habitats for juvenile salmon. Simultaneously, IFG-2 and IFG-4 models were developed at companion side slough and side channel sites (Part 7). Because habitat parameters were measured at only three cells along each transect in this study, we do not expect that these predictions will provide the same degree of resolution that will result from using well calibrated multi-cell hydraulic models.

The WUA calculations projected for mainstem flows not observed are generally subject to review. In the case of projections for low mainstem flows at side sloughs, however, conditions were nearly static so that extrapolations to 6,000 cfs (mainstem discharge) are reasonably solid. In contrast, forecasts for high flow conditions at mainstem side channels should be used as preliminary estimates.

However, we believe that in large glacial systems, like this reach of the Susitna River, catastrophic hydraulic events and the availability of cover are major factors related to the distribution and relative abundance of juvenile salmonids. Our model is designed to provide the resolution necessary to observe overall changes related to these phenomena, and we believe that it does.

4.5 Model Verification

Chinook salmon distribution in low turbidity waters was strongly correlated to the composite weighting factor index but the correlations for chinook salmon in turbid water were much lower. The lower correlations in turbid water may reflect gear efficiency problems because beach seines were used in turbid water and their efficiency varies

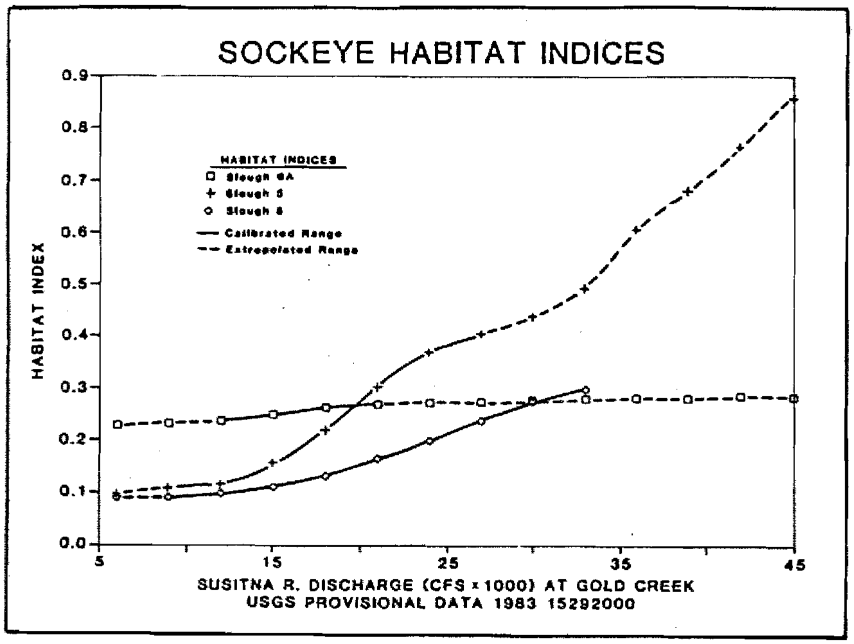

Figure 24. Habitat indices for juvenile sockeye salmon.

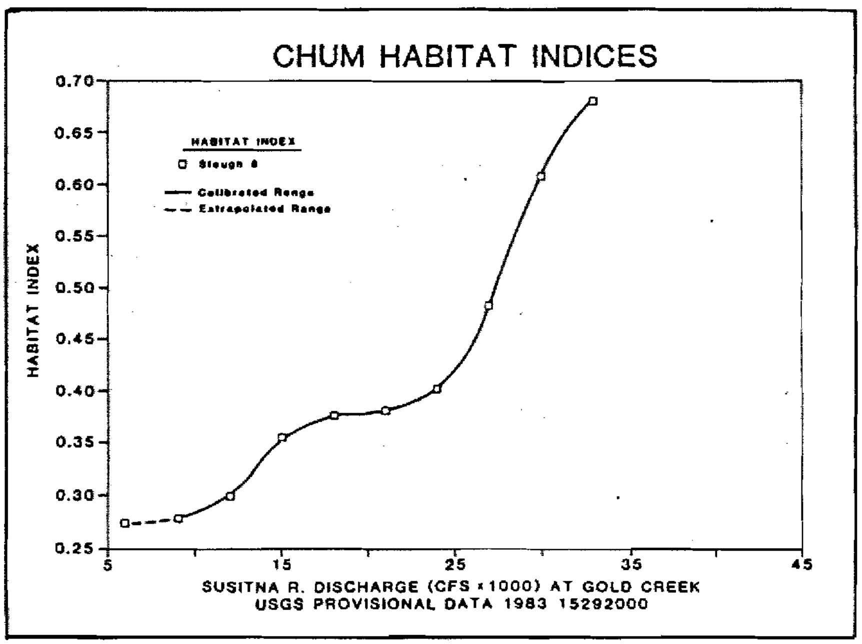

Figure 25. Habitat indices for juvenile chum salmon.

widely with cover type and other habitat conditions (Part 2 of this report). Electrofishing gear, used as a sampling method in clearer waters, was believed to be more reliable when sampling diverse habitat.

Coho and sockeye salmon also were correlated to or associated with the calculated composite weighting factors. Chum salmon catches were so limited at the six model sites that the relationship of composite weighting factors to fish use remains unproven. Factors such as season, of course, are strongly related to fish abundance and obscure the relationships. The analysis is also specific to the ice free months and no analyses of winter processes have been made. Since there is a positive relationship between the composite weighting factors and fish catch at the cell level and by inference between WUA and fish use at the site level, the models are verified on at least a general basis although many refinements in the model are possible.

5.0 CONTRIBUTORS

Woody Trihey and Steve Hale provided helpful discussions. Larry Dugan and Dave Sterritt helped collect the field data. Tommy Withrow, Jodi Miller, Pat Morrow, and Chris Kent installed our staff gages. Allen Bingham and staff managed the mainframe computer data base. Sally Donovan and Carol Riedner did the art work for the final copy. Woody Trihey, Allen Bingham, and Kathrin Zosel reviewed a draft of this paper and provided helpful comments.

6.0 ACKNOWLEDGEMENTS

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We wish to thank the various staff at E. Woody Trihey and Associates (EWT&A), the Arctic Environmental Information Data Center, Harza-Ebasco Susitna Joint Venture, Woodward-Clyde Consultants, The Alaska Power Authority, and especially Cleve Steward (EWT&A) for reviewing the draft of this paper and providing helpful suggestions.

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APPENDIX A

Weighted Usable Area and Habitat Indices Tablulated by Site and Species

Weighted usable area (WUA) and habitat index (HI) projections for species captured in abundance at the juvenile salmon rearing habitat model study sites during the summer of 1983 (Appendix Tables A1 through A6). The habitat index is calculated as the weighted usable area divided by the sites surface area at a mainstem Susitna River discharge of 23,000 cfs.

Appendix Table A-1. Weighted usable area and habitat indices for Side Channel 10A.

Mainstem Discharge (cfs)	Chinook Salmon			
	Turbidity 30 NTU		Turbidity 30 NTU	
	WUA	HI	WUA	HI
6,000*	0	0.000	0	0.000
9,000*	18,580	0.171	8,400	0.078
12,000	27,700	0.256	11,000	0.102
15,000	25,500	0.236	11,000	0.102
18,000	24,400	0.226	11,500	0.106
21,000	23,300	0.216	10,800	0.100
24,000	21,100	0.195	9,500	0.088
27,000	16,800	0.156	7,600	0.070
30,000	11,300	0.105	4,600	0.043
33,000*	9,000	0.083	3,500	0.032
36,000*	7,500	0.069	3,000	0.028
39,000*	6,400	0.059	2,700	0.025
42,000*	5,700	0.053	2,400	0.022
45,000*	5,100	0.047	2,300	0.021

The surface area at 23,000 cfs was 108,000 ft^2

* Data at this discharge extrapolated.

Appendix Table A-2. Weighted usable area and habitat indices for Slough 22.

Mainstem Discharge (CFS)	Chinook Salmon Turbidity > 30 NTU WUA	HI	Turbidity ≤ 30 NTU WUA	HI
6000*	2500	0.035	2500	0.035
9000*	2500	0.035	2500	0.035
12000*	2500	0.035	2500	0.035
15000*	2500	0.035	2500	0.035
18000*	2500	0.035	2500	0.035
21000 a/	2500	0.035	2500	0.035
24000 b/	27100	0.382	6000	0.085
27000	40500	0.570	10100	0.142
30000	18200	0.256	5800	0.082
33000*	13300	0.187	4800	0.068
36000*	11500	0.162	4100	0.058
39000*	10000	0.141	3600	0.051
42000*	8800	0.124	3400	0.048
45000*	7600	0.107	3100	0.044

The surface area at 23,000 cfs was 71,000 ft.

a/ = Side slough condition

b/ = Side channel condition

*Data at this discharge extrapolated

Appendix Table A-3. Weighted usable area and habitat indice for Whiskers Creek Slough.

Mainstem Discharge (CFS)	Chinook Salmon Turbidity > 30 NTU WUA	HI	Chinook Salmon Turbidity ≤ 30 NTU WUA	HI	Coho Salmon All Turbidity WUA	HI
6000*	2300	0.059	2300	0.059	1600	0.041
9000*	2300	0.059	2300	0.059	1600	0.041
12000	2300	0.059	2300	0.059	1600	0.041
15000	2300	0.059	2300	0.059	1600	0.041
18000	2300	0.059	2300	0.059	1600	0.041
21000 a/	2400	0.062	2400	0.062	1600	0.041
24000 b/	18200	0.467	5600	0.144	2700	0.069
27000	20100	0.515	8900	0.228	3600	0.092
30000*	18900	0.485	9600	0.246	3600	0.092
33000*	15500	0.397	9300	0.238	2900	0.074
36000*	11200	0.287	8400	0.215	2200	0.056
39000*	8500	0.218	7300	0.187	1600	0.041
42000*	6900	0.177	5700	0.146	1200	0.031
45000*	5900	0.151	4100	0.105	1100	0.028

The surface area at 23,000 cfs was 39,000 ft.

a/ = Side slough condition

b/ = Side channel condition

*Data at this discharge extrapolated

Appendix Table A-4. Weighted usable area and habitat indices for Slough 8.

Mainstem Discharge (CFS)	Chum Salmon WUA	Chum Salmon HI	Coho Salmon WUA	Coho Salmon HI	Sockeye Salmon WUA	Sockeye Salmon HI
6000*	5300	0.273	670	0.035	1750	0.090
9000	5400	0.278	690	0.036	1780	0.092
12000	5800	0.299	960	0.049	1910	0.098
15000	6900	0.356	1010	0.052	2160	0.111
18000	7300	0.376	890	0.046	2550	0.131
21000	7400	0.381	580	0.030	3200	0.165
24000	7800	0.402	540	0.028	3860	0.199
27000	9350	0.482	790	0.041	4600	0.237
30000	11800	0.608	1020	0.053	5320	0.274
33000	13200	0.680	1140	0.059	5780	0.298

The surface area at 23,000 cfs was 19,400 ft^2.
*Data at this discharge extrapolated

Appendix Table A-5. Weighted usable area and habitat indices for Slough 5.

Mainstem Discharge (CFS)	Coho Salmon WUA	Coho Salmon HI	Sockeye Salmon WUA	Sockeye Salmon HI
6000*	2500	0.058	4200	0.098
9000	2400	0.056	4700	0.109
12000	1400	0.033	5000	0.116
15000	1200	0.028	6700	0.156
18000	1600	0.037	9400	0.219
21000	2100	0.049	13000	0.302
24000	2600	0.060	15900	0.370
27000	3200	0.074	17400	0.405
30000*	3700	0.086	18800	0.437
33000*	4200	0.098	21200	0.493
36000*	4600	0.107	26000	0.605
39000*	5000	0.116	29200	0.679
42000*	5200	0.121	32800	0.763
45000*	5300	0.123	36900	0.858

The surface area at 23,000 cfs was 43,000 ft.
*Data at this discharge extrapolated

Appendix Table A-6. Weighted usable area and habitat indices for Slough 6A.

Mainstem Discharge (cfs)	Coho Salmon WUA	Coho Salmon HI	Sockeye Salmon WUA	Sockeye Salmon HI
6,000*	2,350	0.024	22,000	0.227
9,000*	2,510	0.026	22,600	0.233
12,000	2,670	0.028	23,200	0.240
15,000	2,870	0.030	24,100	0.249
18,000	2,970	0.031	25,400	0.262
21,000	3,000	0.031	26,200	0.271
24,000*	3,020	0.031	26,400	0.273
27,000*	3,040	0.031	26,600	0.275
30,000*	3,060	0.032	26,900	0.278
33,000*	3,080	0.032	27,000	0.279
36,000*	3,110	0.032	27,200	0.281
39,000*	3,140	0.032	27,400	0.283
42,000*	3,170	0.033	27,500	0.284
45,000*	3,200	0.033	27,600	0.285

The surface area at 23,000 cfs was 96,800 ft^2
* Data at this discharge extrapolated.

PART 5

Resident Fish Distribution and Population Dynamics in the Susitna River below Devil Canyon

RESIDENT FISH DISTRIBUTION AND POPULATION DYNAMICS IN THE SUSITNA RIVER BELOW DEVIL CANYON

1984 Report No. 2, Part 5

by Richard L. Sundet and Mark N. Wenger

Alaska Department of Fish and Game
Susitna Hydro Aquatic Studies
2207 Spenard Road
Anchorage, Alaska 99503

ABSTRACT

Studies of resident fish during 1983 were concentrated on the reach of the Susitna River between the Chulitna River confluence and Devil Canyon. With the use of radio telemetry and mark and recapture methods, the seasonal distribution of rainbow trout and estimates of local abundance were obtained. Examination of recapture data over the past several years suggests that the rainbow trout population in this reach is probably less than 4,000 fish. Most of the concentrations are in the smaller tributaries, particularly Fourth of July Creek, which also has the only significant amount of successful spawning documented so far in this portion of the Susitna basin. The large tributaries, Portage Creek and Indian River, had comparatively small numbers of rearing rainbow trout. This species spends much of its annual life cycle in the mainstem Susitna near tributary mouth areas or mixing zone confluences of sloughs. Much of the migratory movements during the summer appear to be in response to the influx of adult salmon spawners, whose eggs apparently provide a major source of food. Radio tagged rainbow trout movement data suggests that the mainstem is important for overwintering. Limited data from tagged rainbow trout below the Chulitna River confluence suggests the reach of river between RM 78.0 and Talkeetna may also be an important overwintering area for Talkeetna River stocks as well. Spawning of round whitefish in October and probably burbot in January is directly influenced by mainstem flows. Young age class Arctic grayling and round whitefish appear to reside in the mainstem Susitna, usually near tributary or slough mouths. Nearly all of the spawning and most of the rearing of older age class Arctic grayling occurs in tributaries. Arctic grayling overwinter in the mainstem Susitna. Dolly Varden are rare in this reach of the Susitna. Selected sites have been established that can be used to monitor catch per unit effort of the resident species, and consequently their response to flow regulation of the proposed hydroelectric project.

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1.0 INTRODUCTION

Study of resident fish[1/] species began in the fall of 1980 to collect baseline data to meet the following objectives:

A. Define seasonal distribution and relative abundance of resident fish species in the Susitna River between Cook Inlet and Devil Canyon.

B. Characterize the seasonal habitat requirements of selected resident fish species within the study area.

During the 1983-84 season, the Resident Fish Studies were refined to also address the following sub-objective:

C. Quantify the important habitat parameters associated with spawning and rearing (growth) of selected resident fish species and measure fish density in spawning and rearing habitats to provide an estimate of habitat quality.

The rationale behind these objectives is that often there can be changes in fish populations after the construction of a hydroelectric dam. These postproject effects result from changes in water temperature, flow, turbidity, and other water quality parameters. Preproject baseline fisheries data and their correlation to habitat conditions, therefore, are necessary to evaluate the potential impact to these fisheries.

Studies on how resident fisheries are affected by hydro-projects similar in magnitude to the Susitna proposals are limited. One of the better pre- and post-project studies was conducted by the Montana Department of Fish, Wildlife, and Parks on the Kootenai River below the Libby Dam site (MDFW&P 1983). The overall effects of the dam were conducive to increased production of rainbow trout and mountain whitefish but adversely affected sturgeon. A quality sport fishery has arisen in the regulated waters below the project after an initial five year problem with supersaturation of dissolved gas. In recent years, however, the average size of the rainbow trout have decreased, which may be related to sport fishing and perhaps to changes in invertebrate comunity structure caused by power peaking fluctuations. The system remains one of the more productive rivers in this portion of the state of Montana. Provision for proper downstream flow is considered by these researchers to be the primary reason the fisheries have developed favorably after project operation.

Sport fishing for rainbow trout and Arctic grayling in the Susitna River drainage occurs throughout the open water season, primarily around the mouths of clearwater tributaries. Burbot fishing occurs mostly in the mainstem Susitna River or at the mouths of clear water tributaries during both summer and winter. In the Chulitna River confluence to

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1/ For the purposes of this report "resident fish" will be defined as any fish species which spend their entire life cycle within the Susitna River drainage.

Devil Canyon reach of the Susitna River, the reach that will probably be most affected by the proposed hydroelectric project, sport fishing occurs at Whiskers Creek [river mile (RM) 101.4], Lane Creek (RM 113.6), Fourth of July Creek (RM 131.1), Indian River (RM 138.6), and Portage Creek (RM 148.8). Current information on the extent of the harvest of these resident fish species is limited to data available from Mills (1982) for the entire Susitna River basin. These catches have been stable for the past five years, with the average harvest of rainbow trout and burbot at 20,000 and 700 fish respectively. The level of fishing effort will probably increase in the Susitna River drainage during the next decade.

2.0 METHODS

This report addresses resident fish studies conducted during the open water period of 1983, spawning surveys done in early May, and radio telemetry results through December 1, 1983. Telemetry results are presented through December 1 to show the movement patterns during the transition period from open water to winter conditions. Although most of the sampling occurred in the mainstem Susitna River between the Chulitna River confluence to Devil Canyon, a few other areas were also studied.

2.1 Study Locations

2.1.1 Relative abundance measurements

Thirteen index sites were sampled twice per month by boat electrofishing to monitor seasonal trends in relative abundance of resident fish (Figure 1). In addition, other mainstem, side channel, slough, and tributary sites on the Susitna River between the Chulitna River confluence and Devil Canyon were also sampled intermittently.

The upper reaches of Fourth of July Creek (RM 131.1), Indian River (RM 138.6), and Portage Creek (RM 148.8) were sampled to determine the extent of resident fish spawning and rearing. These tributaries were selected because of their size, their proximity to Devil Canyon, and their relatively high abundance of resident fish species. Fourth of July Creek was sampled in May, June and July between tributary river mile (TRM) 0.0 and TRM 2.3. Indian River was sampled in June and August between TRM 1.5 and TRM 14.0, while Portage Creek was sampled in June at TRM 6.0 and TRM 10.0.

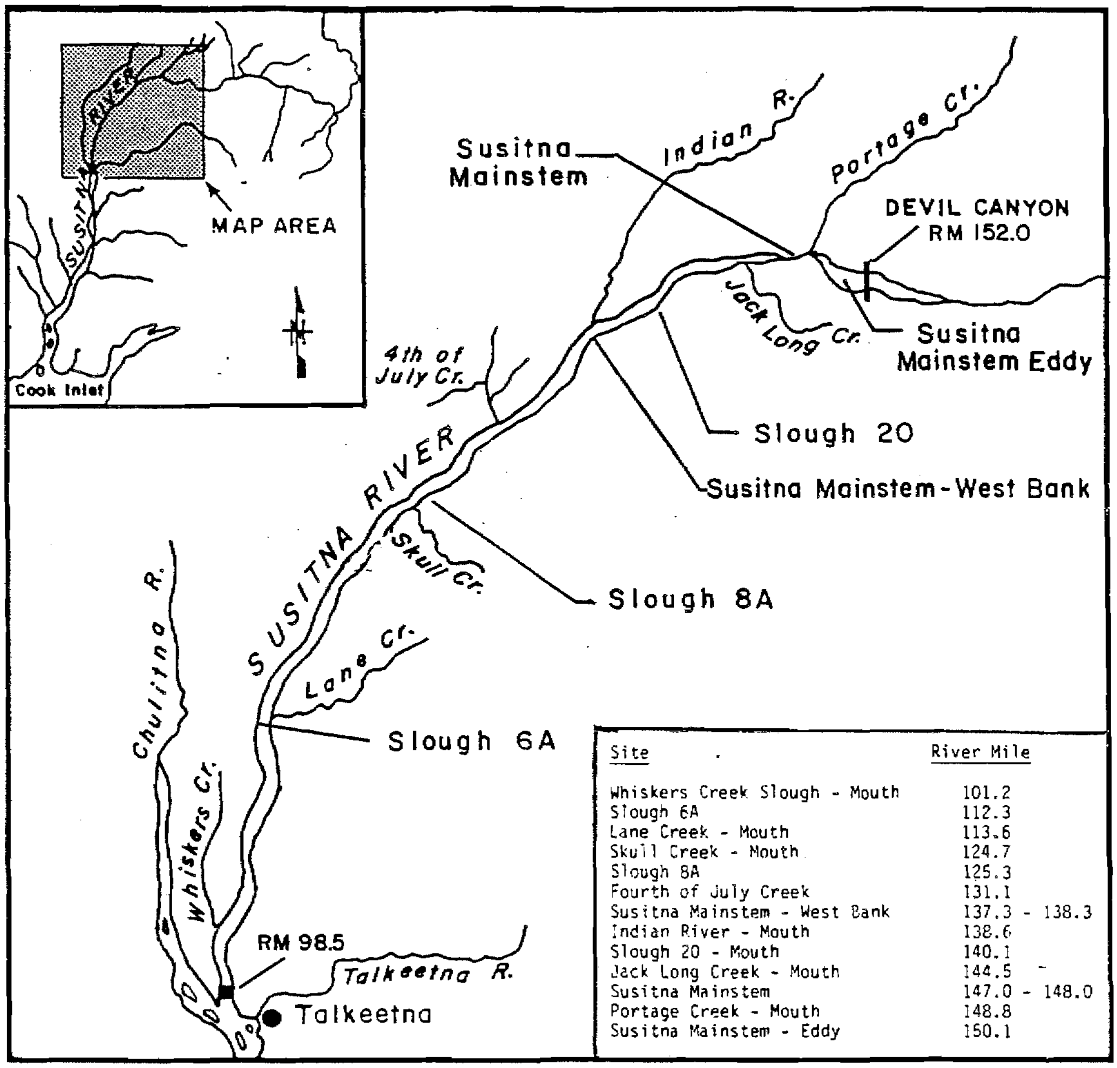
Resident fish catches recorded at four fishwheel sites, two downstream migrant traps (RM 103.0), and 35 juvenile salmon rearing study sites were also examined to evaluate trends in relative abundance and seasonal movements.

2.1.2 Population estimates

Resident fish population estimates were attempted at five sites on the Susitna River between the Chulitna River confluence and Devil Canyon (Table 1). These sites included a slough, a side channel, a tributary, a tributary mouth, and a one-mile reach of the mainstem Susitna River.

2.1.3 Radio telemetry

Selection of radio tagging sites in the mainstem Susitna between the Chulitna River confluence and Devil Canyon were based on resident fish distribution data collected during the 1981 and 1982 open water field seasons (ADF&G 1981c; 1983b). Primary efforts to capture rainbow trout (*Salmo gairdneri* Richardson) in the mainstem were focused at the mouths of Whiskers Creek (RM 101.4), Lane Creek (RM 113.6), Fourth of July Creek (RM 131.1) and Indian River (RM 138.6). Backwater areas in the mainstem were sampled for burbot (*Lota lota* Linnaeus). The upper



Site	River Mile
Whiskers Creek Slough - Mouth	101.2
Slough 6A	112.3
Lane Creek - Mouth	113.6
Skull Creek - Mouth	124.7
Slough 8A	125.3
Fourth of July Creek	131.1
Susitna Mainstem - West Bank	137.3 - 138.3
Indian River - Mouth	138.6
Slough 20 - Mouth	140.1
Jack Long Creek - Mouth	144.5
Susitna Mainstem	147.0 - 148.0
Portage Creek - Mouth	148.8
Susitna Mainstem - Eddy	150.1

Figure 1. Resident fish study sites on the Susitna River between the Chulitna River confluence and Devil Canyon, 1983.

Table 1. Resident fish population estimate sites on the Susitna River between the Chulitna River confluence and Devil Canyon, 1983.

Location	RM	TRM	Dates	Occasion	Methods
Slough 8A	125.3	--	7/15-7/17	6	boat electro-fishing
4th of July Creek	131.1	0.0-0.8	7/19-7/21	3	hook & line
Mainstem	131.0-131.8	--	7/15-7/16	4	gill net and hoop net
Mainstem	138.9-140.1	--	7/1-7/4	4	trotline, burbot sets, and hoop nets
Jack Long Creek	144.5	0.0	8/10	3	boat electro-fishing

Note - Population estimates were also begun at seven other locations in 1983 but were not completed due to insufficient captures of fish.

reaches of Fourth of July Creek, Indian River, and Portage Creek were also sampled for spawning or rearing rainbow trout.

2.2 Data Collection

2.2.1 Relative abundance

Resident fish were collected at mainstem and tributary sites primarily with a boat mounted electrofishing unit (Plate 1). A Coffelt Model VVP-3E boat electrofishing unit powered by a 2,500 watt Onan generator was used for boat electrofishing and techniques used are described in the 1982-83 procedures manual (ADF&G 1983a). Secondary gear types used included downstream migrant traps at RM 103.0, backpack electrofishing units, gill nets, hook and line, hoop nets, trotlines, and catfish traps. Baited hoop nets, trotlines and catfish traps were used mainly to capture burbot. Catfish traps were introduced as a new sampling technique in 1983. They were set and fished using techniques similar to those described for hoop nets (ADF&G 1983a).

All resident fish were identified to species. Biological data (age, length, sex, and sexual maturity) were collected as outlined in the 1982-83 procedures manual. Scales for age determination were taken from a representative sample of rainbow trout, Arctic grayling (*Thymallus arcticus* Pallas), round whitefish (*Prosopium cylindraceum* Pallas), humpback whitefish (*Coregonus pidschian* Gmelin), and longnose suckers (*Catostomus catostomus* Forster).

Survival rates for selected resident fish species were calculated using catch and age data following the methods of Everhart et al. (1975). The log of the number of fish for each age class was plotted. Then, a regression line was fit to the descending leg of the graph. Points (numbers in an age class) in the descended leg were used after the peak and to the oldest age class consisting of greater than three points. The equations are:

$$\log_e S = Z$$

$$S = e^{-Z} = e^{b}$$

where: S = survival

Z = instantaneous mortality rate

b = slope of regression between the log of the number of fish and year classes

Resident fish spawning data were collected whenever gravid female fish were captured. A gravid female fish was defined in this study as one which expelled eggs when its abdomen was palpated. Because of turbidity, direct observations of redds was not possible.

A tag-and-recapture program was continued in 1983 to monitor the seasonal movements of adult resident fish. Floy anchor tags were used to tag seven species of adult resident fish: humpback whitefish, round

Plate 1. Electrofishing with a boat mounted electroshocking unit at Mainstem Susitna-gravel bar opposite Montana Creek (RM 78.0).

whitefish, burbot, longnose suckers, rainbow trout, Arctic grayling, and Dolly Varden (Salvelinus malma Walbaum). All resident fish that appeared healthy after capture and were large enough to be tagged were tagged. Burbot with a total length of 225 millimeters (mm) or greater were tagged. All other resident fish with fork lengths greater than 200 mm were tagged. Tag recoveries were made by the resident fish study group, the adult salmon fishwheel crews, and the angling public.

2.2.2 Population estimates

Population estimates for rainbow trout, Arctic grayling, burbot, round whitefish, and longnose suckers were attempted at five representative sites (Table 1). The study design followed that outlined by Otis et al. (1978) and White et al. (1982) which uses a computer program called CAPTURE to calculate the population estimates and associated statistics. Fourth of July Creek was sampled with hook and line gear to capture rainbow trout and Arctic grayling. Trotlines and hoop nets were used at Mainstem (RM 138.9 - 140.1) to collect burbot. Boat electrofishing and gill nets were used at the remaining three sites to capture resident fish species. Each site was sampled on three to six occasions over a period of one to four days. Resident fish over 200 mm in length were Floy anchor tagged while smaller fish were marked by clipping the upper tip of the caudal fin. Catch and recapture information from 1982 indicated that resident fish movement is at a minimum during late July and early August (ADF&G 1983b). This is important because the CAPTURE model is only valid for closed populations. Population estimates for some species were not obtained at all study sites because of insufficient capture of fish.

The CAPTURE program indicates whether the data set meets the assumption if a closed population (i.e., no in- or out-migration during the sampling period). The program selects one model which best fits the data set out of several possible models. The different models allow for various effects on capture probability such as behavioral effects (for example, fish that are hook-shy or will not take a lure after having done so once). The program also calculates capture probabilities and provides confidence limits on the population estimates.

Population estimates for all species except burbot were made by a capture-recapture model from the CAPTURE computer program. Population estimates for burbot were made using a multiple removal model instead of the capture-recapture model because of the lack of burbot recaptures.

Although population estimates were attempted at five sites, population estimates were only able to be calculated for rainbow trout at Fourth of July Creek and burbot at mainstem Susitna (RM 138.9 - 140.1). Population estimates of resident fish at Jack Long Creek and at the mainstem site between RM 131.0 - 131.8 were not generated due to insufficient numbers of fish captured. Population estimates of resident fish at Slough 8A were also not generated due to low numbers of fish captured for three species, while for two species (longnose suckers and round whitefish) population estimates were inaccurate due to the wrong CAPTURE models used.

In addition to the five sites sampled three or more times, population estimates were stopped at seven other sites in 1983 due to insufficient fish captures during the first sampling occasion. Two of these sites were sampled for burbot in the mainstem at RM 128.3 - 129.3 and at RM 147.0 - 147.3. The remaining five sites were in Indian River between TRM 1.5 - 14.0.

2.2.3 Radio telemetry

2.2.3.1 Equipment

Radio telemetry receiving equipment used in this study was developed by Smith-Root Incorporated in Vancouver, Washington. Receiving equipment consisted of a low frequency (40 MHz) radio tracking receiver (Model RF-40) and scanner (Model SR-40), and a loop antenna (Model LA-40).

Radio transmitters manufactured by Smith-Root Incorporated and Advanced Telemetry Systems (Bethel, Minnesota) were used in the 1983 study. Advanced Telemetry System radio tags with a nine month life expectancy were used in rainbow trout. Smith-Root radio tags with a six month life expectancy were implanted in burbot and a few large rainbow trout.

Advanced Telemetry System transmitters (model BEI 10-35) were cylindrically shaped, encapsulated in epoxy, and had flexible 30 cm external antennas. The copper wire antennas were cut down to 15-20 cm to make implanting easier yet still provide a suitable receiving range. The Advanced Telemetry System transmitters measured 5.6 cm in length, 1.2 cm in diameter and had a dry weight of approximately 13.3 gm. The power source for the transmitters were 3.4 volt lithium batteries providing life expectancies of 200-270 days, depending on the pulse rate. Transmitter frequencies ranged between 40.600 and 40.770 MHz and had pulse rates between 1.0 and 2.0 per second. Radio frequencies from 40.680 - 40.700 MHz were not used to avoid interference with transmitting Alascom radio signals on frequency 40.690.

Smith-Root transmitters were identical to those used in previous resident fish telemetry studies with exception of the pulse rates (ADF&G 1981d; 1983a;1983b). Smith-Root transmitters used in the 1983 studies had pulse rates of 3.0 pulses per second and a life expectancy of 180 days.

All radio tags were immersed in cold water (1-5°C) for 48 hours to ensure they were transmitting properly before they were implanted in fish.

2.2.3.2 Transmitter implantation

Rainbow trout used for radio telemetry studies were captured by drift gill net, boat electrofishing, or hook and line. All burbot used in radio telemetry studies were captured by boat electrofishing. Based on personal communications with Carl Burger (USFWS) and experience gathered from the previous two years of radio telemetry studies, minimum lengths of rainbow trout and burbot radio tagged were set at 380 mm fork length and 525 mm total length, respectively. No injured or lethargic fish were radio tagged. Each fish radio tagged was placed in a 14 gallon cooler filled with a solution of river water and an anesthetic MS-222 (tricaine methane-sulfonate). After the fish were anesthetized, their lengths were measured to the nearest millimeter (fork length for rainbow trout and total length for burbot). Scales were taken from rainbow trout for aging. All radio tagged fish were marked with Floy anchor tags to identify them during subsequent recaptures.

With the exception of two rainbow trout, transmitters were surgically implanted in the coelom using a procedure described in Ziebell (1973). An incision was made on the midline of the ventral surface midway between the pectoral and pelvic fins, and a half capsule of ampicillin (an antibiotic used to prevent infection) was sprinkled into the body cavity. The length of the incision for the Advanced Telemetry System tag was 2.0-2.5 centimeters (cm) and a 3.0-3.5 cm incision was made for the Smith-Root tag. The radio tags were inserted anteriorly with the antenna extended fully toward the posterior of the fish. Incisions were closed with four to seven individual sutures of commercial silk (Plate 2).

Two rainbow trout received subcutaneous implants of Advanced Telemetry System radio transmitters using techniques which had been tested on rainbow trout in the Elmendorf Hatchery. The procedure involved making a 2.0-2.5 cm perpendicular incision through the skin below the posterior of the dorsal fin. A 1.0 cm diameter sharpening steel was used to tunnel anteriorly beneath the skin and separate the skin from the muscle. The radio tag was then inserted through the incision under the skin to the anterior end of the tunneled area. This positioned the anterior end of the radio tag approximately 3-5 cm behind the base of the fish's head with the antenna trailing out the incision. The incision was closed with 3-4 silk sutures (Plate 3).

After the surgical implantation of the radio tag, the fish was placed into a live box and held upright until it regained its equilibrium. The fish was then held overnight for observation. The following day the sutures were checked and the transmitter's signal was tested before releasing the radio tagged fish near the point of capture.

2.2.3.3 Tracking

Biologists radio tracked fish by boat, by aircraft and by ground surveys. Radio tracking by boat and ground surveys was conducted in the mainstem Susitna from Talkeetna (RM 97.0) to Devil Canyon (RM 150.5) once every 10-14 days from mid-May until mid-October 1983. Ground tracking was conducted primarily at tributary mouths and in the lower reaches of tributaries.

Aerial tracking, using methods described in Adult Anadromous Investigations (ADF&G 1981b), was conducted twice per month from mid-May through October 1983. In November and December 1983, aerial tracking was conducted once per month.

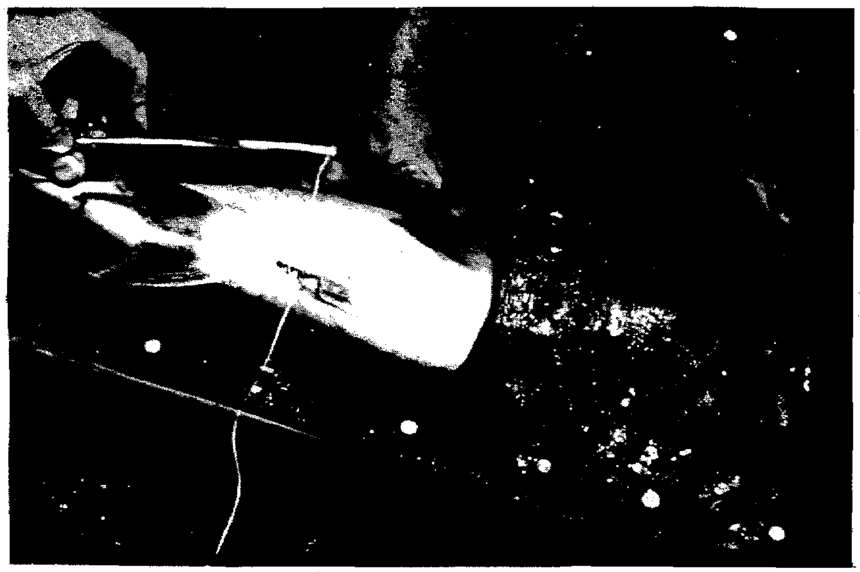


Plate 2. Implanting a radio tag into the abdomen of a rainbow trout.

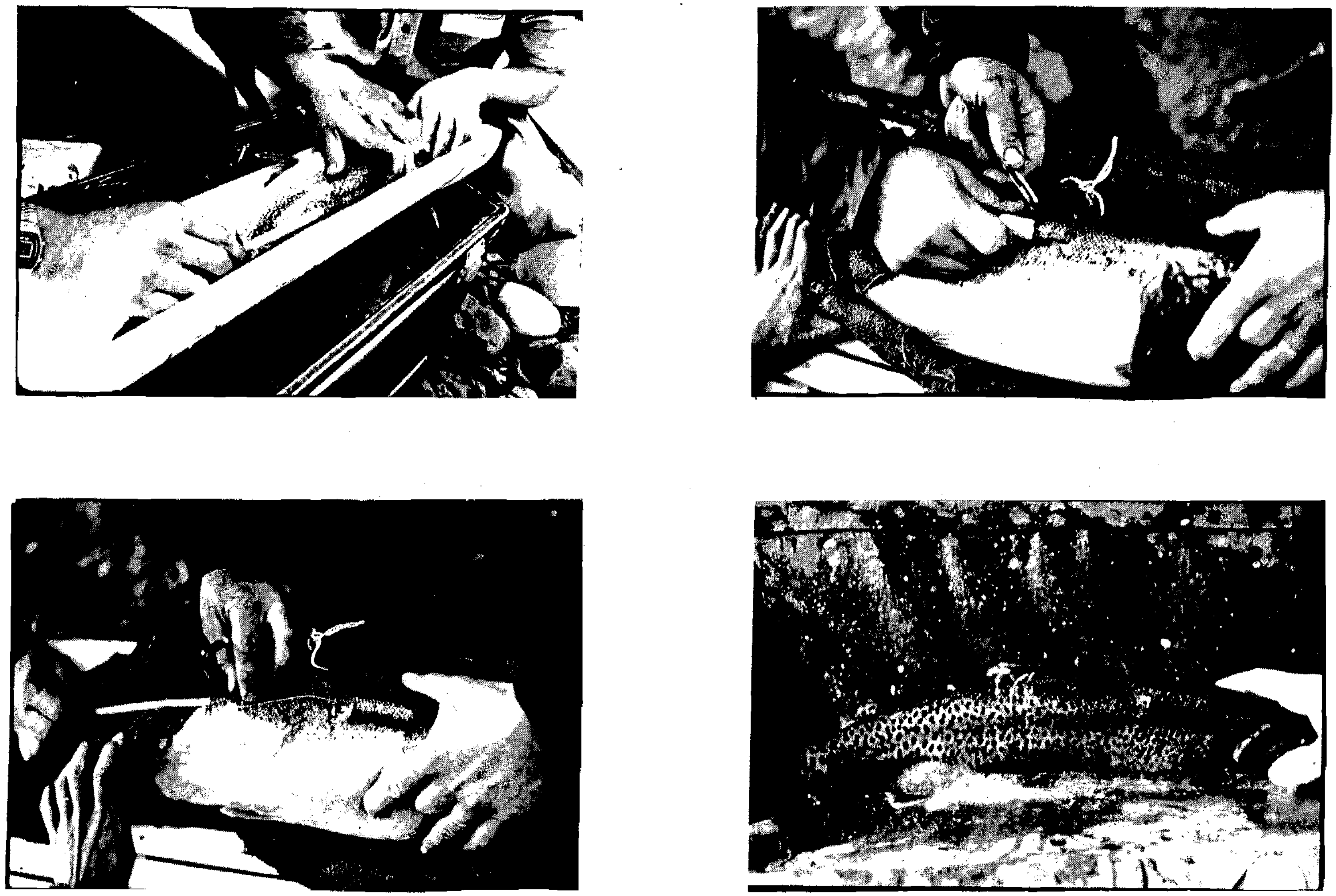


Plate 3. Implanting a radio tag under the skin of a rainbow trout.

2.3 Data Recording and Analysis

Biological data and catch data were recorded at relative abundance study sites as specified in the 1983-84 procedures manual (ADF&G 1984). Habitat data were also collected at resident fish spawning sites and are presented in Part 6 of this report. These data included, but were not limited to, species, length, sex, water velocity, substrate, location, time sampled, and gear type used. Biological and catch data were also recorded at sites where population estimates were obtained and where fish were collected for the radio telemetry study.

Data collected for resident fish relative abundance, population estimates, and radio telemetry were checked for accuracy and completeness following each sampling trip. Relative abundance data were submitted to the data processing unit for key punching. Radio telemetry data was filed for hand compilation at a later date. Printouts of the initial relative abundance data were returned to the individuals who collected the data to be rechecked for errors before being incorporated into the computer data base for analysis.

Analysis of relative abundance, length frequency and catch per unit effort data were provided by the data processing group. Population estimates for resident fish species were computed using the computer program CAPTURE, described by Otis et al. (1978) and White et al.(1982).

An analysis of variance of juvenile salmon catch rate at the juvenile salmon study sites was also run on juvenile round whitefish which were relatively abundant at those sites. Details of the analysis are given in Part 2 of this report.

3.0 RESULTS

3.1 Rainbow Trout

3.1.1 Distribution and relative abundance

Four hundred twenty-eight rainbow trout were captured by Susitna Hydro study groups using various methods between Cook Inlet and Devil Canyon from May to October 1983 (Table 2). Most of these fish were captured on the Susitna River above the Chulitna River confluence by hook and line (43.2%) or boat electrofishing (35.3%).

One hundred sixty-three rainbow trout were caught by a resident fish study crew at 12 selected sites between the Chulitna River confluence and Devil Canyon. Most (80.4%) of these fish were captured by boat electrofishing. The highest catches of rainbow trout at these sites by all gear types were at Fourth of July Creek (RM 131.1) and Indian River (RM 138.6) where 46 and 45 fish were caught respectively. Other sites where relatively high rainbow trout catches were made included Whiskers Creek Slough (RM 101.2), Lane Creek (RM 113.6) and Portage Creek (RM 148.8).

Two hundred twenty-eight rainbow trout were captured by the resident fish crew at sites other than the twelve selected sites. Most (78%) of these fish were captured in Fourth of July Creek between TRM 0.1 and TRM 1.5. In addition to the 391 rainbow trout captured by the resident fish crew, other Su Hydro study groups captured 37 rainbow trout.

The maximum seasonal catch of 168 rainbow trout (all gear types) was recorded in late July. Relatively high catches were also recorded in early (43) and late (41) September (Table 2).

3.1.2 Movement and migration

Twenty-nine rainbow trout were radio tagged at ten different sites on the Susitna River between the Chulitna River confluence and Devil Canyon from May 12 to October 5, 1983. Eighty-three percent of these radio tagged rainbow trout were captured and released at the mouths of tributary streams. Appendix Table B-1 presents a summary of capture and biological data for the individual radio tagged fish. Individual movements of radio tagged rainbow trout during 1983 are presented in Figures 2-5. During the tracking period, ten radio tagged rainbow trout moved downriver over 0.5 mile, four moved upriver over 0.5 mile and seven had both downstream and upstream movements over 0.5 mile. The remaining five radio tagged rainbow trout moved less than 0.5 mile throughout the tracking period. Eighteen rainbow trout moved downstream from 0.1 to 26.7 miles (average of 6.9 miles), with most of the downstream movement occurring after September 1. Eleven rainbow trout moved upstream from 0.4 - 12.0 miles, with an average upstream move of 2.4 miles.

During 1983, one radio tagged rainbow trout was reported caught by a sport fisherman. This rainbow trout (648-1.6) was radio tagged on June 7th in Whiskers Creek (TRM 0.1) and recaptured by a sport fisherman on

Table 2. Rainbow trout catch on the Susitna River between the Chulitna River confluence and Devil Canyon, May to October 1983.

Study Group	May 1-15	May 16-31	June 1-15	June 16-30	July 1-15	July 16-31	Aug 1-15	Aug 16-31	Sept 1-15	Sept 16-30	Oct 1-15	Total
Resident Fish Study												
Boat Electrofishing	-	17[a/]	14	11	5	15	4	5	26	30	24	151
Other Gear	6	1	22	21	0	145	2	17	15	9	2	240
Juvenile Anadromous Habitat Studies (JAHS)	0	0	1	0	1	4	1	1	1	2	0	11
Downstream Migrant Trap	-	0	0	0	2	3	4	3	0	0	-	12
Fishwheel sites	-	-	1	1	5	1	2	3	1	-	-	14 [b/]
Total	6	18	38	33	13	168	13	29	43	41	26	428

- = No effort

a/ One rainbow was captured below the Chulitna River confluence.

b/ Seven rainbows were captured in fishwheels below the Chulitna River confluence. Yentna Station (RM 27.5, TRM 4.0) capturing three in early July. The remaining four were captured during early June, early August, late August, and in September at Sunshine Station (RM 79.0).

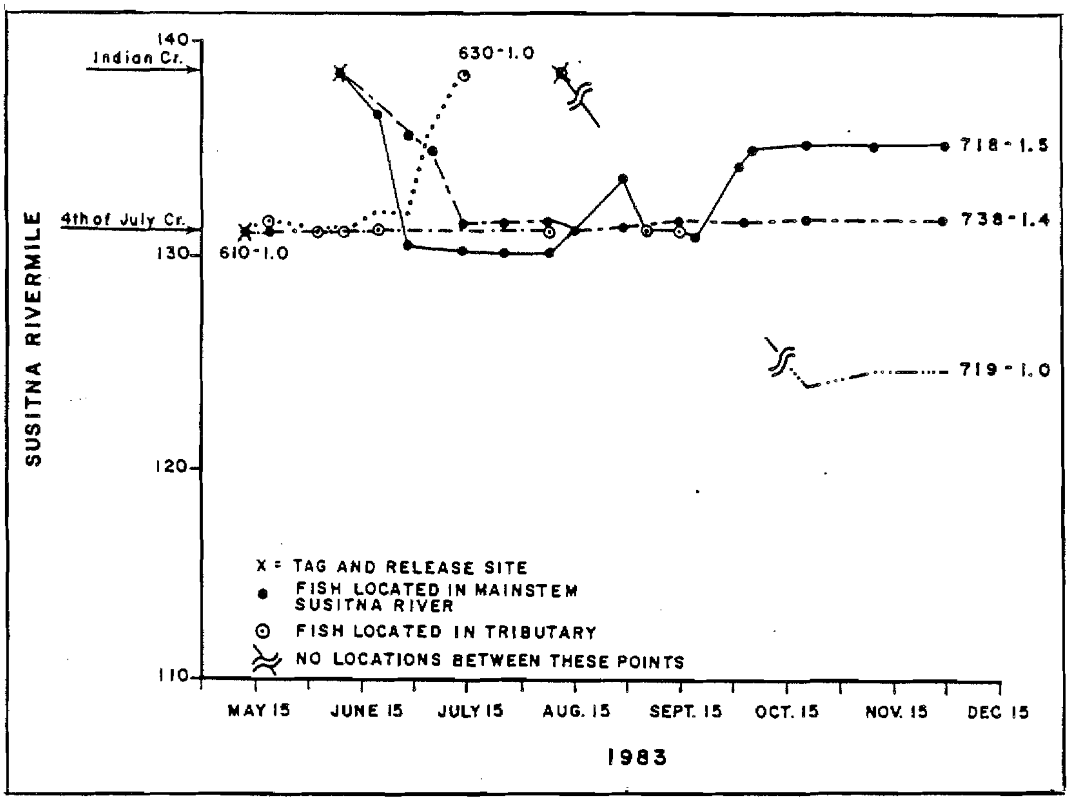


Figure 2. Movement of five radio tagged rainbow trout in the Susitna River below Devil Canyon, May to December 1983.

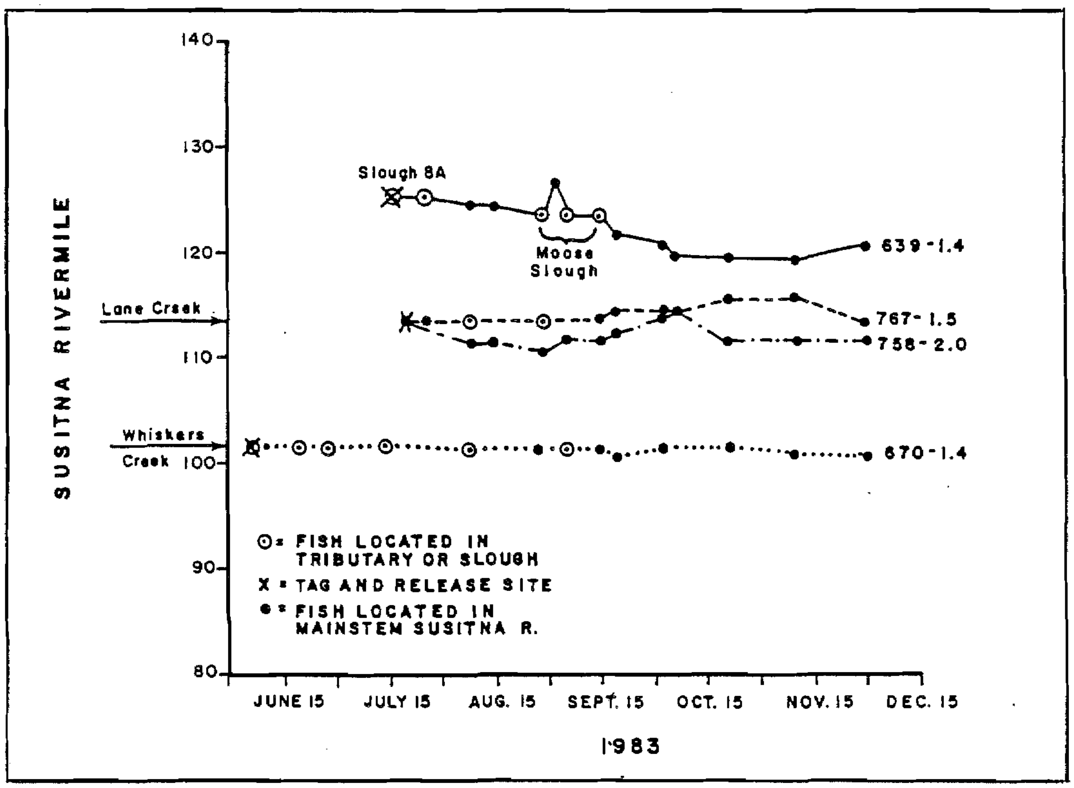


Figure 3. Movement of four radio tagged rainbow trout in the Susitna River below Devil Canyon, June to December 1983.

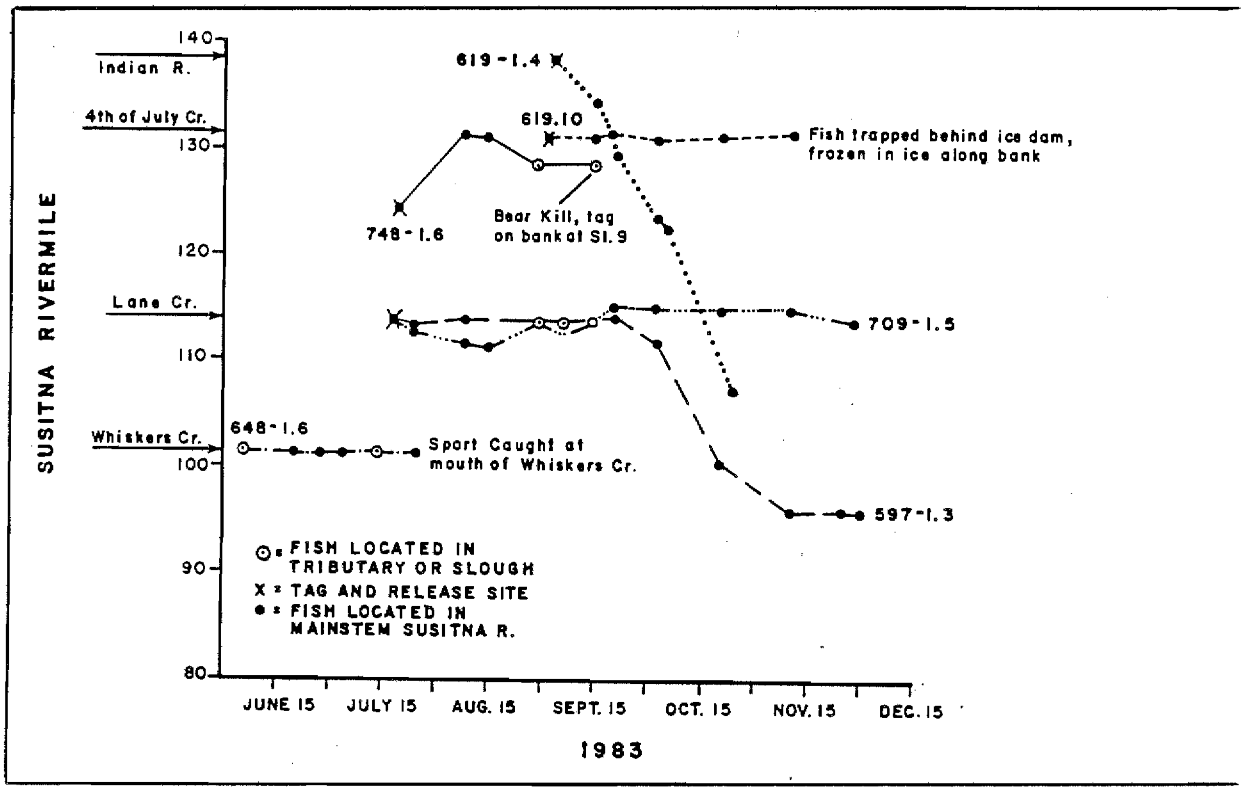


Figure 4. Movement of six radio. tagged rainbow trout in the Susitna River below Devil Canyon, June to December 1983.

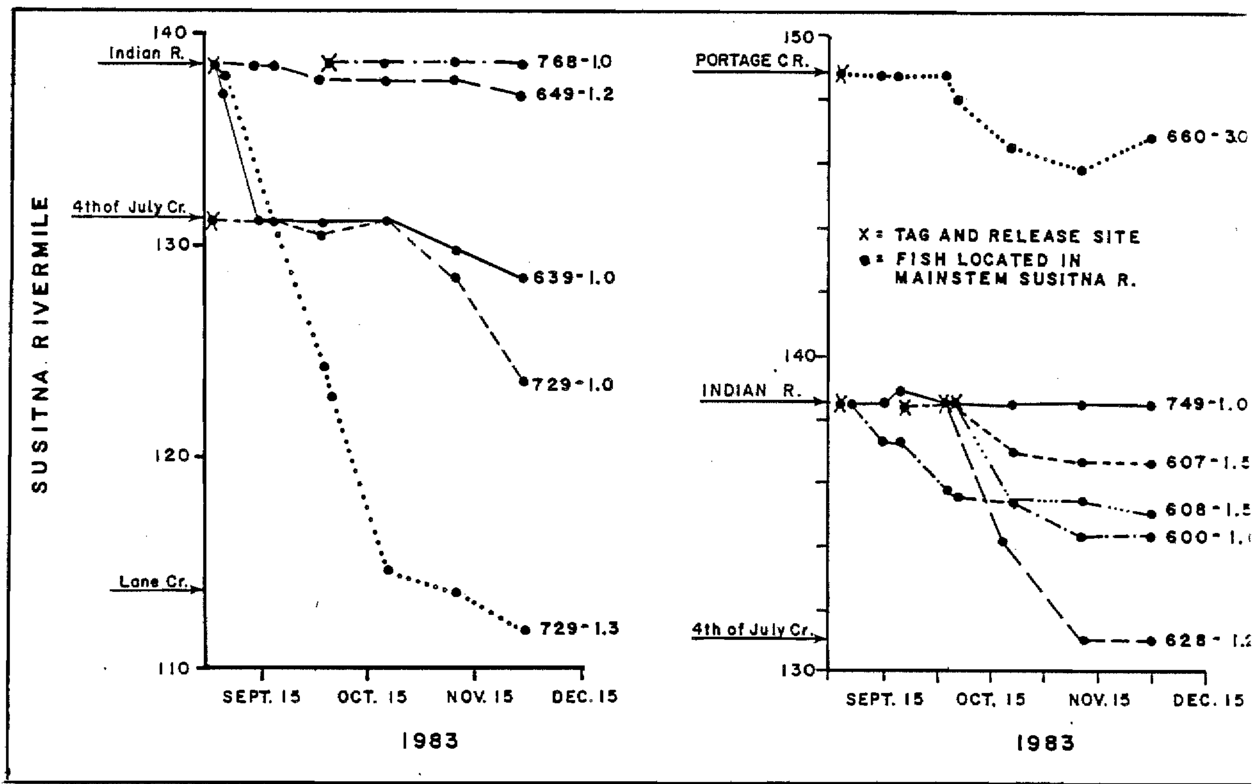


Figure 5. Movement of eleven radio tagged rainbow trout in the Susitna River below Devil Canyon, September to December 1983.

August 8th at the mouth of Whiskers Creek (TRM 0.0). The angler reported that the rainbow trout was in excellent condition and that the sutured incision had healed nicely. Radio tracking data showed that this rainbow trout did move short distances above and below the tagging site before being recaptured, but it largely stayed in the same general area for summer rearing.

Three of the 29 radio tagged rainbow trout provided little or no movement and migration data. One rainbow trout (668-1) radio tagged by the under-the-skin method either dropped its transmitter or died in Moose Slough (RM 123.5). When the slough's water became clear during September, neither the rainbow trout or transmitter could be found. Thereafter, rainbow trout radio tags were surgically implanted. Only one rainbow trout (628-2) was presumed to have been injured from the tagging or capture process during 1983. Immediately following its release, this rainbow trout moved rapidly downriver and was extremely lethargic when recaptured by boat electrofishing 20 days later. A third radio tagged rainbow trout (659-1.8) was injured when it was accidentally recaptured by boat electrofishing and it also moved rapidly downstream. With the exception of these three rainbow trout, it appeared that the remaining radio tagged rainbow trout exhibited normal behavior after being radio tagged.

Floy anchor tagged rainbow trout also provided information on rainbow trout movements. During 1983, 275 rainbow trout were Floy anchor tagged and 35 recoveries were made. Five rainbow trout were recovered at the same site where they were tagged. Sixteen rainbow trout were recovered within 5.0 miles of their tagging site. The remaining 14 rainbow trout were recaptured an average of 18.7 miles from where they were tagged. Ninety-four percent of the recaptured rainbows were recovered in or at mouths of tributaries such as Fourth of July Creek (12, RM 131.1) and Clear Creek (4), a tributary 6.0 miles up the Talkeetna River (RM 97.0). The most rapid movement recorded for a rainbow trout in 1983 was an upstream movement of 37.4 miles in 40 days during the spring. The maximum movement documented for all rainbow trout tagged to date was 53.0 miles by a rainbow trout tagged on July 19, 1982 at Jack Long Creek (RM 144.5) and recaptured at Clear Creek (TRM 0.0) on June 30, 1983.

3.1.3 Population estimates

The population estimate of rainbow trout in Fourth of July Creek between TRM 0.0-0.8 using the behavioral model from the CAPTURE computer program was determined to be 107 rainbow trout. The standard error of this estimate was 15.10 and the 95% confidence interval was from 82-137. The catch during the three day sampling period was 42, 22 and 18 respectively; in addition, eight fish were recaptured.

3.2 Burbot

3.1.2 Distribution and relative abundance

A total of 163 burbot were captured in the Susitna River between the Chulitna River confluence and Devil Canyon during 1983 (Table 3). Most (78 of 118) of the burbot captured by resident fish biologists were

Table 3. Burbot catch on the Susitna River between the Chulitna River confluence and Devil Canyon, May to October 1983.

Study Group	May 1-15	May 16-31	June 1-15	June 16-30	July 1-15	July 16-31	Aug 1-15	Aug 16-31	Sept 1-15	Sept 16-30	Oct 1-15	Total
Resident Fish Study Boat Electrofishing	-	7	5	3	4	13	10	0	10	8	2	62
Other Gear	0	16	0	6	13	0	5	0	0	16	0	56
Juvenile Anadromous Habitat Studies(JAHS)	0	2	0	5	2	2	2	4	1	0	0	18
Downstream Migrant Trap	-	1	8	3	1	1	4	4	0	0	-	22
Fishwheel sites	-	-	0	0	0	4[a]	0	0	1[b]	-	-	5
Total	0	26	13	17	20	20	21	8	12	24	2	163

- = No effort

a/ One burbot was captured in a fishwheel at Yentna River Station (RM 27.5, TRM 4.0).

b/ One burbot was captured in a fishwheel at Sunshine Station (RM 79.0).

caught in the mainstem Susitna River or side channel sites. Burbot were most abundant at mainstem RM 139.6 (18 burbot), mainstem RM 102.5 (16 burbot), and mainstem RM 147.0-148.0.

3.2.2 Movement and migration

From August 18 to September 3, 1983, four burbot were radio tagged on the Susitna River between RM 113.6 and RM 147.5. A summary of 1983 data for radio tagged burbot is presented in Appendix Table B-2.

Radio tagged burbot movements were variable (Figure 6). One radio tagged burbot (610-3) remained within 3.6 miles of its capture site for three months. Two other radio tagged burbot (639-3 and 720-3) moved slowly downstream after their release 11.9 and 13.6 miles, respectively, and remained at these locations. Between its release on September 1 and October 21, radio tagged burbot (670-3) moved 36.5 miles downstream. Three radio tagged burbot also made small movement upstream. Burbot (610-3) moved upstream 2.5 miles, burbot (720-3) moved upstream 0.6 miles, and burbot (670-3) moved upstream 0.4 miles.

One hundred eight burbot were Floy anchor tagged and three burbot were recaptured in 1983. Movements exhibited by these burbot were minimal. All three Floy anchor tagged burbot were recaptured with 0.1 miles of their tagging location.

3.2.3 Population estimates

The burbot population estimate for the mainstem Susitna River between RM 138.9-140.1 was 15 burbot with a standard error of 4.18 and a 95% confidence interval of 13-24 burbot. The catch was 6, 1, 4 and 2 respectively for the four days sampled; no burbot were recaptured.

3.3 Arctic Grayling

3.3.1 Distribution and relative abundance

A total of 1,165 Arctic grayling were captured on the Susitna River between the Chulitna River confluence and Devil Canyon in 1983 (Table 4). Arctic grayling were most abundant at a mainstem site (RM 137.3-138.3) where 195 Arctic grayling were captured. Other sites where more than 60 Arctic grayling were captured are Lane Creek (RM 113.6), Indian River (138.6) and Portage Creek (RM 148.8). Catches of Arctic grayling were high in the spring at Whiskers Creek Slough (RM 101.2) and at RM 150.1 in the mainstem. During the summer, most Arctic grayling were captured in late May - early June and in September. The maximum Arctic grayling catch by all gear types (307 fish) was recorded in late September.

3.3.2 Movement and migration

Seven hundred sixty-five Arctic grayling were Floy anchor tagged and forty-one Arctic grayling were recaptured in 1983. Sixty-one percent of the recovered fish were from fish tagged in 1981 or 1982. Recaptured Arctic grayling movements ranged from 0.0 to 29.4 miles with an average

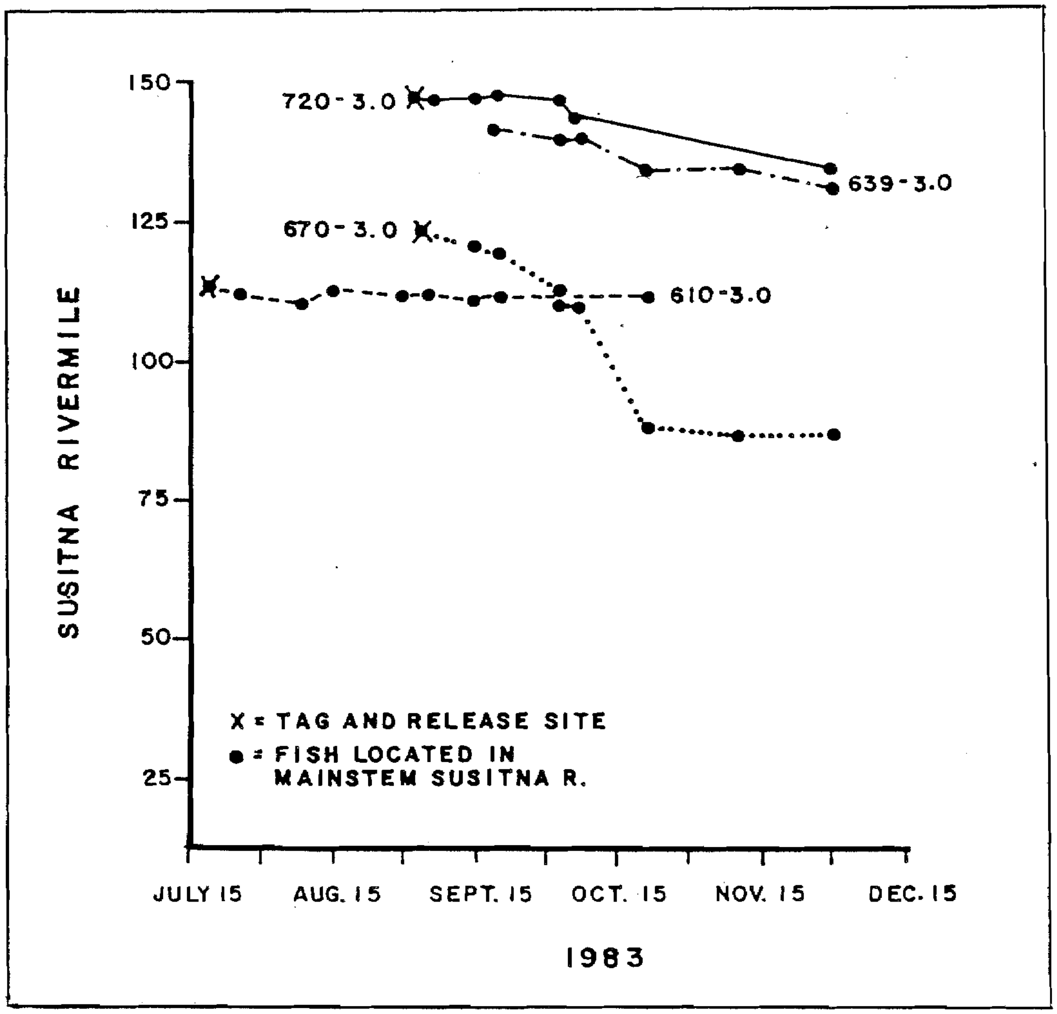


Figure 6. Movement of four radio tagged burbot in the Susitna River below Devil Canyon, July to December 1983.

Table 4. Arctic grayling catch on the Susitna River between the Chulitna River confluence and Devil Canyon, May to October 1983.

Study Group	May 1-15	May 16-31	June 1-15	June 16-30	July 1-15	July 16-31	Aug 1-15	Aug 16-31	Sept 1-15	Sept 16-30	Oct 1-15	Total
Resident Fish Study Boat Electrofishing	-	136[a]	126	72	19	89	57	12	169	299	35	1,014
Other Gear	0	29	7	17	6	5	4	7	2	8	1	86
Juvenile Anadromous Habitat Studies(JAHS)	0	0	0	0	9	3	6	3	0	0	0	21
Downstream Migrant Trap	-	1	5	13	8	4	5	1	0	0	-	37
Fishwheel sites	-	-	1	2	0	1	1	2	5	-	-	12 [b]
Total	0	166	139	104	42	102	73	25	176	307	36	1,170

- = No effort.

a/ Two Arctic grayling were captured below Chulitna River confluence.

b/ Three Arctic grayling were captured in fishwheels at Sunshine Station (RM 79.0). One was caught in late August and two were caught in September.

movement of 5.4 miles. About half (19) of the 43 recaptured Arctic grayling were recaptured at their tagging sites. Another six Arctic grayling were recovered within 5.0 miles of their tagging sites. The remaining 18 Arctic grayling recaptures moved an average of 12.5 miles from their tagging locations. Thirty of the 43 recoveries were made in tributaries or at tributary mouths. Eight Arctic grayling were recaptured at Fourth of July Creek (RM 131.1) and seven at Lane Creek (RM 113.6).

3.4 Round Whitefish

3.4.1 Distribution and relative abundance

A total of 4,917 round whitefish were captured in 1983 on the Susitna River between the Chulitna River confluence and Devil Canyon (Table 5). Many of the round whitefish were juveniles (< 200 mm) captured by two downstream migrant traps at RM 103.0.

The analysis of variance on the round whitefish catch at juvenile salmon rearing sites (JAHS sites) , which was almost all juvenile fish, showed that time of year had a significant effect on the catch rate (Part 2 of this Report). Juveniles were captured mainly in July and August at the JAHS sites; however, sampling efforts in their preferred habitat (turbid side sloughs and side channels) was minimal in June. The fish were in the river and moving earlier than July as evidenced by the catch at the downstream migrant traps (also almost all juveniles) in June.

Adult round whitefish (≥ 200 mm) were most abundant at a mainstem site between RM 147.0-RM 148.0. Other sites where over 100 adult round whitefish were captured were Slough 8A (RM 125.3), a mainstem site between RM 137.3-138.3, Indian River (RM 138.6), Jack Long Creek (RM 144.5), and Portage Creek (RM 148.8). Boat electrofishing catches of round whitefish were the highest in early September. Relatively high catches were also made in early June, late July, late September, and October.

3.4.2 Movement and migration

During 1983, 1,081 round whitefish were Floy anchor tagged and 73 round whitefish were recovered. Most of the 36 recoveries were from round whitefish tagged in 1982. The maximum downstream movement for round whitefish was 69.5 miles and the maximum upstream movement was 17.0 miles.

Thirty round whitefish were recaptured at sites where they were originally tagged. Twenty-seven were recaptured within 5.0 miles of their tagging locations. The remaining 16 tagged round whitefish moved an average of 18.5 miles downstream before being recaptured.

Thirty-three of round whitefish tag recaptures were made at tributary mouths and two were made 3.0-5.0 miles upstream of tributary mouths. Another 29 were recovered in the mainstem and the remaining nine were recovered in sloughs.

Table 5. Round whitefish catch on the Susitna River between the Chulitna River confluence and Devil Canyon, May to October 1983.

Study Group	May 1-15	May 16-31	June 1-15	June 16-30	July 1-15	July 16-31	Aug 1-15	Aug 16-31	Sept 1-15	Sept 16-30	Oct 1-15	Total
Resident Fish Study												
Boat Electrofishing	-	58[a/]	138	60	106	244	100	8	270	174	161	1,319
Other Gear	0	6	21	0	4	3	0	0	1	6	2	43
Juvenile Anadromous Habitat Studies(JAHS)	0	0	0	0	307	99	172	41	9	1	0	629
Downstream Migrant Trap	-	5	56	871	1,539	295	66	59	9	1	-	2,901
Fishwheel sites	-	-	2	4	0	3	0	23	16	-	-	48 [b/]
Total	0	69	217	935	1,956	644	338	131	305	182	163	4,940

- = No effort.

a/ Three round whitefish were captured below the Chulitna River confluence.

b/ Twenty round whitefish were captured below the Chulitna River confluence. Fishwheels at Yentna Station (RM 27.5, TRM 4.0) captured two in August. Fishwheels at Sunshine Station(RM 79.0) captured one in early June, one in late June, six in August, and 10 in September.

3.5 Humpback Whitefish

3.5.1 Distribution and relative abundance

Eight hundred twenty humpback whitefish (*Coregonus pidschian*) were captured in the Susitna River during 1983 with most (83.5%) being captured above the Chulitna River confluence (Table 6). Downstream migrant traps (RM 103.0) and fishwheels captured the majority (92.6%) of the humpback whitefish.

A total of 466 juvenile humpback whitefish (< 200 mm) were captured by two downstream migrant traps. The maximum catch of humpback whitefish at the downstream migrant traps occurred during late July. Relatively high catches were also recorded during early July and early August.

Fishwheels captured 293 adult humpback whitefish. Fishwheels at Yentna River station (RM 28.5, TRM 4.0) captured 60.8% of the humpback whitefish caught by fishwheels. The maximum seasonal humpback whitefish catch (137 fish) by fishwheel was recorded in late August.

Boat electrofishing catches of humpback whitefish (36) were most numerous at the mouth Slough 8A (RM 125.3). Gill net and hoop net humpback whitefish catches (14) were greatest in Slough 6A (RM 112.3). JAHS crews captured nine juvenile humpback whitefish in Slough 22 (RM 144.3) with beach seines.

3.5.2 Movement and migration

In 1983, 329 humpback whitefish were tagged with Floy anchor tags. Three tagged humpback whitefish were recaptured in 1983. One recaptured humpback whitefish moved upriver 17.0 miles in two days. A second tagged humpback whitefish moved downriver 11.0 miles in 43 days. The third humpback whitefish, tagged in 1982, moved downriver 8.7 miles in one year.

3.6 Longnose Suckers

3.6.1 Distribution and relative abundance

A total of 713 longnose suckers were captured in the Susitna River in 1983 (Table 7). All but 20 of these were captured in the Susitna River between the Chulitna River confluence and Devil Canyon.

Boat electrofishing longnose sucker catches were most abundant at Slough 8A (RM 125.3), Lane Creek (RM 113.6), Fourth of July Creek (RM 131.1), a mainstem site between RM 147.0-RM 148.0, and Portage Creek (RM 148.8) during late July and early August.

Juvenile longnose suckers (< 200 mm) were captured incidentally by beach seines and backpack electroshocker at mainstem and slough sites by JAHS crews. Longnose sucker juveniles captured at JAHS sites were most abundant at Mainstem II (RM 114.4). The downstream migrant traps at RM 103.0 also captured 111 juvenile longnose suckers.

Table 6. Humpback whitefish catch on the Susitna River between the Chulitna River confluence and Devil Canyon, May to October 1983.

Study Group	May 1-15	May 16-31	June 1-15	June 16-30	July 1-15	July 16-31	Aug 1-15	Aug 16-31	Sept 1-15	Sept 16-30	Oct 1-15	Total
Resident Fish Study Boat Electrofishing	-	0	0	2	7	18	2	0	3	4	0	36
Other Gear	0	0	14	0	0	0	0	0	0	0	0	14
Juvenile Anadromous Habitat Studies(JAHS)	0	0	0	0	9	1	1	0	0	0	0	11
Downstream Migrant Trap	-	0	0	11	93	228	92	40	2	0	-	466
Fishwheel sites	-	-	3	6	33	81	15	137	18	-	-	293[a/]
Total	0	0	17	19	142	328	110	177	23	4	0	820

- = No effort.

a/ A total of 235 humpback whitefish were captured below the Chulitna River confluence. Yentna Station fishwheels (RM 27.5, TRM 4.0) captured 178 and Sunshine Station fishwheels (RM 79.0) captured 57. Yentna Station humpback whitefish catch by two week periods from early July to early September was 28, 59, 11, 76, and 4, respectively. Catch at Sunshine Station by two week periods from early June to early September was 3, 1, 0, 1, 2, 45, and 5, respectively.

Table 7. Longnose sucker catch on the Susitna River between the Chulitna River confluence and Devil Canyon, May to October 1983.

Study Group	May 1-15	May 16-31	June 1-15	June 16-30	July 1-15	July 16-31	Aug 1-15	Aug 16-31	Sept 1-15	Sept 16-30	Oct 1-15	Total
Resident Fish Study Boat Electrofishing	-	3	20	29	37	37	85	0	90	43	5	349
Other Gear	0	26	32	2	19	4	0	0	3	1	6	93
Juvenile Anadromous Habitat Studies(JAHS)	1	6	2	8	14	11	26	29	21	4	0	122[1]
Downstream Migrant Trap	-	3	30	6	10	14	11	35	2	0	-	111
Fishwheel sites	-	-	2	4	11	12	0	7	2	-	-	38
Total	1	38	86	49	91	78	122	71	118	48	11	713

- = No effort

1 Three fish were captured below the Chulitna River confluence with one being captured in late May and two in early June.

2 Seventeen fish were captured below the confluence with Yentna station (RM 27.5, TRM 4.0) capturing two in early July, six in late July and one in early September. The remaining nine fish were captured at Sunshine station (RM 79.0) with one being captured in early June, two in early July, one in late July, three in late August, and one in early Septembber.

3.6.2 Movement and migration

During 1983, 467 longnose suckers were tagged with Floy anchor tags and 24 longnose suckers were recaptured. Six longnose suckers were recaptured at their tagging sites and another seven were recaptured less than 5.0 miles from their tagging sites. Six tagged longnose suckers moved downriver (5.0 to 47.6 miles) and five moving upriver (5.0 to 36.9 miles). The average movement of the 11 fish which moved over 5.0 miles was 18.5 miles.

The most rapid movement recorded for a tagged longnose sucker was 25.5 miles over a period of 15 days. This longnose sucker was tagged on June 6 at Slough 6A (RM 112.3) and recaptured on June 21 at mainstem RM 137.8.

3.7 Other Species

3.7.1 Dolly Varden

A total of 47 Dolly Varden were captured in the Susitna River in 1983. Most (89%) of these were captured in the Susitna River between the Chulitna River confluence and Devil Canyon. The largest Dolly Varden catches in this reach of river were made at the mouth of Portage Creek (30%) and at the mouth of Indian River (19%).

During 1983, 12 Dolly Varden were tagged and two were recaptured. One fish was recaptured at Kashwitna River (RM 61.0) and the other recaptured at Clear Creek, a tributary of the Talkeetna River (RM 97.0, TRM 6.0). Both fish had moved upriver (2.5 miles and 10.0 miles, respectively) from their tagging site.

3.7.2 Threespine stickleback

A total of 1,834 threespine stickleback (*Gasterosterus aculeatus* Linnaeus) were captured in 1983. Downstream migrant traps at RM 103.0 captured 1,601 and the remaining fish were captured incidentally by JAHS crews with beach seines or backpack electroshockers. Among the JAHS sampling sites threespine stickleback were most abundant at Slough 5 (RM 107.6). Most threespine stickleback young of the year were captured in early August.

3.7.3 Arctic lamprey

A total of 69 Arctic lamprey (*Lampetra japonica* Martens) were captured in the Susitna River in 1983. Forty-four were captured by the downstream migrant trap at RM 103.0. Arctic lamprey catches at the downstream migrant traps were highest in late May and late June. The remaining Arctic lamprey were captured with a backpack electroshocker at Chase Creek (RM 106.9) in late August.

4.0 DISCUSSION

4.1 Rainbow Trout

The 1983 studies provided considerable information about the distribution of rainbow trout in the Susitna River between the Chulitna River confluence and Devil Canyon. The deployment of radio tags yielded over 6 months of data on the distribution of rainbow trout and gave new insights into their movement which previously had been hypothesized from catch per unit effort data. In Part 6 of this report, the distribution of this species by macro and microhabitat is described. Although our data is somewhat limited in the early spring, the seasonal distribution of rainbow trout within the Susitna River system is reasonably well documented. The following discussion includes descriptions of what we have learned about the life history of this species and its vulnerability to altered conditions in the mainstem Susitna River. We have also established index areas (Table 1) and have estimated the population size of rainbow trout in one of the tributaries (Fourth of July Creek) important to this species.

Rainbow trout catch rates in 1981 and 1982 in the mainstem Susitna rapidly dropped off after June suggesting movement out of mainstem areas and probably into tributaries. This movement was verified by random sampling of the upper reaches of tributaries during 1983 and reinforced by studies of radio tagged fish during the summer. The highest catches of rainbow trout were recorded in Fourth of July Creek where significant spawning activity was documented. Minnow trap catches of juveniles rainbow trout during 1983 was the highest recorded since the onset of these studies in 1981. Spawning occurred in late May-early June as suggested by the capture of pre- and post-spawned adults and movements into Fourth of July Creek by two radio tagged fish. Movements of radio tagged fish out of this tributary after spawning suggests that at least some of the fish will emigrate from their spawning tributaries to other forage areas.

Random sampling for rainbow trout was conducted during 1983 in most tributaries of the Susitna River between the Chulitna River confluence and Devil Canyon. Fourth of July Creek had the highest concentration of rainbow trout as reflected by the CPUE. These data suggest that adult rainbow trout move into tributaries during the spring to spawn and some of these fish remain in the tributaries throughout the summer.

Examination of the limiting factors during the life cycle of rainbow trout will help evaluate the vulnerability or the enhancement potential of this species under postproject conditions. The comparatively small numbers of juvenile rainbow trout collected, during the three years of this study suggests reproduction could be limiting or survival of juvenile is very low. Our survival data suggests this species shows a relatively high turnover rate compared with other species but not necessarily a younger age of maturity.

Catch rates of juvenile (<200 mm, Age 3) rainbow trout in Indian River and Portage Creek have been very low suggesting poor rearing or low spawning success in these major tributaries (ADF&G 1981c; 1983b). In contrast, the catch of juvenile rainbow trout in Fourth of July Creek in 1983 was the highest recorded since resident fish studies began in 1981. Because so few juvenile rainbow trout have been captured in the mainstem it appears that the juveniles primarily rear in the upper reaches of tributaries and move little.

Radio tagged rainbow trout using the mainstem Susitna for summer rearing were often located near tributary mouths, especially from August through mid-September. The association of rainbow trout with tributaries during this period coincides with the timing of spawning chum and pink salmon (Barrett et al. 1984). The concentration of rainbow trout at tributary mouths and their periodic ascents into tributaries is believed to be due to the abundance of food (salmon eggs) in these areas. Rainbow trout, presumably feeding on salmon eggs, were observed being chased from spawning redds by male chum salmon (Part 6 of this report). The abnormally expanded ventral body cavities of other rainbow trout captured in August and September in both 1982 and 1983 also provide evidence of rainbows foraging on salmon eggs.

In addition to the concentration of rainbow trout at tributaries during summer periods, radio tagged rainbow trout were observed holding in several sloughs [Moose (RM 123.5), A^1 (RM 124.6), 8A (RM 125.3), and 9 (RM 128.3)]. The use of these sloughs by radio tagged rainbow trout in August and September coincided with the presence of spawning chum salmon in these same sloughs (Barrett et al. 1984). Although high turbidities prevented actual observation in most of these instances, it is suspected that these fish were in the sloughs to feed on salmon eggs. This hypothesis is substantiated in one case; one radio tagged rainbow trout was observed in Slough A^1 milling around spawning chum salmon in an area of clear water (Barry Stratton pers. comm.)

Areas of the mainstem Susitna River not influenced by tributaries or sloughs were also used during summer months by radio tagged rainbow trout. The mainstem, however, appears to be more of a migration path between tributaries and sloughs rather than a holding area during the open water season.

By mid-September, all radio tagged rainbow trout in tributaries had descended to the mouths. This movement supports the hypothesis that most adult rainbow trout outmigrate from tributaries during fall to overwinter in the mainstem (ADF&G 1983b). The hypothesis is further supported by the increased catch rate of rainbow trout at tributary mouths in September. Rainbow trout in the middle Susitna River are vulnerable to sport fishing during these fall outmigrations. Local anglers take advantage of the outmigration at the mouth of Indian River (RM 138.6) each fall. As the Susitna River basin continues to develop, the rainbow trout population may decline from the increased fishing pressure.

Beginning in October, radio tagged rainbow trout began to move away from tributary mouths into the mainstem Susitna River. By early December only six of 20 radio tagged rainbow trout were within the influence of a tributary. Because of the difficulty of characterizing winter habitat, we are uncertain why radio tagged rainbow trout seek mainstem areas in the winter.

The recaptures of six Floy anchor tagged rainbow trout at Clear Creek in the Talkeetna River drainage suggests that this tributary may be an important summer rearing area for adult rainbow trout. Tag deployment data indicated that these rainbow trout also overwinter in the mainstem Susitna River between RM 77.0 and RM 87.0.

The final activity pursued during the 1983 studies was the establishment of index areas to monitor annual changes in the populations of rainbow trout and other species. Population (density) estimates were planned for five sites but were found to be unfeasible because of low capture rates. Only the lower reach of Fourth of July Creek had sufficient numbers of rainbow trout recaptures to generate a population estimate (107 fish greater that 150 mm FL.). A discussion of the methodological problems of estimating population sizes for resident fish in this system and other areas are included in Appendix D. Catch per unit effort data will probably have to suffice as an estimator of site specific densities of resident species. An examination of the annual recovery of tagged fish as a percentage of tags deployed provides a more robust perspective of the population of rainbow trout in this reach. A true "population" estimate cannot be made from this data because of lack of randomness of the sample over the entire reach, mortality between years, emigration, etc. Nevertheless, our tagging efforts have been broadly distributed in habitats associated with the mainstem Susitna in this reach. The movements of radio tagged fish also suggests that our samples include fish from throughout the basin rather than representing only the specific locale where they were collected. Of 92 rainbow trout tags deployed in this reach in 1981, only seven out of 221 rainbow trout captured in 1982 were tagged recaptures from fish tagged in 1981. If no mortality or recruitment were considered, this would provide an estimate of about 2,581 rainbow trout. Using 1982 and 1983 data the population estimate for rainbow trout (5,057) is low.[2/] However, our mortality estimate for rainbow trout suggests high mortality of the post-spawning fish, which when coupled with recruitment would substantially reduce this estimate, probably by over half. This must be tempered with the non-randomness of the sampling effort, which probably eliminated significant portions of the population from sampling effort and decreased the estimate.

2/ In 1983, 10 out of 365 rainbow trout (> 200 mm) recaptures were tagged in 1982. A total of 151 rainbow trout were tagged on the Susitna River in 1982 between the Chulitna River confluence and Devil Canyon. The population estimate equation used was:

$$N = \frac{(X+1)(Y+1)}{(Z+1)}$$

where

N = Population estimate
X = Number of fish tagged in preceding year
Y = Number of fish tagged in current year
Z = Number of recaptures made in current year from fish tagged in preceding year

This order of magnitude estimate provides an approximation of the extent of the resource at stake in this basin and can be used as a starting point to assess potential management concerns if increased sport fishing pressure follows development of the hydroelectric project.

Current data indicates that rainbow trout in the Susitna River between the Chulitna River confluence and Devil Canyon use three primary tributaries for spawning [Whiskers Creek (RM 101.4), Lane Creek (RM 113.6) and Fourth of July Creek (RM 131.1)]. It is not known why only a few rainbow trout spawn in the larger Indian River (RM 138.6) and Portage Creek (RM 148.8) except that these rivers are close to the northernmost range of the species. With a better knowledge of rainbow trout spawning or rearing limitations in these two systems, possible enhancement of habitat within these tributaries could be made to increase rainbow trout populations.

While few rainbow trout have been captured during the springs of 1981 to 1983, data shows that spawning primarily occurs between late May to mid-June and that both sexes spawn after Age 5+.

The occurrence of so few juvenile rainbow trout ($<$ 100 fish captured or observed) in the mainstem or at tributary mouths suggests that spawning probably occurs in the upper reaches of tributaries. The low numbers of juveniles found in mainstem areas further implies that primary rearing of juvenile rainbow trout occurs in the upper reaches of tributaries.

Catch data from the upper reaches of three tributaries [Fourth of July Creek (RM 131.1, TRM 0.0-2.3), Indian River (RM 138.6, TRM 0.0-14.0) and Portage Creek (RM 148.8, TRM 0.0-10.0)] indicates a higher incidence of rainbow trout spawning in Fourth of July Creek than in the other two tributaries.

A further indication of the importance of Fourth of July Creek to rainbow trout spawning was made by examining the movements of two radio tagged rainbow trout captured and tagged in mid-May 1983 at the mouth of Fourth of July Creek. After their release, both fish migrated to the upper reaches of the tributary between TRM 1.0 and TRM 1.5. The radio tagged rainbow trout were prevented from moving upstream beyond TRM 1.8 by an apparent fish barrier; two waterfalls (2.1 and 3.9 meters high respectively) that are located back-to-back in the main channel with no plunge pool between them. No juvenile or adult resident fish or salmon were observed or captured above this barrier. Presumably both of these rainbow trout spawned between TRM's 1.0 and 1.5 in early June. After spawning, one of these fish dropped out of Fourth of July Creek and moved upriver into Indian River between late June and mid-July for summer rearing.

With habitat enhancement, Fourth of July could potentially become a greater producer of rainbow trout. While there are numerous pools for juvenile rearing in Fourth of July Creek from TRM's 0.6-1.8, there are few areas that appear to have suitable spawning gravel. Suitable spawning habitat does exist, however, above the barrier. Therefore a potential mitigation measures to enhance rainbow trout in the Susitna River between the Chulitna River confluence and Devil Canyon would be to remove the fish barrier at TRM 1.8 and allow rainbow trout to migrate further upstream and utilize the abundance of spawning gravel which exists there.

Rainbow trout growth and length data also suggest that reproduction is the major limiting factor to rainbow trout populations in the Susitna River. Age-length data taken during 1981-83 show rainbow trout are fast growers over all age classes (ADF&G 1981c; 1983b) Growth of Susitna stocks have been found to be similar to other nothern populations (ADF&G 1983f). Although Susitna rainbow trout are relative fast growers, they appear to have a short life span. Since 1981, the largest and oldest rainbow trout captured was 612 mm in fork length and nine years old. Using data from fish captured by hook and line and boat electrofishing, the survival rate for rainbow trout in the Susitna River was found to be only 33.3%. Reasons for the low survival rate are not known, however, hatchery personnel at Elmendorf report that mortalities of post-spawning male and female rainbow trout are exceedingly high, as do Scott and Grossman (1973). This may also be due to low egg and juvenile survival. In addition, another possible reason for the low survival rate of rainbow trout may be high overwintering mortalities. High winter mortalities of rainbow trout are most likely to result from physical catastrophes such as dewatering, collapsed snow banks, and anchor ice formation (Needham and Jones 1959; Needham and Slater 1945). Reimer (1957) found that physical catastrophes caused more mortalities than the lack of food availability.

4.2 Burbot

Burbot occupy the turbid waters of the mainstem Susitna and apparently rear and spawn in reaches directly influenced by mainstem flow. In the Susitna River, this species appears to avoid clear water areas although it is found over a broad range of conditions in other areas. Because of winter effects of regulated flow on water temperature and the potential for clearing of the mainstem Susitna, this species has a relatively high potential to be adversely affected by habitat alterations although increases in prey species may be a net benefit. Because alternative modes of operation of the project will probably influence turbidity levels appreciably, and the behavioral response to turbidity changes is the most likely effect on this species, we have focused our studies on monitoring this species to determine the extent of the resource at risk. The presence of juveniles in this reach suggests spawning occurs in this area but our efforts at data collection during the spawning season in January have not been sufficient to locate specific spawning sites. The spawning does not appear to be as important or concentrated as in major spawning areas in the lower river, such as the mouth of the Deshka River.

Burbot catches between 1981 and 1983 indicate that burbot seem to prefer mainstem sites or slough mouths rather than tributary mouths or tributaries in the Chulitna River confluence to Devil Canyon reach. In this reach, burbot are found more often in backwater areas, however they have also been captured in fast, shallow water.

Burbot movements in the Susitna River occur primarily before and after their spawning period in late January. Data collected during three years (1981-83) of monitoring 20 radio tagged fish show that instream migrations begin in September and last until March (ADF&G 1983b; 1983e). While most of the radio tagged burbot moved little during the spawning period, some have moved over ten miles with one moving 113.6 miles in 1982-83. This movement has been discussed previously in the 1982-83 winter report and fish tagged in 1983 show similar behavior (ADF&G 1983e). Although most movement information for burbot to date has been from fish radio tagged during the fall, one fish was monitored throughout the summer in 1983. This burbot (610-3.0) moved only 3.6 miles from its tagging site between July 19 to October 21 (Figure 6).

It appears that there is an adequate food supply for burbot in the mainstem Susitna during the summer. During 1982 and 1983, electrofishing crews captured few burbot near spawning salmon compared to other resident fish species. Although necropsied burbot have been found with salmon eggs in their stomachs, Morrow (1980) states that burbot are an omnivorous carnivore with a strong preference for fish.

A burbot population estimate study conducted in a one-mile reach of the mainstem estimated a population of 15 burbot. Because no recaptures were made, the confidence in this value is very limited. Although the removal method used in the estimate is quite robust, the low probability of capture makes the methodology somewhat suspect. A very high trap avoidance appears to be a characteristic of this species. This aspect of burbot behavior also limits the value of interpreting our annual tag recoveries with respect to population estimates of the entire reach. The very small percentage of tags deployed that were recovered suggest either high avoidance to recapture, high mortality of tagging, or very large populations. Monitoring changes in population by catch per unit effort appear to be the most reliable method for long term study of this species.

Catch data from 1981-83 shows few adult burbot captured in the Susitna River above the Chulitna River confluence compared to below the confluence (ADF&G 1981c, 1983b). In addition, relatively few juvenile burbot have been captured in the reach above the Chulitna River confluence. This leads us to believe that few burbot spawn in the Susitna River between the Chulitna River confluence and Devil Canyon. During intensive sampling by Juvenile Anadromous Habitat Studies (JAHS) in 1983 at 35 sites above the confluence, only 18 juvenile burbot were captured by beach seining or by backpack electroshocking. Catch data from the downstream migrant traps at RM 103.0 in 1982 (70 juvenile burbot) and 1983 (22 juvenile burbot) also supports the hypothesis that little spawning occurs above the confluence.

The exact spawning locations and numbers of burbot spawners in the reach above the Chulitna River confluence is not known. It is speculated that burbot spawning in this reach occurs primarily at the mouths of sloughs and in deep backwater areas influenced by ground water. Support for this theory are the juveniles found at Slough 9 in 1982, and the high numbers of adult fish found in deep backwater areas compared to other types of habitat. In addition, prior winter studies on the Susitna below the confluence suggest that spawning and rearing burbot seek areas of upwelling. This behavior could apply to areas above the confluence as well (ADF&G 1983e).

Age-length data for burbot captured between 1981 and 1983 show that Susitna River burbot grow rapidly up through Age 4 and then their growth rate slows to approximately 40 mm a year (ADF&G 1983e). To date, the oldest resident fish captured in the Susitna River was an Age 15 burbot.

Pooled age-length data from burbot captured between 1981 and 1983 showed that the survival rate is relatively high (70.5%). To pool the data in determining the instantaneous survival rate, we assumed that the survival rate was constant between years sampled. Since burbot live long and the mainstem where they reside is relatively stable between years, we believe the assumption was met.

Morrow (1980) states that burbot have a high reproductive capacity and their survival rate is quite high. Therefore the limiting factor for the burbot population in the Susitna River between the Chulitna River confluence and Devil Canyon may be the amount of acceptable habitat for spawning or rearing, or lack of food. Burbot production in this reach may be limited by one or several of these factors. Burbot are less numerous and appear to be slightly smaller for a given age class in this reach of river in comparison to the reach of river downstream of the Chulitna confluence (ADF&G 1981c, 1983b, 1983e). Susitna River burbot appear to grow faster than burbot studied in interior Alaska by Chen (1969). The mean total length of Age 5 burbot in the Susitna River was 453 mm and Chen reported a mean total length of 355 mm for the same age class in interior Alaska.

4.3 Arctic Grayling

Arctic grayling provide local sport fisheries at tributary mouths in this reach of the Susitna. Our data suggest that overwintering in mainstem areas may be of major importance for this species. Summer rearing of Arctic grayling in the mainstem Susitna appears to be limited to younger age class fish, apparently unable to maintain territories in the more favorable habitat of the clear water tributaries. The data we have obtained provides a basis to evaluate the population trends over time and changes in the populations in response to mainstem habitat changes and overwintering conditions.

Six sites which were sampled consistently by boat electrofishing in 1982 and 1983 and produced relatively high numbers of Arctic grayling were Whiskers Creek Slough (RM 101.2), Lane Creek (RM 113.6), Fourth of July Creek (RM 131.1), Indian River (RM 138.6), Jack Long Creek (RM 144.5), and Portage Creek (RM 148.8).

Tag and recapture data support the theory that most Arctic grayling spawn in tributaries. Recoveries of tagged fish in May and early June show movement into tributaries.

Boat electrofishing catch data in 1982 suggests that most of the large Arctic grayling move into tributaries immediately after ice out (ADF&G 1983b). In 1981, adult Arctic grayling were gillnetted in early May at open water tributaries when the mainstem was still partially covered with ice (ADF&G 1981c), indicating that Arctic grayling begin moving prior to the open water sampling. Boat electrofishing data from 1983 support 1981 findings. We did not monitor tributary temperatures which probably influence Arctic grayling movements more than ice cover on the mainstem and may also account for the differences in timing between years. Arctic grayling elsewhere in Alaska begin to migrate as the water temperature increases to about 1°C (Armstrong 1982).

Data from 12 spawning Arctic grayling captured at RM 150.1 in late May 1983 suggest that either mainstem spawning occurs there or that spawning occurs nearby. Since no Arctic grayling recaptures have been made above Devil Canyon (RM 150.1-161.0) from fish tagged below Devil Canyon and no tagged fish have been observed in the tributaries in the canyon [Cheechako Creek (RM 152.5), Chinook Creek (RM 156.8), and Devils Creek (RM 161.0)], it appears unlikely that lower or middle river Arctic grayling spawn above RM 150.1.

Higher CPUE's for Arctic grayling were recorded in late July during 1983 than in past years at the mouths of several tributary sites such as Indian River (RM 138.6) and Jack Long Creek (RM 144.5). We are not certain why this occurred, however, the drought which decreased the water levels in these tributaries during 1983 may have caused some Arctic grayling to move out of the tributaries earlier than in 1982.

Recaptures of Floy anchor tagged Arctic grayling show that a strong spring migration of Arctic grayling occurs in the Susitna River. In the summer, most Arctic grayling have been recaptured at or near their tagging locations. This suggests that Arctic grayling do not move far from their summer rearing areas. The outmigration of adult Arctic grayling from tributaries to the mainstem occur in September. Boat electrofishing CPUE's in 1982 and 1983 increased steadily from late August through late September and then decreased in early October. This suggests that most of the Arctic grayling have moved into the mainstem by the end of September.

Little is known about Arctic grayling distribution during the winter in the Susitna River. It is believed that many Arctic grayling overwinter in the mainstem Susitna, however, specific overwintering areas in the mainstem have not been identified. It is also believed that significant numbers of Arctic grayling overwinter in Portage Creek. This tributary is characterized by many deep (20 feet) pools which may provide adequate overwintering conditions for Arctic grayling. The proportion of the population that uses this habitat is not known.

The survival rate of Arctic grayling between the Chulitna River confluence and Devil Canyon is 56%, which is similar to the population above Devil Canyon. Although few individuals grow past 400 mm fork length or Age 8, there appears to be a high recruitment from the younger age classes, notably Ages 3 and 4.

Since reproduction is relatively high for Arctic grayling, the availability of rearing habitat may be a critical factor for this species (Scott and Crossman 1973). Studies in 1982 indicate that younger fish, Age classes 2 to 4, use the mainstem Susitna to a limited extents, probably due to their displacement from tributaries by the territorial behavior of the larger fish (ADF&G 1983b). Future changes in the availability of rearing habitat may be expected to directly affect the population size of Arctic grayling in the Susitna River.

The congregation of older Arctic grayling (>300mm) at the mouths of only a few selected streams between the Chulitna River confluence and Devil Canyon makes them vulnerable to overfishing. Local residents have stated that fishing for Arctic grayling has deteriorated since 1970 because of increased fishing pressure (Harold Larsen pers. comm.).

4.4 Round Whitefish

The distribution and abundance of round whitefish in the Susitna River between the Chulitna River confluence and Devil Canyon in 1983 was similar to findings in 1981 and 1982.

The catch of round whitefish has increased substantially each year since 1981 because of increased electrofishing efforts and the addition of downstream migrant traps. The deployment of a second downstream migrant trap off the west bank of the Susitna River (RM 103.0) contributed significantly to the increased round whitefish catch in 1983.

Pooled CPUE rates based on boat electrofishing data from 1982 and 1983 showed that CPUE's at tributary or slough sites were much higher than at mainstem sites above the Chulitna River confluence (ADF&G 1983b). During both years sampling efficiency appeared to be the same for mainstem and tributary or slough sites. Although boat electrofishing CPUE's of round whitefish are generally lower at mainstem sites compared to tributary sites, high CPUE's were recorded in the mainstem during June in both 1982 and 1983. Relatively high catch rates in the mainstem were also recorded in September of both years. Pooled boat electrofishing data from 1982 showed higher catch rates of round whitefish at all sites above the Chulitna River confluence than below. We speculated this was due to more preferable habitat in this reach of river. In 1983, mainstem boat electrofishing data pooled into three subreaches (RM 98.5 - 115.5, RM 115.6 - 138.5, and RM 132.6 - 150.1) showed that round whitefish are most abundant in the area between RM 132.6 - RM 150.1 in the Susitna River above the Chulitna River confluence.

Extensive sampling by JAHS crews above the Chulitna River confluence in 1983 showed that juvenile round whitefish are found more frequently at mainstem and slough sites than at tributary sites. Although it is unknown where they hatched, it is probable that round whitefish prefer areas with slow velocities and turbid water for rearing.

Seasonal boat electrofishing CPUE's at tributary sites above the Chulitna River confluence during 1982 were the highest in late June, late August and late September (ADF&G 1983b). It was speculated in 1982 that the high catches during June and September were due to migration of fish into and out of tributaries. A similar trend in movement was observed in the 1983 boat electrofishing CPUE data.

Most of the recaptured round whitefish from 1981-83 showed little movement. During this time, only 26 of 110 recaptured round whitefish moved over 5.0 miles (ADF&G 1981c, 1983b). Round whitefish recaptured in 1981 and 1982 exhibited a pronounced fall movement. In 1983 round whitefish exhibited a general downstream movement throughout the summer.

The longest move documented for a tagged round whitefish was 69.5 miles downriver from its tagging site. This fish was recaptured in 1983 by a sport fisherman at Willow Creek (RM 49.1).

While round whitefish spawning has not been observed in the mainstem, the distribution of sexually ripe males and females captured suggests that spawning probably occurs within mainstem areas. Sexually ripe male and female round whitefish have been found in the mainstem Susitna River during early October in 1981, 1982 and 1983.

Although few sexually ripe round whitefish were captured in 1981 and 1982, over 50 were captured in 1983. This was due to differences in sampling efficiencies rather than variability in timing of spawning. In 1983 extensive boat electrofishing was done in early October, while in 1981 and 1982 mechanical breakdowns of electrofishing equipment limited sampling during this time.

Since 1981, nine locations have been determined to be spawning sites for round whitefish in the mainstem Susitna according to the criterion used to determine a spawning site (female fish able to discharge eggs upon palpation). In 1981 and 1982 spawning was observed at RM 100.8 and RM 102.6, respectively. In 1983 seven sites were found including four mainstem sites (RM 102.0, RM 114.0, RM 142.0 and 147.0) and three tributary mouth sites [Lane Creek (RM 113.6), Indian River (RM 138.6) and Portage Creek (148.8)].

Catch data suggests that round whitefish spawning may occur throughout the mainstem. Sexually mature fish ($>$300mm) have been captured during October in locations characterized by slow to moderate water velocities with silt to rubble substrate. Most sexually ripe fish have been captured in pairs or small groups. Mass spawning behavior of round whitefish has been reported elsewhere (Normandeau 1969; Bryan and Kato 1975).

Large schools of adult round whitefish have also been captured at the mouth of Portage Creek and Indian River in late September. This may indicate that some round whitefish use these tributaries to spawn.

While catch data suggests that spawning areas of round whitefish are widespread in the mainstem, the selection of specific spawning sites may not be random. Anchor ice, water fluctuations and ice cover can all limit egg survival. Due to these reasons, round whitefish in the Susitna River may seek out areas which have an adequate influx of ground water. Habitat data taken at one mainstem site (RM 147.0 in 1983), where eight sexually ripe males and females were captured, supports this hypothesis. Specific conductance was relatively high (160 umhos/cm) in this area indicating an area of upwelling. This hypothesis is also believed to be true for another mainstem spawning species in the Susitna River, chum salmon (ADF&G 1983c).

There is probably an upstream spawning run of round whitefish in the fall. Spawning takes place at temperatures slightly above 0°C (Morrow 1980). Many of the juveniles subsequently migrate to the lower river for rearing during their first year as evidenced by the catch rate of juveniles in the downstream migrant traps.

Comparisons of 1981-1983 age-length data for round whitefish shows considerable differences in each age class. Although results are similar between 1981 and 1982, we believe the findings in 1983 are more accurate. Fish were probably underaged in 1981 and 1982. Although positive aging cannot be verified for fish of all three years, comparisons of the annuli of scales from fish initially tagged in 1982, and recaptured in 1983 provided better information on when round whitefish in the Susitna River form their annuli.

Age-length data in 1983 show that round whitefish are one of the older living resident fish species in the lower Susitna River with fish older than Age 8 occurring rather often. The oldest round whitefish found in the Susitna River by our crews was Age 12. Subsamples of aged fish also show that the population appears stable with fish captured frequently over all spawning age classes Age 5 and older.

Most round whitefish in the Susitna River have rather slow growth rates. This slow growth begins at Age 3, decreases steadily thereafter, and becomes almost non-existent after Age 10. Few round whitefish in the Susitna River attain fork lengths greater than 390 mm. However, scale analysis showed four fish experienced periods of extremely rapid growth. For example, one fish aged at four years old was 265 mm fork length while the mean fork length of 33 aged fish was 187 mm and the 95 percent confidence intervals ranged from 141-233 mm. This fish showed extremely rapid growth during the first and second years of its life. Based on recapture data and reports of round whitefish being found in brackish water (McAllister 1964; Morin et al. 1982) we believe that this fish may have migrated from the estuary. Tag-and-recapture data from 1981 to 1983 show that some round whitefish migrate long distances in the Susitna River.

4.5 Humpback Whitefish

Humpback whitefish have been found in the Susitna River from RM 10.1 to RM 150.1, however, they are captured infrequently except during certain time periods (ADF&G 1981c; 1983b). Sampling in 1981 and 1982 in the reach of river below and above the Chulitna River confluence (RM 98.5) further showed that humpback whitefish were more numerous in the reach of river below the Chulitna River confluence than above.

Although boat electrofishing in 1983 was limited to sampling above the confluence, the data show a similar humpback whitefish distribution and abundance in this reach of river as in prior years. Pooled boat electrofishing CPUE data in 1982 and 1983 reveal generally higher humpback whitefish densities at tributary or slough sites than at mainstem sites (ADF&G 1983b).

Fishwheel catches in 1982 and 1983 indicate similar yearly distributions and abundance of adult humpback whitefish. Peak catches at fishwheels during both years were in late August with 148 and 137 fish captured in 1982 and 1983 respectively.

Few juvenile humpback whitefish have been captured from 1981 to 1983 except by the downstream migrant traps (RM 103.0). It is currently unknown where most young juvenile humpback whitefish rear.

Morrow (1980) reports that adult humpback whitefish move little except during the spawning run beginning in June and lasting throughout September. In the Susitna River, fishwheel catches in 1982 and 1983 also reveal a spawning run occurs during this time period. Catches during both years peaked at Yentna (RM 28.5, TRM 4.0) and Sunshine (RM 79.0) in late August (ADF&G 1983b). High catches were also recorded at Talkeetna (RM 103.0) and at Curry (RM 120.0) in late August or early September. Fishwheel catch data recorded at Sunshine in 1981 reflect a similar a mid-September peak in catch (ADF&G 1981c). Susitan River humpback whitefish spawning is presumed to occur in October in tributaries.

Tag-recapture data on humpback whitefish is limited but seems to indicate a spawning or overwintering movement. Three fish tagged in September 1981 were recaptured in May or early July 1982, presumably before they migrated again in fall 1982. Since these fish were recaptured long distances (16-38 miles) downriver, it is thought that these fish were originally tagged during their upstream migration in September. After spawning, they returned downriver to overwinter where they were recaptured in 1982. In addition, two fish tagged and recovered in 1983 also show an upstream movement. One fish moved 11.0 miles from late June to mid-August, while another moved 17.0 miles in two days in mid-July, possibly an early spawning movement.

While little is known of juvenile humpback whitefish distribution and movement, downstream migrant trap catches in 1983 suggest that there is a downstream movement of juvenile humpback whitefish during late July. Nearly all of these fish were young of the year.

Comparisons of mean lengths of humpback whitefish by age class between 1981, 1982, and 1983 shows little differences. However, comparisons of humpback whitefish age-length data by reach indicate that fish below the Chulitna River confluence appear to be larger than fish between the Chulitna confluence and Devil Canyon (ADF&G 1981c; 1983b).

Scale analyses indicated that some humpback whitefish undergo a period of very rapid growth during their first two years of life. The data suggest that some humpback whitefish may spend part of their life history rearing in an estuarian environment. Elsewhere in Alaska, ADF&G (unpublished), Alt (1979) and Berg (1948), report that C. pidschian does not venture into estuary zones as often as other species of the humpback whitefish complex.

4.6 Longnose Sucker

Longnose suckers occur throughout the Susitna River below Devil Canyon, however, they appear to be more abundant in the reach of river below the Chulitna River confluence (RM 98.5) (ADF&G 1981c; 1983b). Boat electrofishing catches in 1982 and 1983 were higher at tributary and slough sites than at mainstem sites. Boat electrofishing data in both years showed higher CPUE's at tributary and slough sites above the confluence in August and September than in June or July. Longnose suckers may move into tributary and slough sites in August and September to feed on salmon eggs.

Recapture data indicate that adult longnose suckers are relatively sedentary. Thirty-two of 45 longnose suckers recaptured from 1981 to 1983 did not move over 5.0 miles from their tagging locations (ADF&G 1981c; 1983b).

Movements of the remaining 13 recaptured longnose suckers suggest an upstream migration occurs in the spring and a downstream movement occurs in the fall to overwintering areas.

Catch per unit effort data also support the hypothesis that there is a spring and fall movement. Boat electrofishing catch rates at sites sampled above the Chulitna River confluence progressively increased in the spring and the fall in 1982 and 1983 (ADF&G 1983b).

Inferences of population dynamics for longnose suckers aged between 1981 and 1983 are difficult due to problems with aging this species accurately by scale analysis. While longnose sucker age data from 1983 is similar to 1981 data up to Age 7, results from 1982 are similar to 1983 data only up to Age 3 and to 1981 data only after Age 6. Bond (1972) found that he could accurately determine the ages of a closely related species of sucker (white sucker, *C. commersoni*) by scale analysis up to Age 9. However, since the mean lengths of several longnose sucker age classes from our data vary considerably from year to year, we believe that scale analysis is not an accurate technique for aging longnose suckers on the Susitna River.

Another indication of the problem relating to age determination of longnose suckers was provided by examining scales from two recaptured fish one year later. One of the recaptured longnose suckers was accurately aged for both years and the other was misaged both years. By comparing scales from the two years, no new annulus was formed on the 1983 scale. Other studies of longnose suckers show similar results in regard to the failure of tagged fish to form an annulus (Geen et al. 1966). Bucholz and Carlander (1963) suggest that when there is little or no growth, fish do not forming a scale annulus. Evidently, this is prevalent among longnose suckers in the Susitna River.

Several authors suggest alternate methods to age suckers. Beamish and Harvey (1969) found that by using cross sections of pectoral fin rays they were able to age older fish. Quinn and Rose (1982) found that aging by pectoral fin rays for slower growing populations of suckers this method was reliable only up to Age 7 suckers. They further imply that otoliths are the best method to age older suckers.

While it is difficult to characterize the oldest age classes of Susitna River longnose suckers, it appears that above the Chulitna River confluence annual growth increments decline steadily after Age 5 (ADF&G 1981c, 1983b). Age-length data from longnose suckers captured in the Susitna River below the Chulitna River confluence in 1981 and 1982 indicate that fish continue to grow steadily after Age 5. Catch data from these two years also show a higher frequency of larger fish being caught below the Chulitna confluence. This is probably due to more favorable habitat conditions in this reach which allows for more growth.

4.7 Other Species

4.7.1 Dolly Varden

Dolly Varden occur throughout the Susitna River drainage, however, extremely low catches have been made from 1981 to 1983. The most productive areas are the Kashwitna River (RM 61.0), Lane Creek (RM 113.6), Indian River (RM 138.6), and Portage Creek (RM 148.8).

Catch data from 1982 show that Dolly Varden move out of the mainstem and into tributaries by late June (ADF&G 1983b). After June, catch rates at all sites influenced by the mainstem river stayed low all summer in 1982 and 1983. It is thought that Dolly Varden rear in the upper reaches of tributaries until fall and then migrate back into the mainstem to overwinter. Although it is not known when the exact timing of the fall outmigration occurs, anglers at the mouth of the Talkeetna River and Kashwitna River report high catches after mid-September (S. Kreuger and R. Bloomfield pers. comm.).

Tag-recapture data from a small number of Dolly Varden recovered in 1982 and 1983 show an upstream spring movement as well as a summer movement (ADF&G 1983b). In 1982 it was speculated this may be due to a spawning movement.

Two out of nine Dolly Varden recaptured between 1981 and 1983 were recovered in Clear Creek, suggesting that this tributary creek may be an important producer of Dolly Varden in the lower Susitna River.

4.7.2 Threespine stickleback

Distribution and abundance of threespine stickleback appears to be variable in the Susitna River. In 1981 sticklebacks were found upstream as far as RM 146.9, in 1982 they were found upriver only to RM 101.2, and in 1983 upriver to RM 112.3 (ADF&G 1981c; 1983b). A comparison of catches at several sites sampled all three years suggest that catches peaked in 1981 and increased again in 1983. While over 2,000 threespine sticklebacks were captured at Slough 6A in 1981, none were captured in 1982 and 77 were caught in 1983.

Capture data in 1981 and 1982 suggest an upstream migration begins to occur during late May (ADF&G 1981c; 1983b). This movement is presumed to originate from the estuary as a spawning migration.

Downstream migrant trap data suggest that threespine stickleback outmigrate in the summer following emergence. Thirty-two age 0+ (under 40 mm) threespine stickleback were captured in 1982 by a downstream migrant trap, while approximately 1,406 of 1,601 threespine stickleback captured by these traps in 1983 were age 0+.

The catch in 1982 was lower than in 1983 probably due to a smaller spawning population in 1982. Morrow (1980) also reports that after hatching, young of the year threespine stickleback immediately move downstream to brackish water.

4.7.3 Arctic lamprey

Arctic lamprey are believed to be abundant in the Susitna River below RM 50.5 and decrease in abundance above this river mile (ADF&G 1983b). Most Arctic lampreys have been captured at the mouths of small tributaries such as Chase Creek (ADF&G 1981c; 1983b). Arctic lamprey distribution and abundance data from 1983 was similar to 1981 and 1982 for the reach of river above the Chulitna River confluence (RM 98.5). Less than 100 Arctic lamprey have been captured each year.

5.0 CONTRIBUTORS

Data was collected by Richard Sundet and Mark Wenger with help from Kathrin Zosel.

Dana Schmidt provided the study design. Steve Hale assisted with running the CAPTURE program.

Data processing was done by Allen Bingham, Gail Heineman, Donna Buchholz, Carol Kerkvliet, Kathrin Zosel, and Alice Freeman.

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Drafting was done by Sally Donovan and Carol Kerkvliet.

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APPENDIX A

Gear Efficiency and Selectivity and Tag Retention

INTRODUCTION

Between August 9 and October 7, 1983, the responses of 13 radio tagged fish (12 rainbow trout and one burbot) to boat motors, electrofishing, and the generator in the electrofishing boat were observed.

METHODS

Gear efficiency

Boat electrofishing efficiency was analyzed by reviewing field notes concerning observed effects of electroshocking on radio tagged fish.

Several radio tagged fish were also tested to observe their responses to other noises associated with boat electrofishing such as boat motors and the electric generator which powers the electrofishing unit.

Gear selectivity

Gear selectivity of the different gear types was evaluated by examining length frequency distributions by gear type.

Tag retention efficiency

The external Floy anchor tag (model FD-67) has been used to tag resident fish since January 1981 to determine seasonal and yearly movements. The dimensions of the tag and tagging procedure are explained in the 1981 procedures manual (ADF&G 1981c). Disc dangler tags were used to tag burbot for several months during 1981 and spring 1982.

The efficiency of the Floy anchor tag was evaluated for Arctic grayling and round whitefish by comparing the number of fish with tag scars to the total number of fish with tag scars and Floy anchor tags of that species recaptured in 1983. By subtracting this ratio from 1.00, Floy anchor tag retention efficiencies were determined. Tag retention efficiencies for rainbow trout and longnose suckers were not determined because the smaller scales on these species regenerate rapidly and make it difficult to detect tag scars.

RESULTS

Gear efficiency - Response of radio tagged fish to boat electrofishing

During these 13 observations, all radio tracking was conducted by the electrofishing boat.

Two of the rainbow trout and one burbot were recaptured and the others fled from the sound of the boat or generator, or the electric field and avoided capture.

Rainbow trout (659-2.0) and burbot (639-3) were accidentally recaptured during routine sampling. Rainbow trout (628-2.0) had moved 10.9 miles downriver in 20 days and it appeared healthy when it was recaptured, but it was late presumed to have died due to tagging injuries. The remaining ten radio tagged fish moved away from the electrofishing boat during the experiment. The location of each fish was pinpointed before and after each experiment to observe their behavior.

Six fish moved away from the sampling area when electrofishing occurred in their vicinities. Three of these fish (rainbow trout 718-1.5, 738-1.4 and 748-1.6) were located at the mouth of Fourth of July Creek (RM 131.1) on August 14. After 20.0 minutes of electrofishing at the mouth of the creek the tagged fish all moved out of the area. Rainbow trout (718-1.5) was relocated 0.6 miles downriver on the opposite bank of the Susitna River. Rainbow trout (738-1.4) moved 200 yards into a side channel. Rainbow trout (748-1.6) moved 150 feet downriver and into the main channel of the Susitna. All three returned to the mouth later that day. Rainbow trout (639-1.4) was located at Moose Slough (RM 123.5) on August 14. After electrofishing the area for 19.0 minutes, the fish was relocated 20 feet from its original location in a deeper section (10 feet) of the slough. Another rainbow trout (670-1.4) was located at the mouth of Whiskers Creek Slough (RM 101.2) on October 7. This area was shocked for 12 minutes and the tagged fish was not captured. After shocking, the fish was found to have moved 20 feet into the main channel. The remaining rainbow trout (660-3) was located at the mouth of Portage Creek (RM 148.8) on September 19. This area was shocked for 26.5 minutes. This fish was seen moving in 3.5 feet of water away from the electric probe. After electrofishing, this fish was found approximately 20 feet from its previous location in deeper water.

At all sites where these six radio tagged fish were located, other non-radio tagged fish were captured during electrofishing.

On September 17 three fish were tested for responses to the sound of the boat's electrofishing generator. These fish (rainbow trout 597-1.3, 709-1.5 and 768-1.5) were located next to the bank of the mainstem river within 100 yards of each other at RM 114.3.

After locating the fish, the boat was positioned approximately 10 feet away from each fish and the generator was started. All three fish moved 100-200 feet downriver after the generator was started. This was done twice for each fish and the response was the same each time.

Ten fish were tested to observe their responses to the boat's motor. The ten fish included the six which fled during electrofishing (rainbow trout 718-1.5, 738-1.4, 748-1.6, 639-1.4, 670-1.4, and 660-3), the three that fled during the operation of the generator (rainbow trout 597-1.3, 709-1.5 and 768-1.5), and one other fish (rainbow 649-1.2). All but one fish (649-1.2) remained in the same area when the boat was near them. The estimated distance between the boat and each fish was from 10-30 feet.

Rainbow trout (649-1.2) was located at the mouth of Indian River (RM 138.6) on September 19. While moving towards the fish and monitoring at the same time, the fish moved across the river (200 yards). After locating and moving towards the fish on the opposite side, the fish returned to the mouth. The closest distance the boat came to the fish was estimated at 100 feet.

Gear Selectivity

Rainbow trout

Rainbow trout were captured by nine of the 11 sampling techniques used during the 1983 resident fish studies. The length frequencies of the rainbow trout captured by the four methods accounting for 95% of the total catch are shown in Appendix Figure A-1. Hook and line and boat electrofishing techniques sampled a wide range of lengths (89 - 612 mm), while minnow and migrant traps captured only juvenile fish (30 -191 mm).

Burbot

Burbot were captured by seven of the 11 sampling techniques used during the 1983 resident fish studies. Ninety-three percent of all the burbot caught were captured by the four techniques shown in Appendix Figure A-2. Boat electrofishing sampled the widest range of lengths (107 - 751 mm), while the migrant trap collected only juvenile fish (26 - 134 mm).

Arctic grayling

Arctic were captured by five of the 11 sampling techniques used during the 1983 resident fish studies. Boat electrofishing accounted for 90% of the total Arctic grayling catch. The five techniques which captured Arctic grayling are shown in Appendix Figure A-3. Boat electrofishing sampled the widest range of lengths (97 - 444 mm) and the smolt trap, with the exception of a few incidental adult catches, only sampled the juveniles (36 - 175 mm). The other methods only sampled the fish between 200 and 400 mm.

Round whitefish

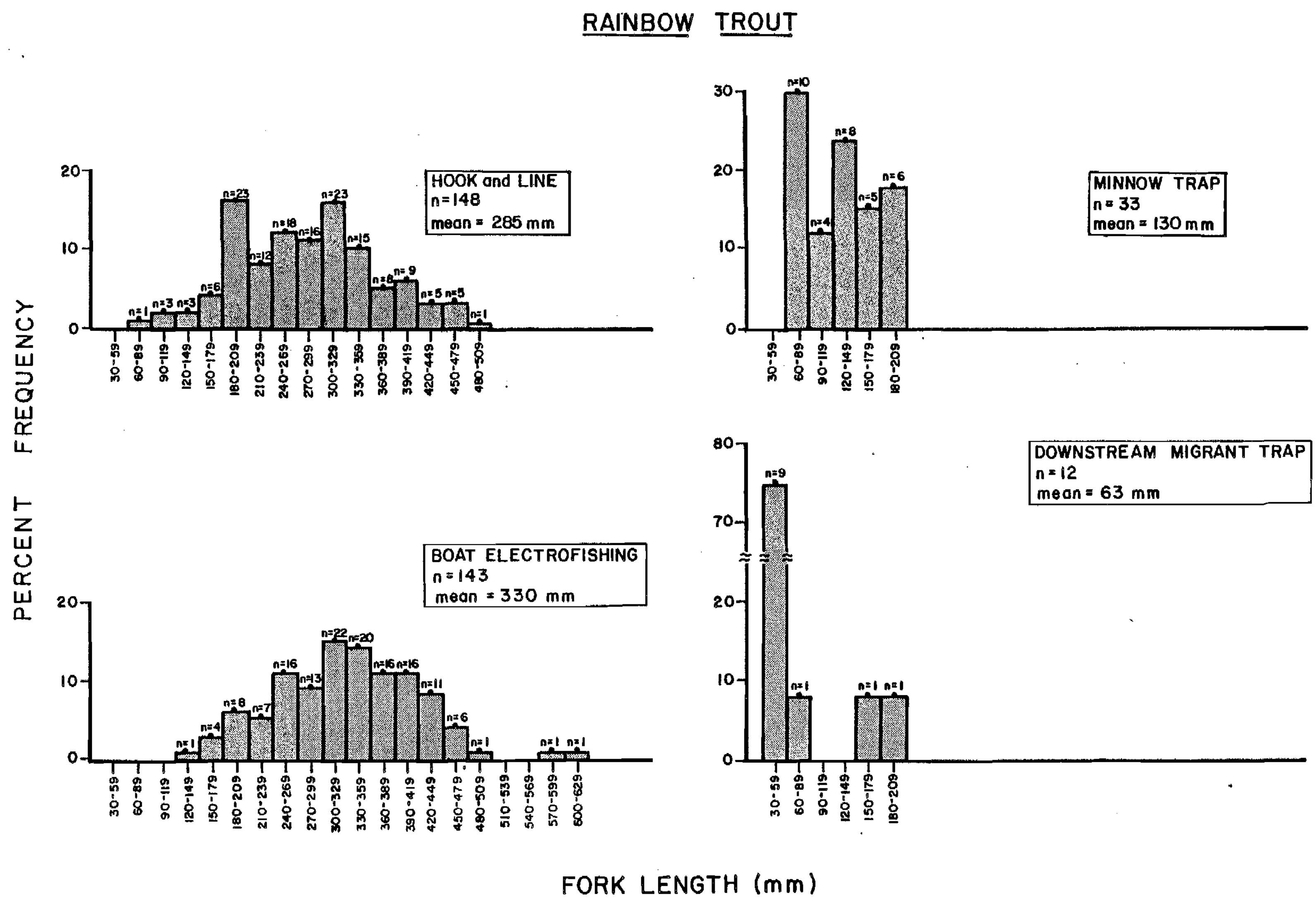
Round whitefish were captured by five of the 11 sampling techniques used during the 1983 resident fish studies. The length frequencies of the round whitefish captured by the four major methods (hook and line captured only one fish) are shown in Appendix Figure A-4. Boat electrofishing and the migrant traps accounted for 98% of the total catch. Boat electrofishing sampled a wide range of lengths (94 -403mm) while the migrant trap captured mainly juveniles (23 - 208mm).

Humpback whitefish

Humpback whitefish were captured by four of the 11 sampling techniques used during the 1983 resident fish studies. The length frequencies of the humpback whitefish captured by these four methods are shown in Appendix Figure A-5. The migrant traps accounted for 77% of the total catch, most being juvenile (30 - 145mm). The other methods were selective for fish between 140 and 480mm.

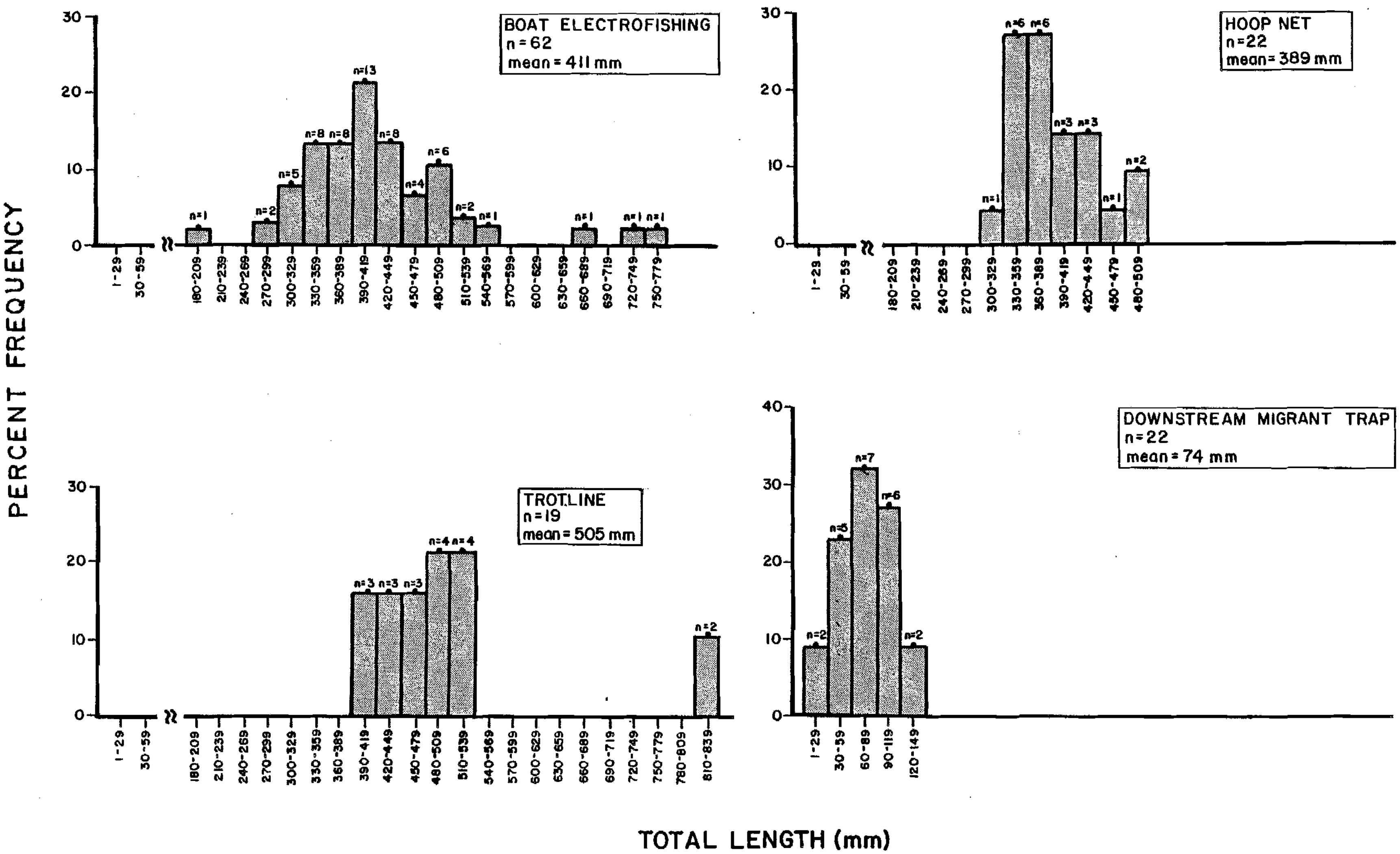
Longnose sucker

Longnose sucker were captured by five of the 11 sampling techniques used during the 1983 resident fish studies. The length frequencies of the

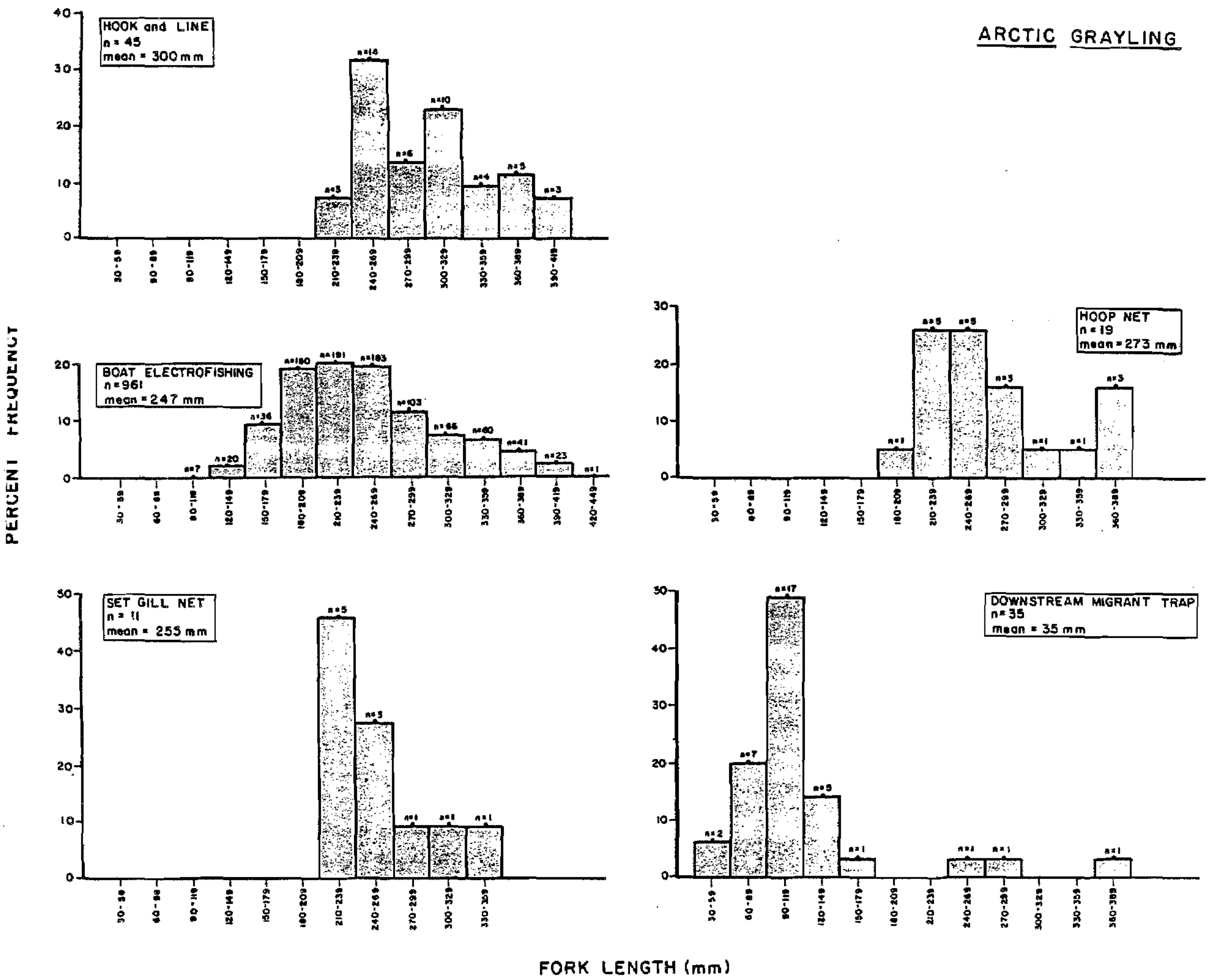


Appendix Figure A-1. Gear selectivity for rainbow trout in the Susitna River, May through October 1983.

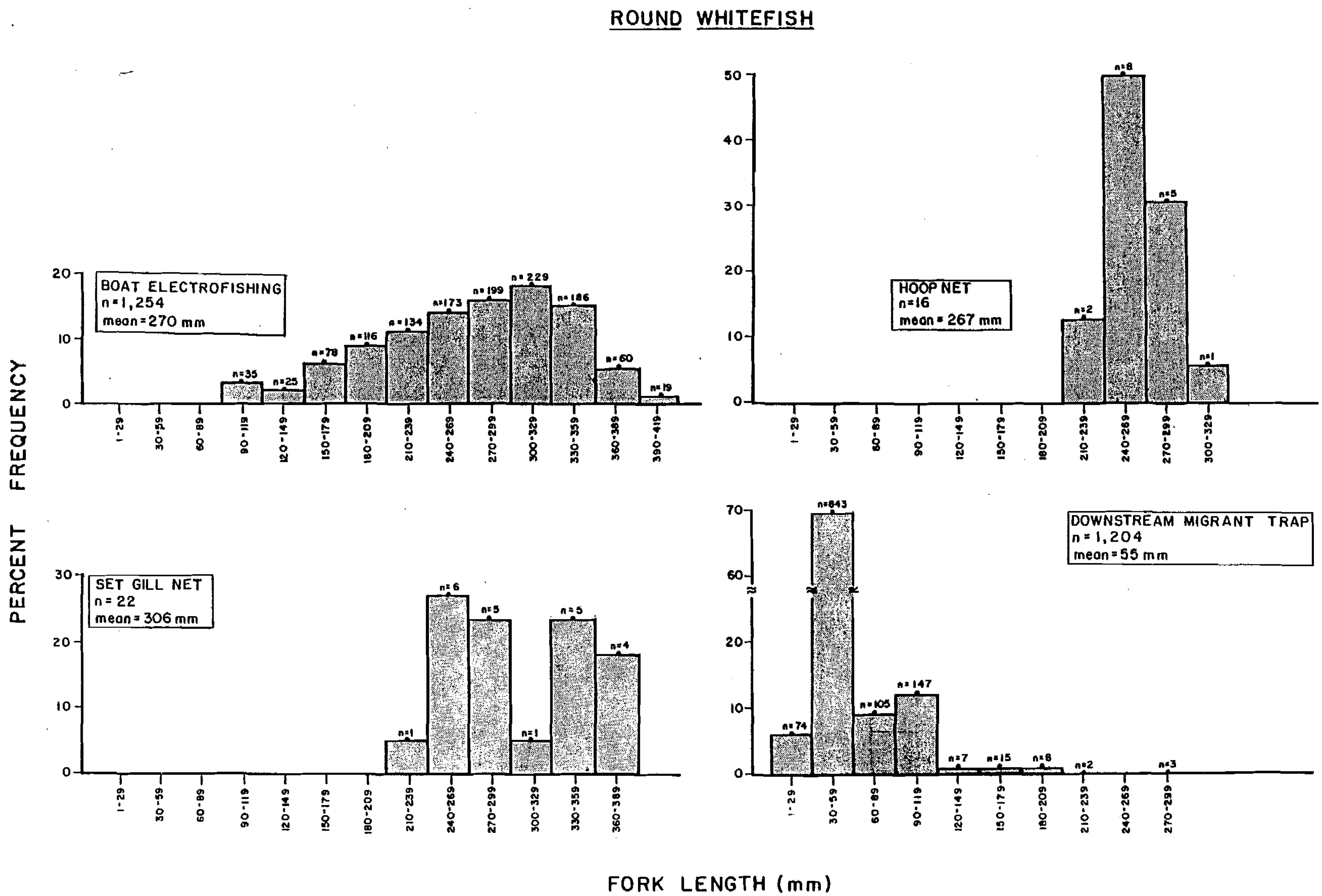
BURBOT



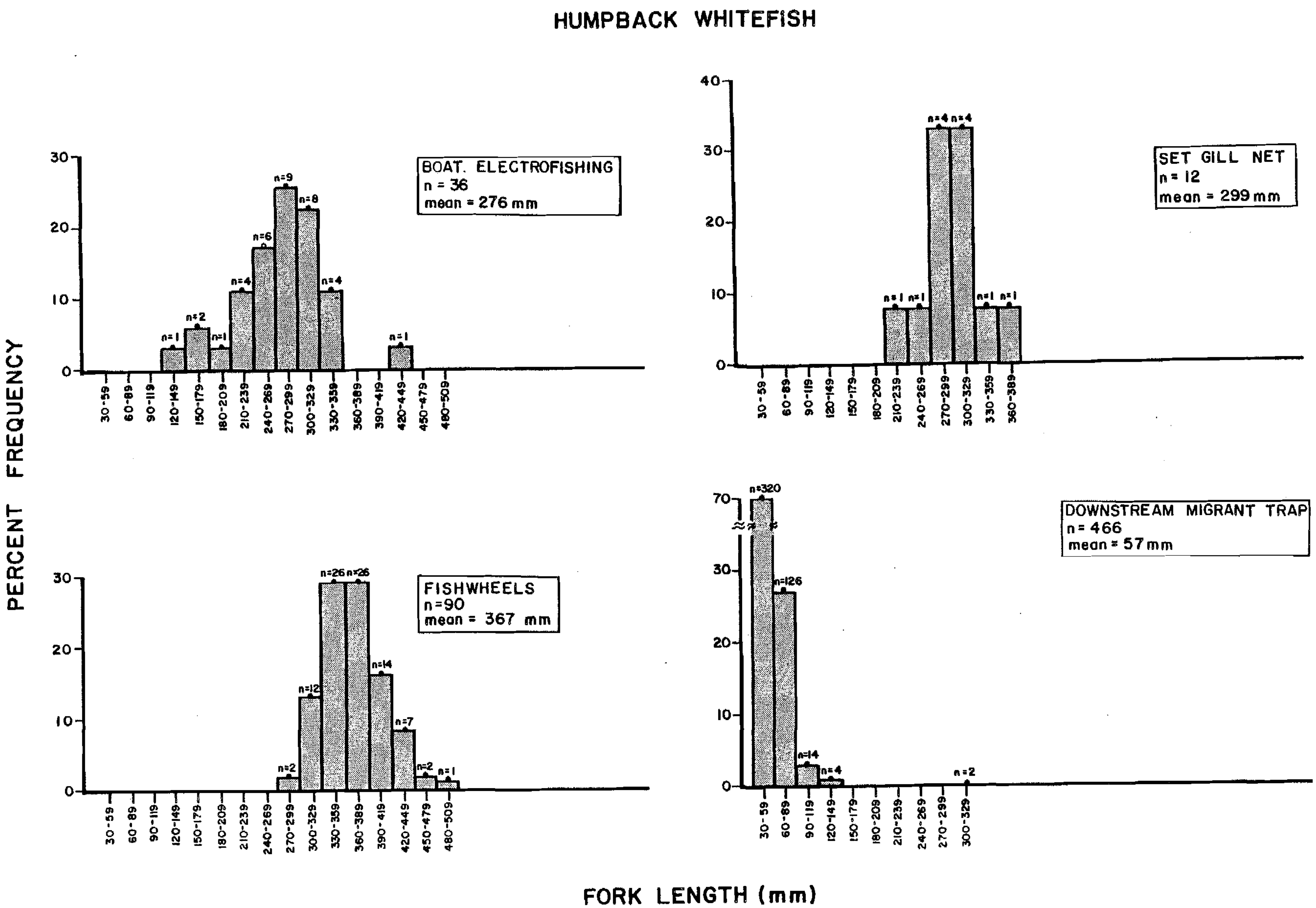
Appendix Figure A-2. Gear selectivity for burbot in the Susitna River, May through October 1983.



Appendix Figure A-3. Gear selectivity for Arctic grayling in the Susitna River, May through October 1983.



Appendix Figure A-4. Gear selectivity for round whitefish in the Susitna River, May through October 1983.

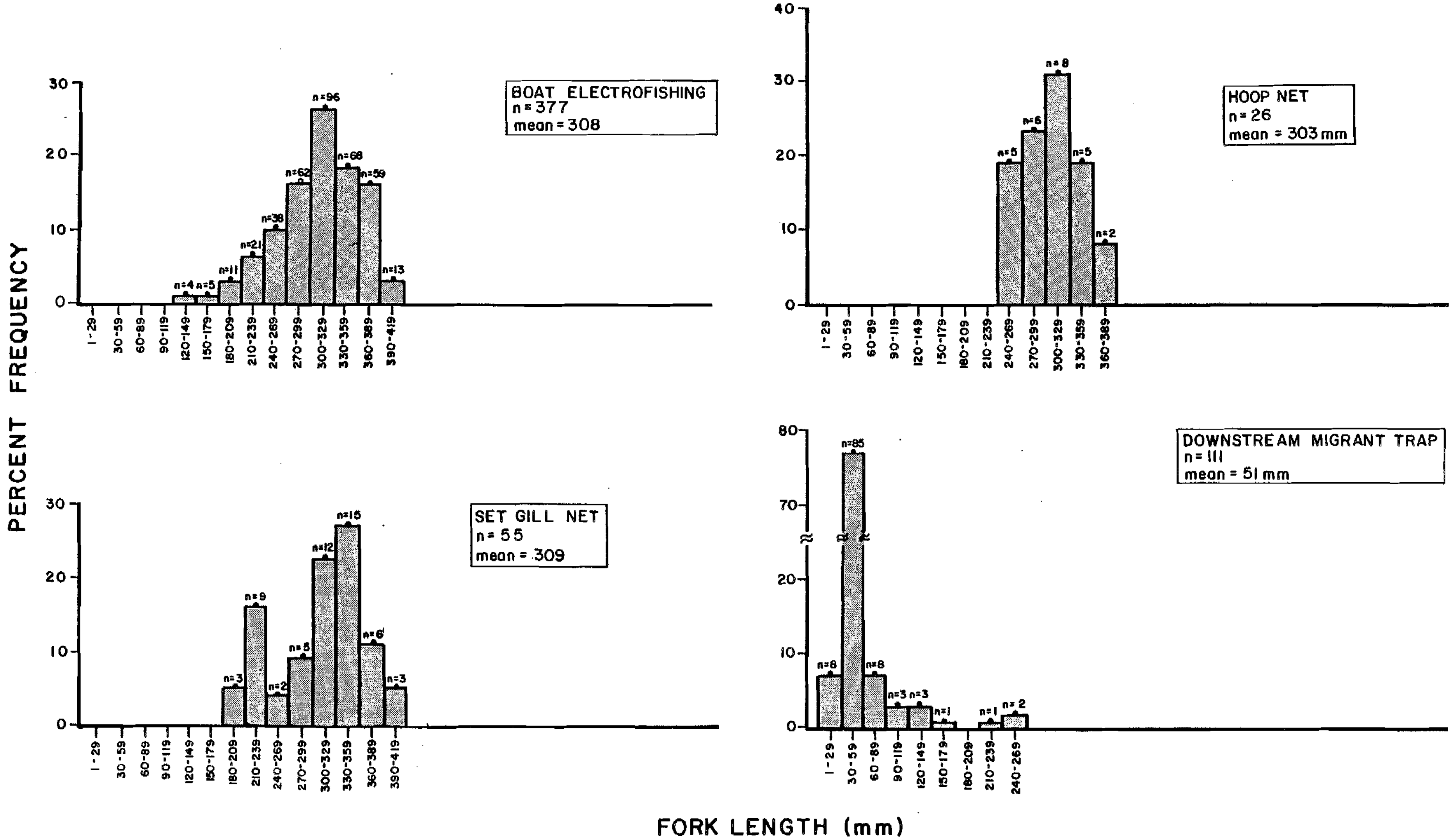


Appendix Figure A-5. Gear selectivity for humpback whitefish in the Susitna River, May through October longnose suckers captured by these four major methods are shown in Appendix Figure A-6 (hook and line captured only 2 fish). Boat electrofishing accounted for 66% of the total catch and captured the widest range of lengths (133-407mm). The migrant trap once again captured mainly juvenile longnose suckers (21-175mm) while the net methods were selective for the median lengths (200-380mm).

Tag retention efficiency

The Floy anchor tag efficiency determined for round whitefish in the Susitna River during 1983 was 77.5 percent with 20 of 89 recaptured round whitefish showing a tag scar. The tag efficiency, meanwhile, for Arctic grayling during 1983 was 69.4 percent with 15 of 49 recaptured Arctic grayling showing a tag scar.

LONGNOSE SUCKER



Appendix Figure A-6. Gear selectivity for longnose suckers in the Susitna River, May through October 1983.

DISCUSSION

Gear efficiency - Response of radio tagged fish to boat electrofishing

Observed responses of 13 radio tagged fish to boat electrofishing equipment suggest that fish learn to avoid recapture. A similar hypothesis has been reported elsewhere (Jacobs and Swink 1982).

Only three of the 13 radio tagged fish were recaptured and the others avoided the electrofishing boat. Twelve of these fish were originally captured by electrofishing and one by hook and line (670-1.4).

Since only one of ten fish moved away from the sound of the boat motor, it appeared that they disassociate the effects of the electric field and capture to the sound of boat motors. This was probably due to the constant "traffic" on the river between the time of capture and when the experiment occurred. This enabled the fish to become acclimated to the sound of boat motors.

While most of the fish did not respond to the sound of boat motors, they did respond to generator noise. All of the fish tested for a response to generator noise moved away from the source of the noise. Prior to these observations we believed that the radio tagged fish would not associate the generator sound with the electric field because of the extended periods of time between successive samplings.

It appears that while boat electrofishing provides a good method to capture fish for collection of biological data, it is a poor method by itself for a tag-and-recapture program since fish learn to avoid the field.

Gear selectivity

For each of the six species that the gear selectivity study was conducted on, there was always at least one sampling technique which sampled a wide range of lengths, one that sampled only the juveniles and others that sampled a small segment of the population between the smallest and largest. Boat electrofishing was generally the best technique in sampling a wide range of lengths, while the downstream migrant traps was often the most effective means of capturing juveniles.

Tag retention efficiency

Studies in 1983 show that the Floy anchor tag, model FD-67, is lost from 25 percent of recaptured round whitefish and Arctic grayling. Other studies have also reported tag losses using the model FD-67 anchor tag. Wilbur and Duchow (1973) reported tag losses on largemouth bass up to 78 percent using the model FD-67 tag. Arctic grayling tagging studies in the Chena River and the upper Susitna River basin reported 10 percent tag losses (R. Holmes and M. Stratton, pers. comm., respectively).

Rawstroms (1973) reported that the primary reason for tag shedding is improper securement. He found that tag retention rates increase if the tag is inserted behind the interneurals rather than into the dorsal musculature. Rawstroms also stated that secondary causes of tag loss occur due to breakage of the T-section of the tag or to separation of the vinyl tube from the monofilament anchor.

Our studies also suggest that the primary cause of tag loss is improper placement of the tag. Very few (under five) tagged fish in our study have been found without the vinyl tube. Observations of recaptured round whitefish and Arctic grayling show that an ulcer forms around the area where the tag has been inserted. Since both these species have large scales, regeneration may be impeded due to the constant movement of the external part of the Floy tag. The constant movement impedes regeneration, and the wound ultimately enlarges. With the greater hole from the wound, the tag falls out enabling the scales to regenerate or to form a scar. Other resident fish species such as rainbow trout and longnose suckers probably have higher tag retention rates than Arctic grayling and round whitefish. This may be due to their smaller scales which adhere to the tag better.

Although some Floy anchor tags are lost due to shedding it is still the best tag to use for our studies because it can be deployed rapidly and because it is more economical to use than other types of tags.

Tag losses during our 1983 studies appeared to decrease due to better placement of tags. In 1982 most of the tags were injected into the dorsal musculature. In 1983, tags were anchored at the base of the dorsal fin.

APPENDIX B

Radio Tagged Fish Movement Data

Appendix Table B-1. Summary of tagging data for radio tagged rainbow trout on the Susitna River Between Cook Inlet and Devil Canyon, May to December 1983.

Radio Frequency/Fork Length (mm)	Age/ Sex	Method captured	Location Captured	River Mile	Date Capt'd	Date Rels'd
597-1.3/424	6, F	EF	Lane Creek	113.6	7/18	7/19
600-1.0/508	-, F	HL	Indian River	138.6	9/2	9/2
607-1.5/385	7, M	HL	Indian River	132.6	9/18	9/19
608-1.2/444	8, -	EF	Indian River	138.6	10/4	10/5
610-1.0/548	-, M	DN	4th of July Cr	131.1	5/11	5/12
619-1.0/440	-, M	HL	4th of July Cr	138.6	9/1	9/2
619-1.4/387	5, -	EF	Indian River	138.6	9/2	9/3
628-1.2/423	6, -	EF	Indian River	113.6	10/4	10/5
630-1.0/558	-, M	DN	4th of July Cr	131.1	5/11	5/12
639-1.0/382	6, -	EF	Indian River	138.6	9/2	9/3
639-1.4/460	-, -	EF	Slough 8A	125.3	7/16	7/17
648-1.6/405	6, F	HL	Whiskers Cr	TRM 0.2	6/5	6/6
649-1.2/427	7, -	EF	Indian River	138.6	9/2	9/3
660-3.0/508	8, F	EF	Protage Cr	148.8	9/2	9/3
670-1.4/391	7, -	HL	Whiskers Cr	TRM 0.2	6/6	6/7
709-1.5/418	-, -	EF	Lane Creek	113.6	7/18	7/19
718-1.5/376	5, -	EF	Indian River	138.6	6/8	6/9
719-1.0/455	5, -	HL	Indian River	TRM 5.0	8/11	8/11
729-1.0/455	-, F	HL	4th of July Cr	131.1	9/1	9/2
729-1.3/446	6, M	HL	Indian River	138.6	9/2	9/3
738-1.4/455	-, -	EF	Indian River	138.6	6/8	6/9
748-1.6/442	-, F	EF	Skull Creek	124.5	7/18	7/19
749-1.0/438	7, -	HL	Indian River	138.6	9/2	9/3
758-20/416	7, -	EF	Lane Creek	113.6	7/18	7/19
767-1.5/435	6, -	EF	Lane Creek	113.6	7/18	7/19
768-1.0/432	6, F	EF	Indian River	138.6	10/4	10/5

- = Not sexed or not aged, EF = Electrofishing, HL = Hook & Line, DN = Drift Net

Appendix Table B-2. Summary of tagging and tracking data for radio tagged burbot on the Susitna River between Cook Inlet and Devil Canyon, July to December 1983.

Radio Frequency/ Total length (mm)	Method Captured	Date Capt'd	River Mile	Date Rels'd	July	August			September			October			Nov	Dec
					25 B[b]	8 P[a]	15 B	29 P	5 B	15 P	19 B	3 P	6 B	21 P	10 P	1 P
610-3.0/550	Electroshock	7/18	113.6	7/19	112.3	110.0	112.5	112.0	112.0	111.3	112.0	112.0	112.0	112.0	NS[c]	NS
639-3.0/728	Electroshock	9/18	142.0	9/19								140.0	140.0	134.3	134.3	131.8
670-3.0/677	Electroshock	9/1	123.5	9/2					123.5	120.5	118.6	110.2	110.2	88.0	87.3	87.7
720-3.0/750	Electroshock	9/3	147.5	9/3					146.9	146.7	147.3	147.0	144.0	NS	NS	134.8

[a] Tracked by plane
[b] Tracked by boat
[c] No signal

APPENDIX C

Population and Biological Characteristics

Rainbow Trout

The sexual maturity of 28 rainbow trout from the Susitna River were examined between May 11 and July 18, 1983. Sexually ripe pre-spawners were captured from May 11 to June 7. Spawned out rainbow trout were captured from June 5 to July 18.

Fork lengths of 16 male rainbow trout examined for sexual maturity ranged from 260-558 mm with a mean of 403 mm. The fork lengths of twelve sexually mature female rainbow trout ranged from 325-454 mm with a mean of 399 mm.

Ages of twenty-one rainbow trout ranged five to eight (Appendix Figure C-1).

A total of 424 rainbow trout were captured between the Chulitna River confluence and Devil Canyon during 1983. The length frequency composition for rainbow trout is presented in Appendix Figure C-2. Fork lengths ranged from 30-612 mm with a mean of 284 mm.

Scale analysis was used to determine the ages of 265 rainbow trout captured on the Susitna River between the Chulitna River confluence and Devil Canyon. Ages ranged from one to nine. Ages 3 (18.1%), 4 (18.1%), 5 (25.3%) and 6 (17.7%) rainbow trout were the most abundant age classes (Appendix Table C-1). A graphical presentation of age-length data in Appendix Figure C-3 shows a steady growth rate for rainbow trout.

Two hundred forty-four of the 265 rainbow trout aged were captured by boat electrofishing or hook and line. Data from fish captured by these two methods, were used to calculate an instantaneous survival rate of 33.3 percent by using age versus catch (Appendix Figure C-4).

Burbot

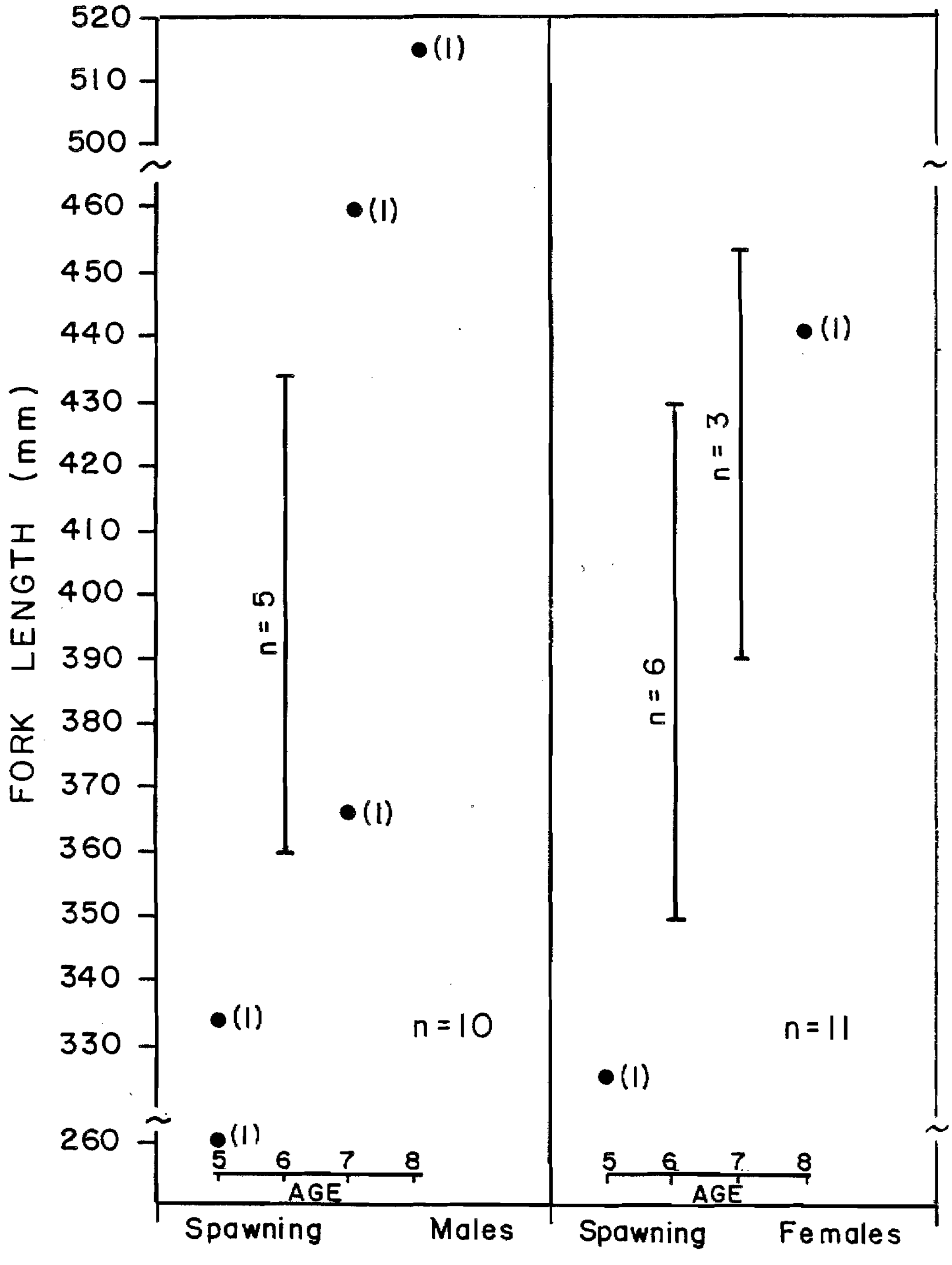
One hundred sixty one burbot were captured in the Susitna River between the Chulitna River confluence and Devil Canyon during 1983. Total lengths measured on 135 burbot ranged from 26-815 mm with a mean of 366 mm (Appendix Figure C-5). Most of the burbot measured ranged from 330 mm to 510 mm in total length.

Few juvenile burbot (total length $<$ 200 mm) were captured in 1983. The majority (22 of 24) of the juvenile burbot measured were caught by the downstream migrant traps at RM 103.0.

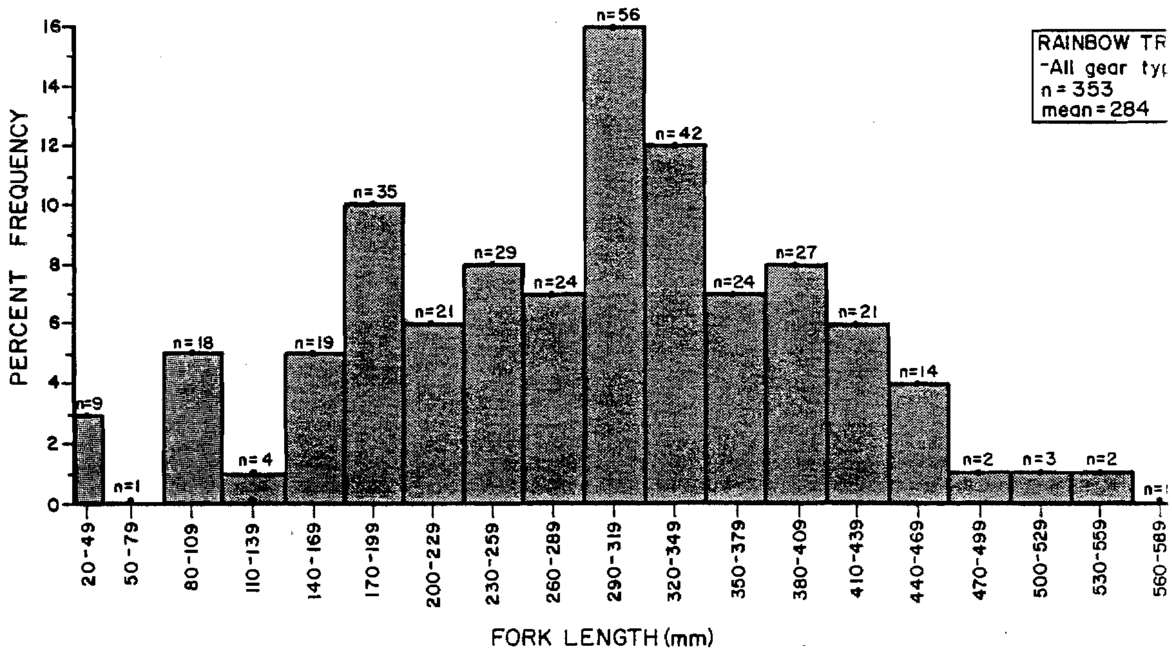
The instantaneous survival rate for burbot was calculated using pooled data from fish aged from otoliths from January 1981 to March 1983. The instantaneous survival rate for burbot aged in this time period was calculated to be 70.5 % (Appendix Figure C-6).

Arctic Grayling

The sexual maturities of 51 Arctic grayling from the Susitna River were examined between May 20 and June 22, 1983. Sexually ripe pre-spawners



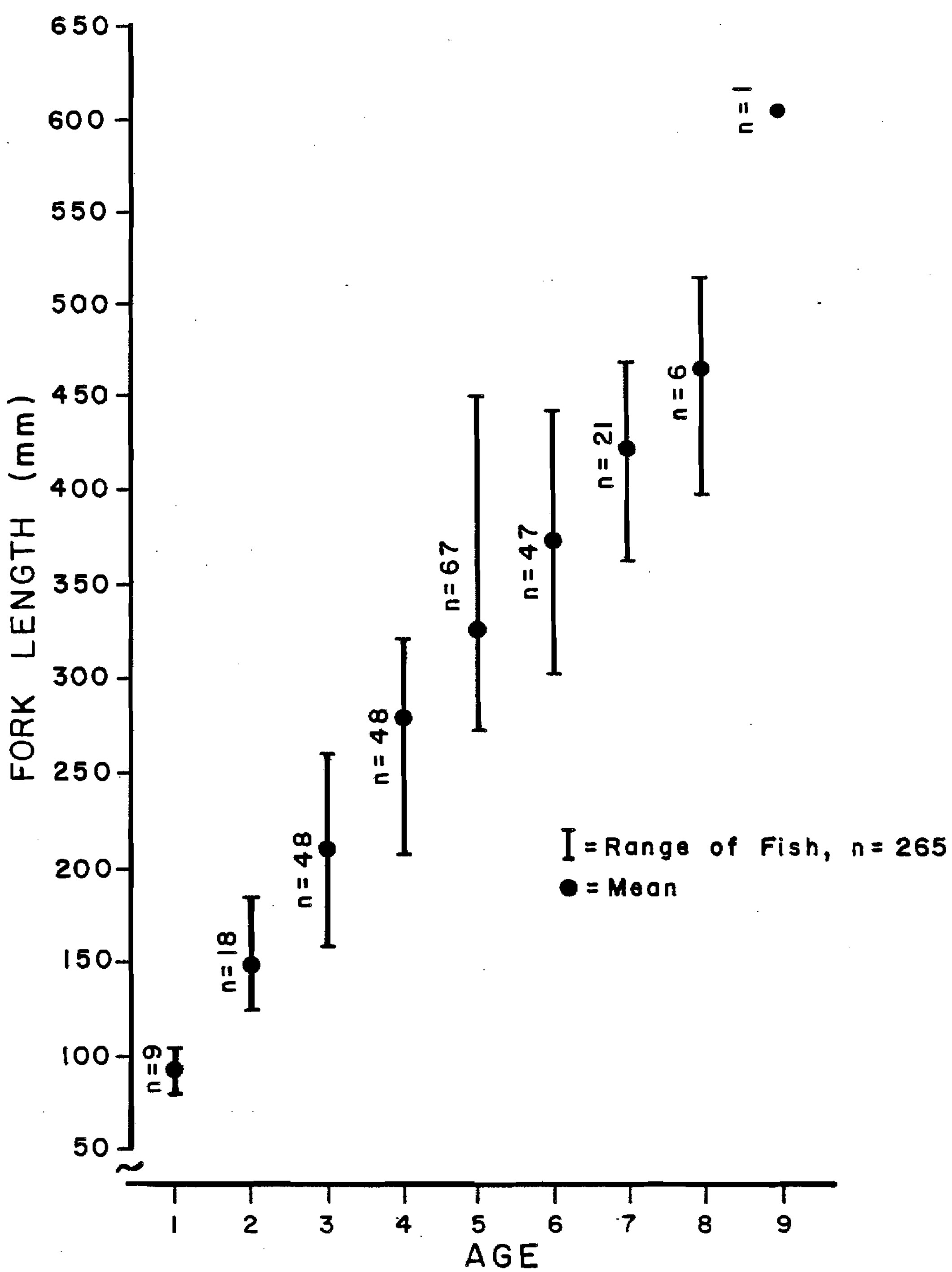
Appendix Figure C-1. Age and length relationship for spawning rainbow trout captured in the Susitna River between the Chulitna River confluence and Devil Canyon, May 11 through July 18, 1983.



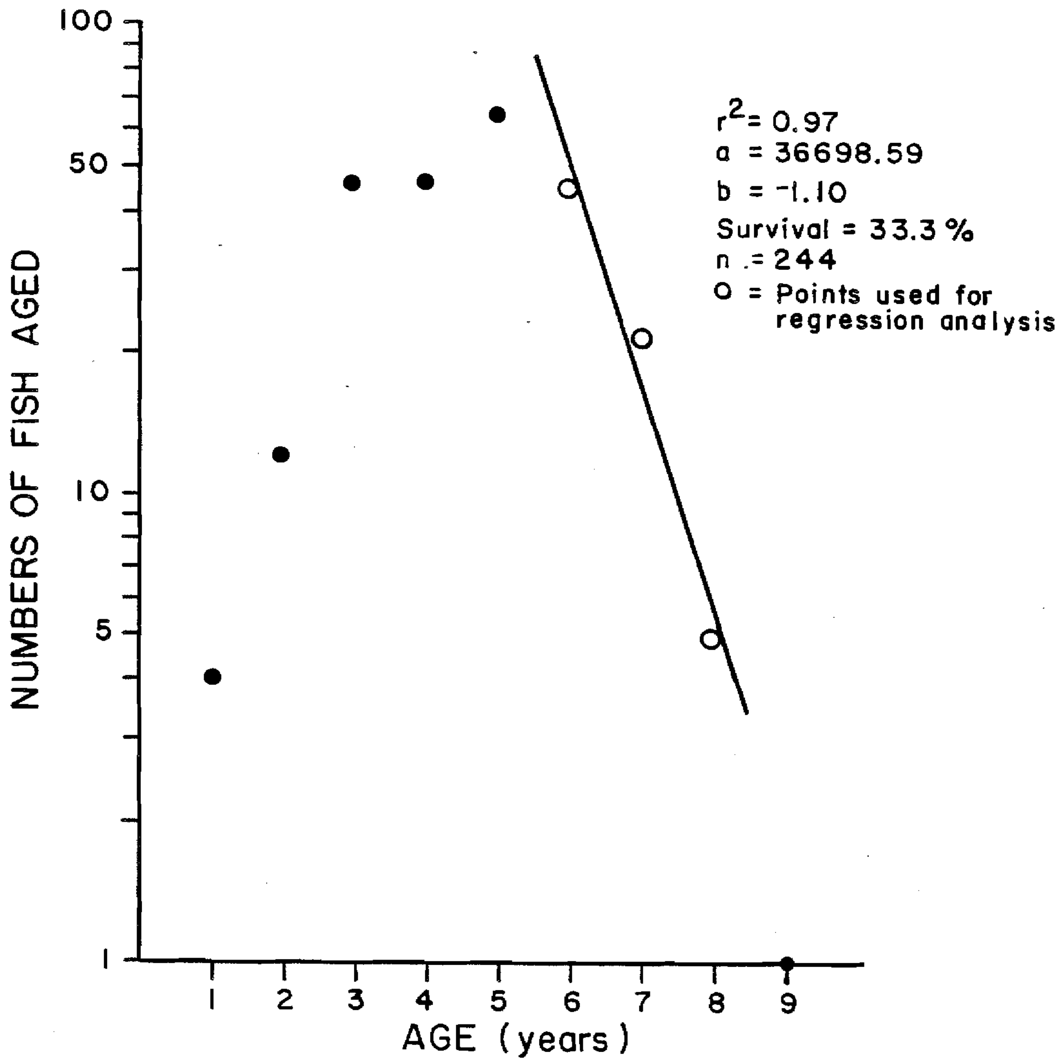
Appendix Figure C-2. Length frequency composition of rainbow trout captured in the Susitna River between the Chulitna River confluence and Devil Canyon by all gear types, May to October 1983.

Appendix Table C-1. Rainbow trout age-length relationships on the Susitna River between the Chulitna River confluence and Devil Canyon, May to October 1983.

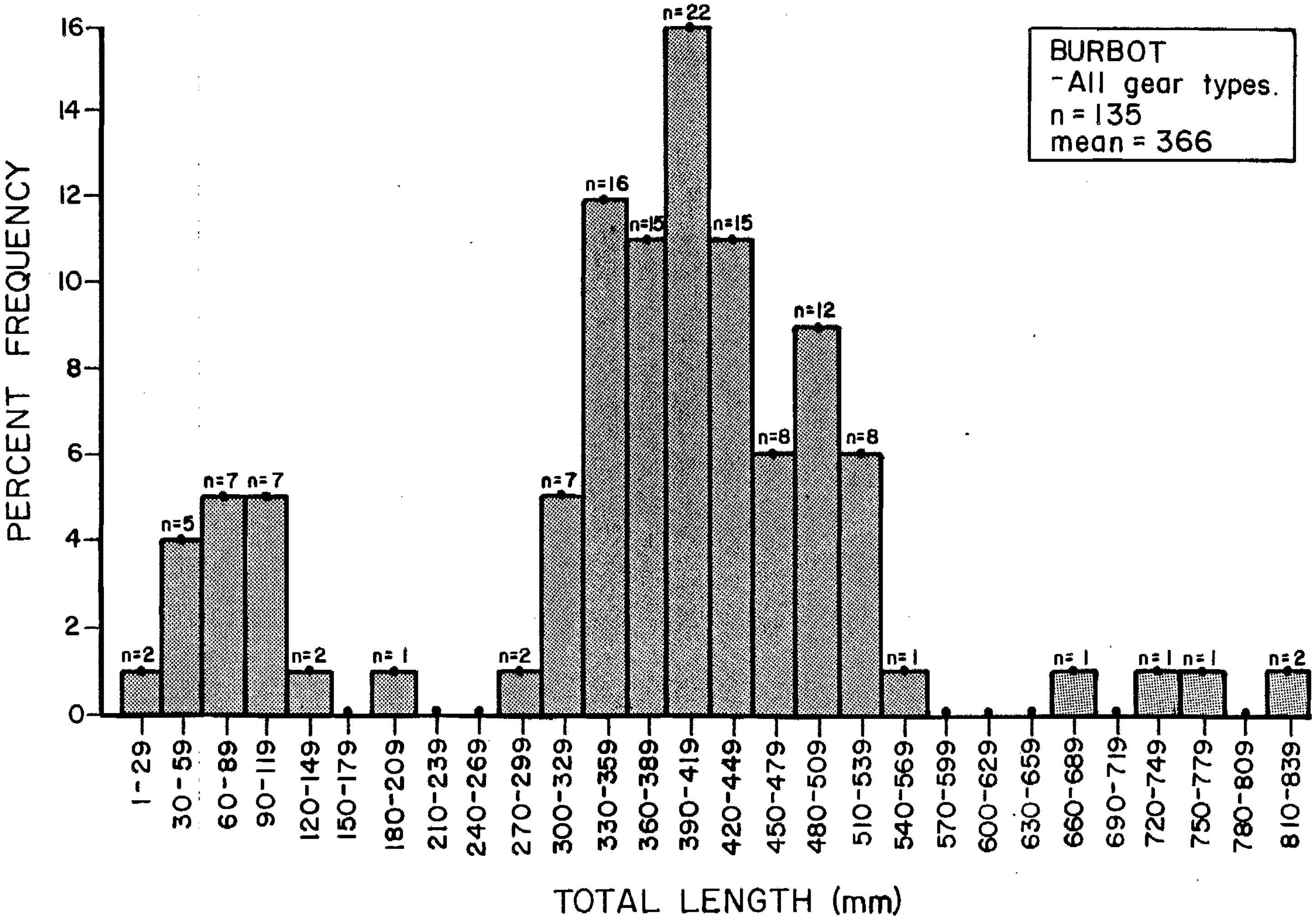
Age (years)	Total No. of Fish Sampled	Length (mm) Mean	Standard Deviation	95% Confidence Intervals	Range
Fish Captured by Boat Electrofishing and Hook and Line					
1	5	97	9.43	85 - 109	93 - 106
2	12	155	15.51	145 - 165	124 - 180
3	46	210	31.54	201 - 219	159 - 260
4	45	274	33.55	264 - 284	205 - 329
5	65	331	36.62	322 - 340	260 - 455
6	45	377	38.84	365 - 389	301 - 446
7	21	423	31.45	409 - 437	366 - 471
8	5	452	43.67	398 - 506	390 - 508
9	1	612			
Total	244	306			193 - 612
Fish Captured by All Methods					
1	9	92	7.95	86 - 98	84 - 106
2	18	150	14.96	143 - 157	124 - 180
3	48	210	31.15	201 - 219	159 - 260
4	48	275	33.50	265 - 285	205 - 329
5	67	330	36.00	321 - 339	260 - 455
6	47	378	38.41	367 - 389	301 - 446
7	21	423	31.45	409 - 437	366 - 471
8	6	462	46.86	413 - 511	390 - 515
9	1	612			
Total	265	298			84 - 612



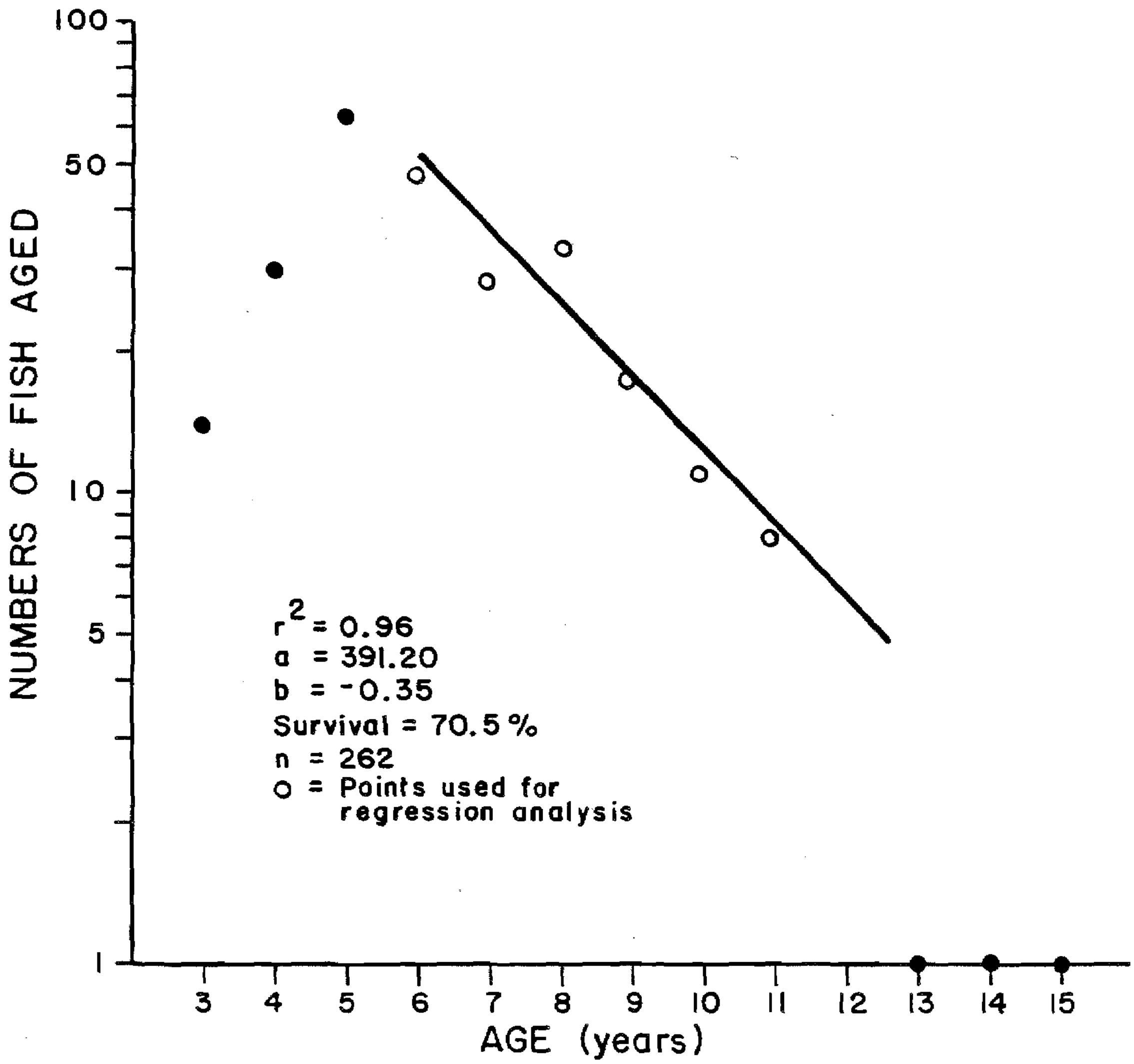
Appendix Figure C-3. Age and length relationships for rainbow trout captured in the Susitna River between the Chulitna River confluence and Devil Canyon, May to October 1983.



Appendix Figure C-4. Survival rate curve for rainbow trout captured in the Susitna River between the Chulitna River confluence and Devil Canyon, 1983.



Appendix Figure C-5. Length frequency composition of burbot captured in the Susitna River between the Chulitna River confluence and Devil Canyon by all gear types, May to October 1983.



Appendix Figure C-6. Survival rate curve for pooled burbot catch data from the Susitna River between Cook Inlet and Devil Canyon, 1981 to 1983.

were captured from May 20 to May 24. Post spawners were captured from May 21 to June 22.

Fork lengths for 30 male Arctic grayling which spawned in 1983 ranged from 308-444 mm with a mean length of 367 mm. Twenty-one female Arctic grayling spawners had fork lengths ranging from 320-386 mm with a mean of 349 mm.

Ages of 29 of the 30 male Arctic grayling examined for spawning condition ranged from Age 5 to Age 10. Ages of 19 female Arctic grayling spawners ranged from Age 5 to Age 8 (Appendix Figure C-7).

A total of 1,168 Arctic grayling were captured on the Susitna River between the Chulitna River confluence and Devil Canyon during 1983. Fork lengths of 1,071 of those fish were measured to the nearest millimeter. Arctic grayling fork lengths ranged from 30 mm to 444 mm with a mean of 246 mm (Appendix Figure C-8). Juvenile Arctic grayling (fork length under 200 mm) made up 26.4% of the catch.

Age analysis from scales of 523 Arctic grayling captured on the Susitna River between the Chulitna River confluence and Devil Canyon yielded ages which ranged from age 0+ to Age 10 (Appendix Figure C-9). Ages 3 (27.0%) and 4 (31.4%) were sampled most often (Appendix Table C-2).

Five hundred sixteen of the 523 Arctic grayling aged were captured by boat electrofishing, hook and line, and hoop net. The instantaneous survival rate for Arctic grayling captured by these three methods was calculated at 56.0 % (Appendix Figure C-10).

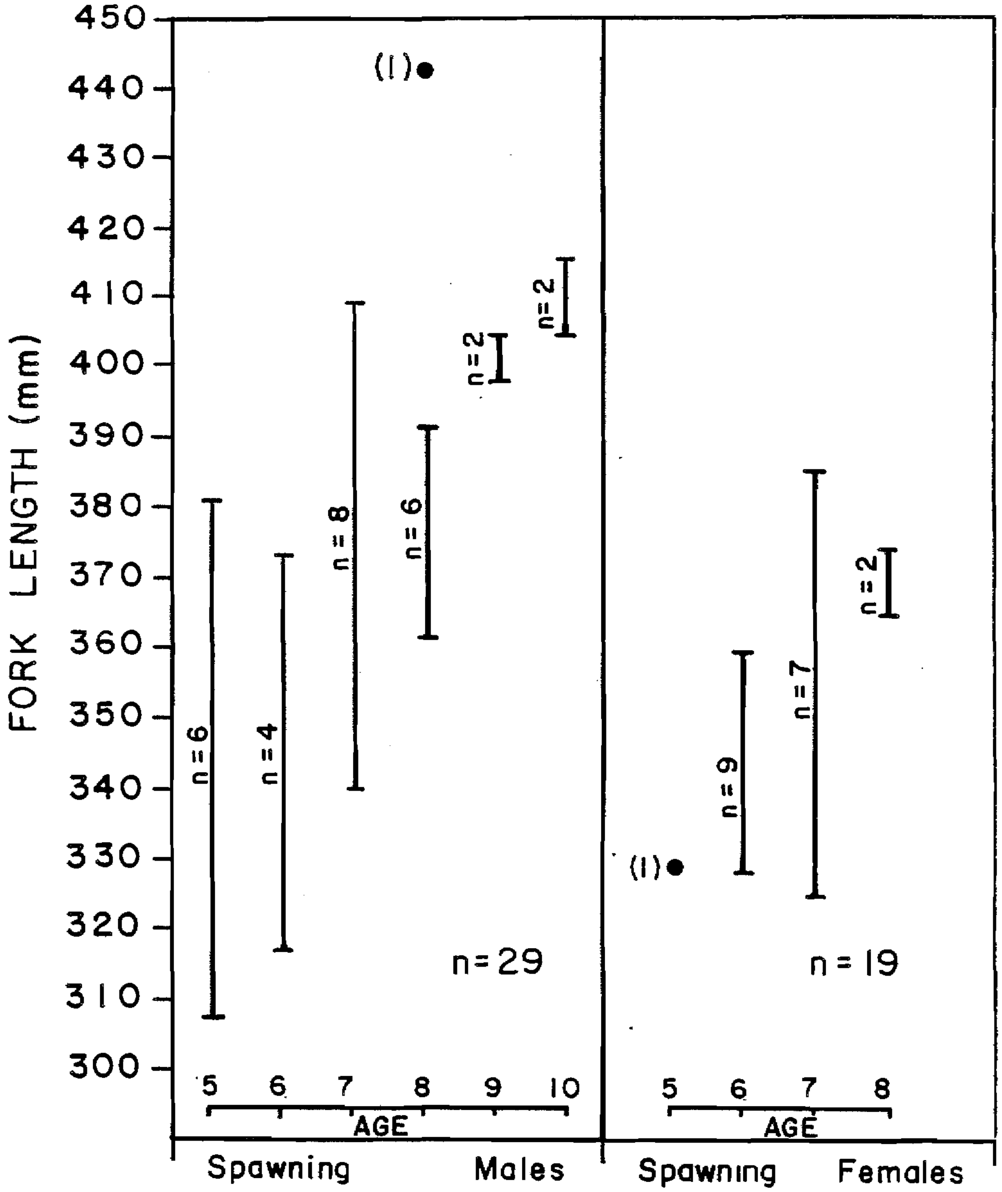
Round Whitefish

Sexual maturity was determined for a subsample of round whitefish captured on the Susitna River between the Chulitna River confluence and Devil Canyon from October 3 to October 7, 1983. Forty males and 12 female round whitefish were sampled, all were pre-spawners. Fork lengths of the males ranged from 266 mm to 380 mm with a mean of 319 mm. Fork lengths for the females ranged from 319 mm to 403 mm with a mean of 355 mm. Ages of seventeen of the spawning males ranged from Age 5 to Age 8 (Appendix Figure C-11). One female was Age 7.

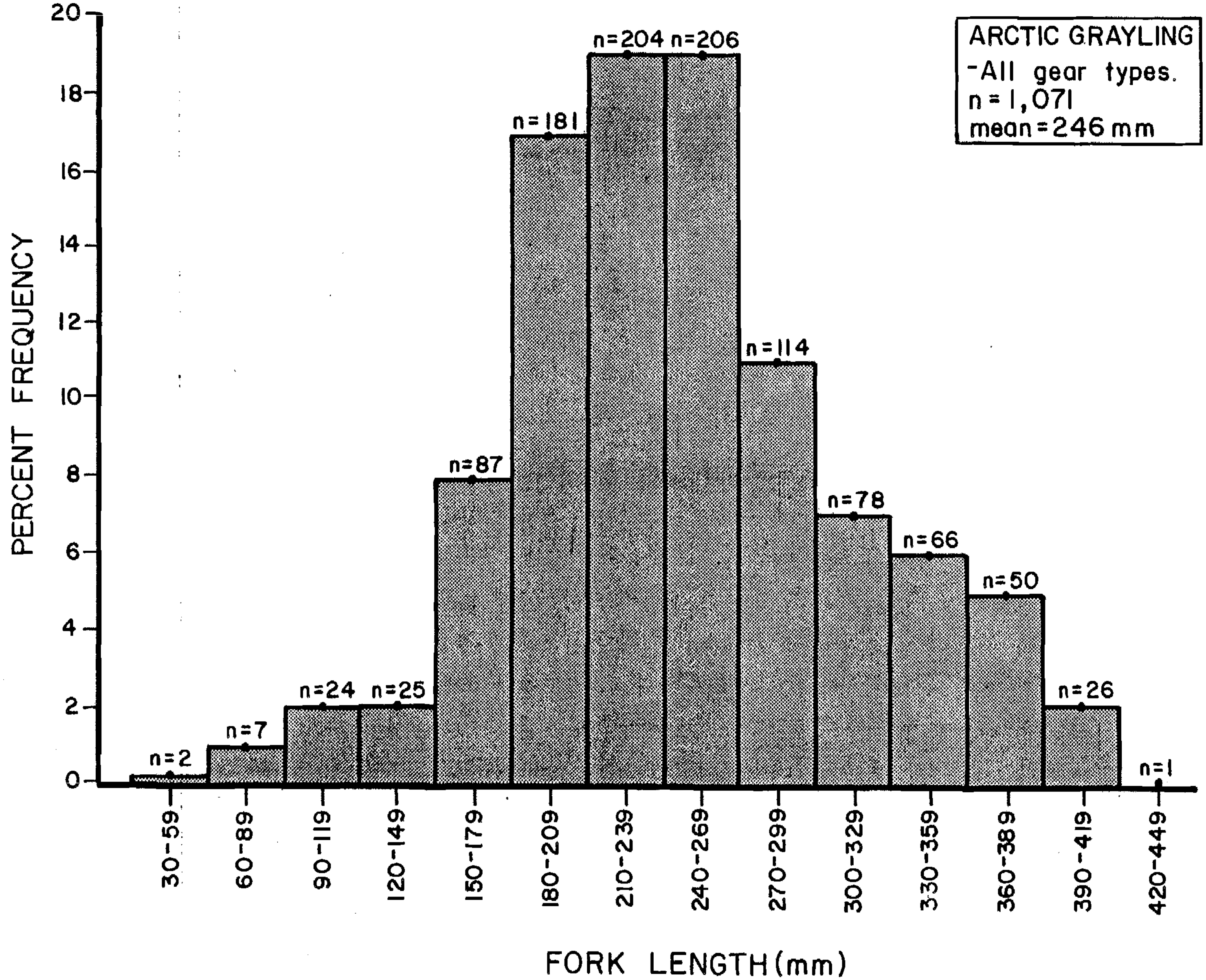
In October 1983 three spawning sites for round whitefish were found. Two sites were at the mouth of tributaries, Lane Creek (RM 113.6) and Portage Creek (RM 148.8), and the other site was in the mainstem Susitna at RM 147.0 off an island. At each site several extremely ripe females and males were captured. Female round whitefish expelled eggs when their abdomens were palpated. No spent fish were captured at these sites.

Fork lengths of 2,497 round whitefish ranged from 23-403 mm with a mean of 167 mm. Appendix Figure C-12 illustrates the length frequency composition of all fish measured.

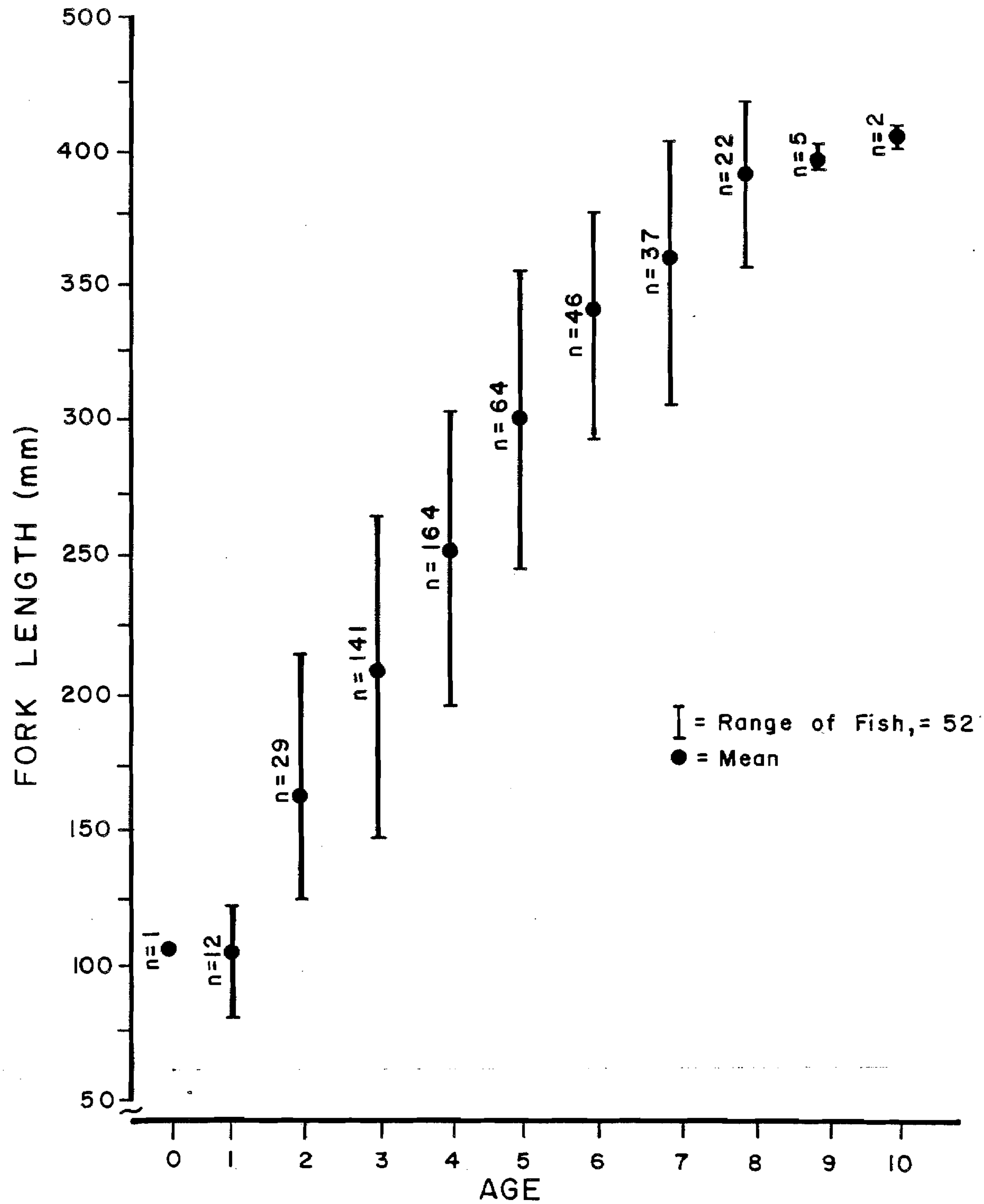
Four hundred fifty-six round whitefish were aged using scale analysis. Ages ranged from Age 1 to Age 12 and Ages 4 (12.3%), 5 (16.2%), 6



Appendix Figure C-7. Age and length relationships for spawning Arctic grayling captured in the Susitna River between the Chulitna River confluence and Devil Canyon, May 20 to June 22, 1983.



Appendix Figure C-8. Length frequency composition of Arctic grayling captured in the Susitna River between

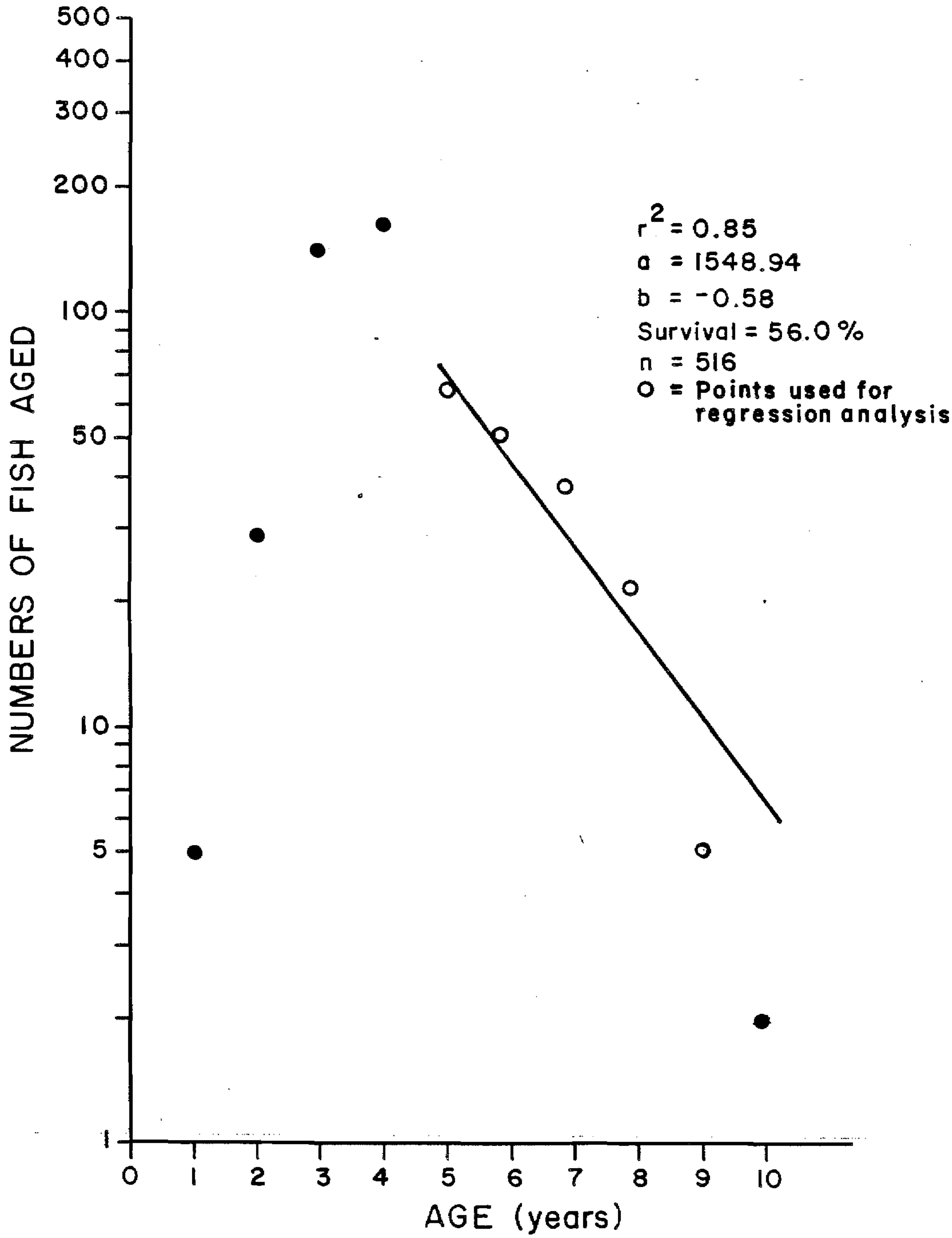


Appendix Figure C-9. Age and length relationship for Arctic grayling captured in the Susitna River between the Chulitr River confluence and Devil Canyon, May to October 1983.

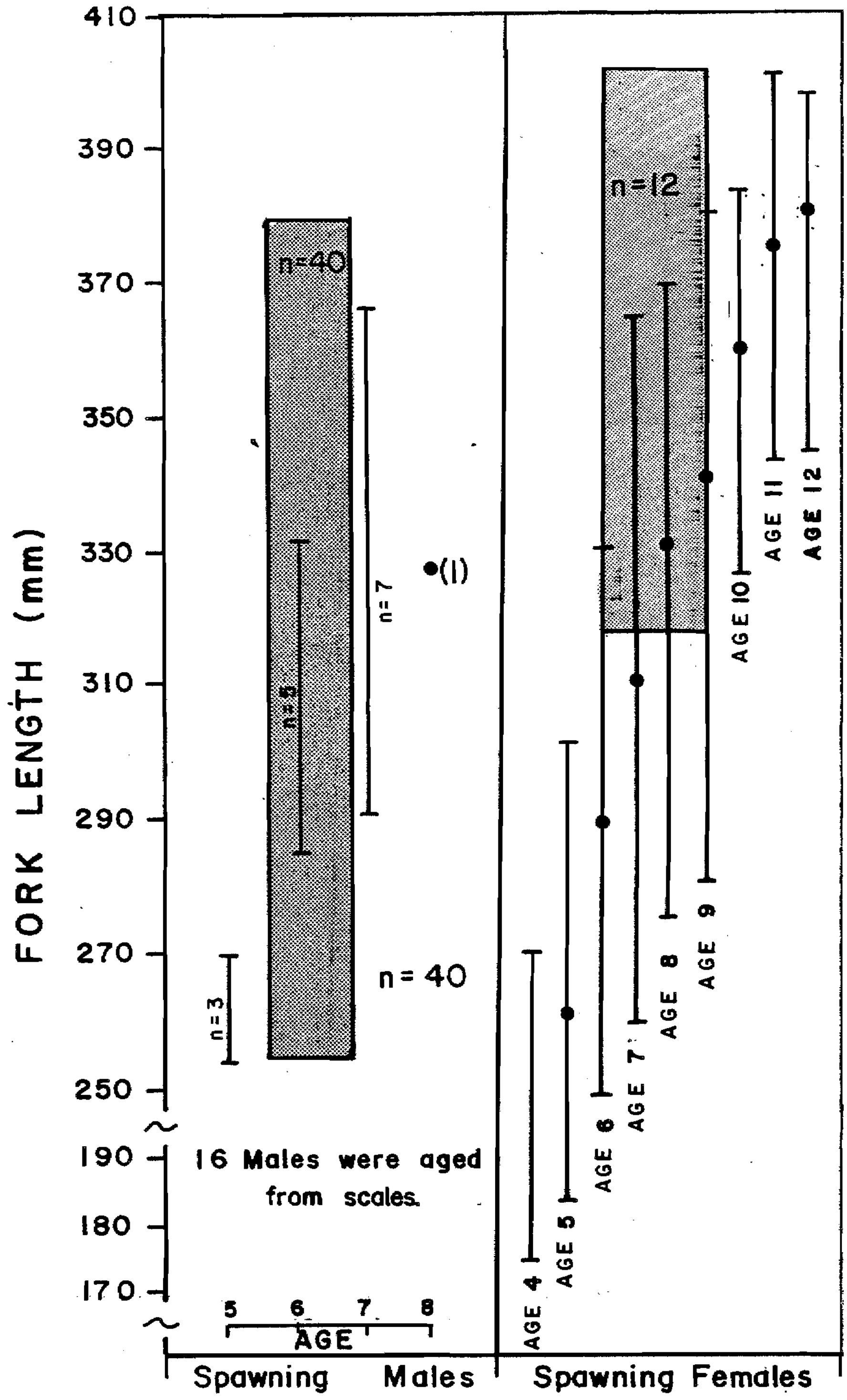
Appendix Table C-2. Arctic grayling age-length relationships on the Susitna River between the Chulitna River confluence and Devil Canyon, May to October 1983. Fish aged were captured by boat electrofishing, hook and line and hoop net.

Age (years)	Total No. of Fish Sampled	Length (mm) Mean	Standard Deviation	95% Confidence Intervals	Range
0	1	108			
1	5	113	9.63	101 - 125	97 - 122
*1	12	105	12.83	97 - 113	80 - 122
2	29	160	19.92	152 - 168	126 - 212
3	141	207	25.38	203 - 211	142 - 265
4	164	254	24.76	250 - 258	198 - 315
5	64	301	28.72	294 - 308	245 - 365
6	46	341	19.45	335 - 347	290 - 380
7	37	364	23.52	356 - 372	315 - 409
8	22	390	19.87	381 - 399	362 - 444
9	5	396	6.28	388 - 404	390 - 405
10	2	411	7.78	341 - 481	405 - 416
*Total	523	261			80 - 444

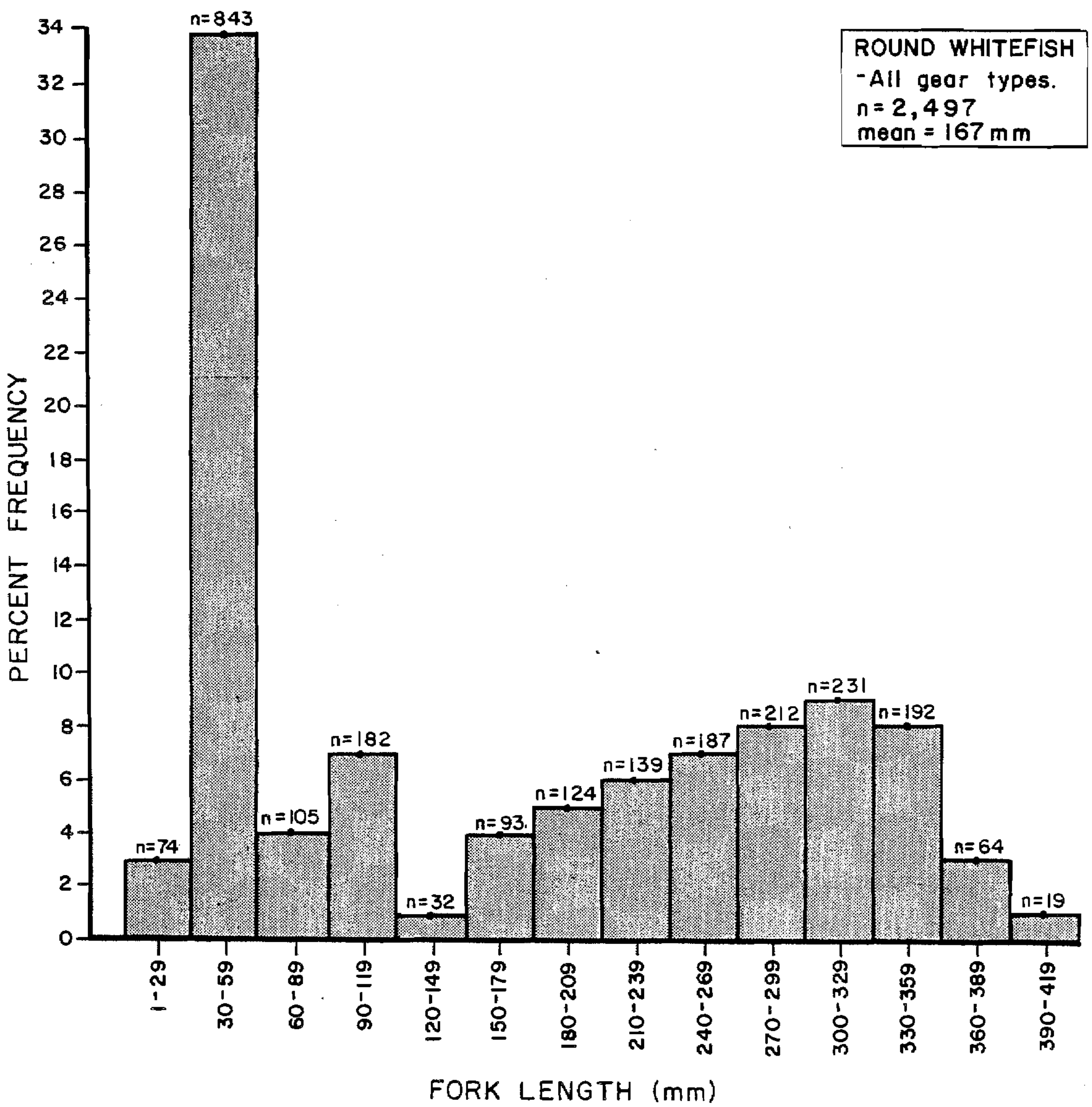
* Aged fish caught by all sampling methods.



Appendix Figure C-10. Survival rate curve for Arctic grayling captured in the Susitna River between the Chulitna River confluence and Devil Canyon, 1983.



Appendix Figure C-11. Age and length relationship for spawning round whitefish in the Susitna River between the Chulitna River confluence and Devil Canyon, October 4 to November 7, 1983.



Appendix Figure C-12. Length frequency composition of round whitefish captured in the Susitna River between the Chulitna River confluence and Devil Canyon by all gear types, May to October 1983.

(11.4%), 7 (13.4%), and 8 (11.6%) were sampled most often (Appendix Table C-3). Appendix Figure C-13 shows rapid growth rates for Susitna River round whitefish to Age 3 then slower growth rates thereafter.

Four hundred nineteen round whitefish were captured by boat electrofishing and aged. The instantaneous survival rate for round whitefish captured by boat electrofishing was determined to be 58.3 % (Appendix Figure C-14).

Humpback Whitefish

Eight hundred twenty humpback whitefish were captured in the Susitna River between Cook Inlet and Devil Canyon during 1983. Fork lengths of 604 humpback whitefish were measured to the nearest millimeter. Fork lengths ranged from 30-480 mm with a mean of 125 mm. The length frequency composition of the humpback whitefish catch is presented in Appendix Figure C-15.

Ages of 78 humpback whitefish captured in the Yentna River (TRM 4.0) and 41 humpback whitefish captured in the Susitna between the Chulitna River confluence and Devil Canyon were determined by scale analysis. Ages from fish captured on the Yentna River ranged from Age 5 to Age 12 with Ages 6 (25.6%), 7 (18.0%) and 8 (20.5%) predominating (Appendix Table C-4). Humpback whitefish were captured between the Chulitna River confluence and Devil Canyon ranged from Age 1 to Age 8 with Ages 4 (26.8%) and 5 (22.0%) predominating. The age-length relationship of humpback whitefish presented in Appendix Figure C-16 shows that humpback whitefish are slow growing with a wide range of fork lengths occurring at several age classes.

Longnose Suckers

Sexual maturity was determined for 55 longnose suckers captured on the Susitna River from May 22 to September 20, 1983. Sexually ripe male longnose suckers were captured throughout the summer. Sexually ripe female longnose suckers were captured during June and September. Spawned out males and females were captured from June 6 to July 18.

Fork lengths for the spawning male longnose suckers ranged from 282-392 mm with a mean of 332 mm. Spawning female longnose suckers ranged from 300-408 mm with a mean of 348 mm.

Thirteen of the male longnose suckers were aged by scale analysis with ages ranging from six to nine (Appendix Figure C-17). Eight female longnose suckers aged ranging from seven to ten years old.

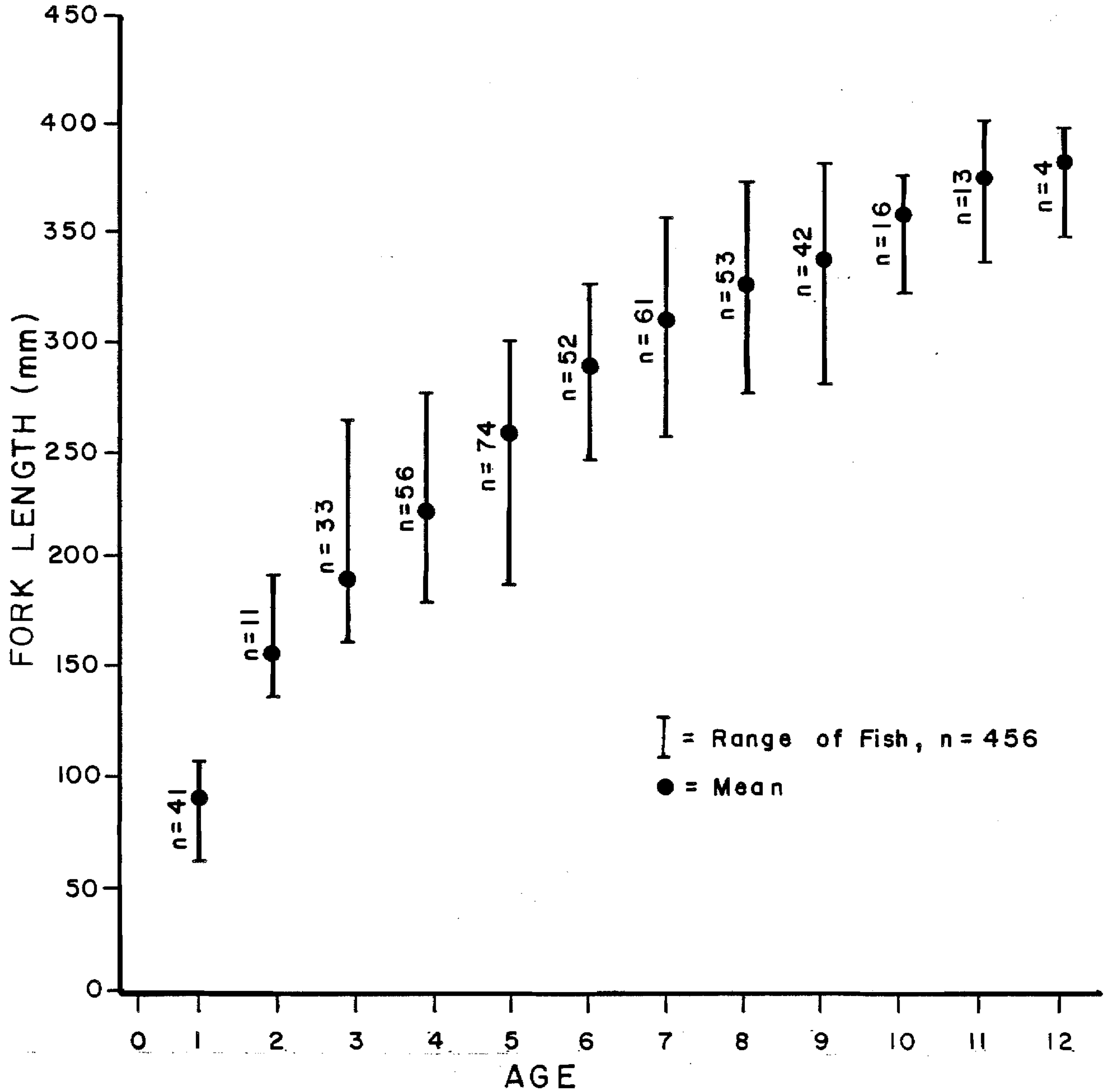
Fork lengths of 571 longnose suckers were measured. Fork lengths of longnose suckers ranged from 21-411 mm with a mean of 258 mm. The length frequency composition of longnose suckers captured in 1983 is presented in Appendix Figure C-18.

One hundred thirty-six longnose suckers were aged by scale analysis. Ages ranged from Age 1 to Age 11 and Ages 7 (23.5%) and 8 (25.0%) were the most abundant age classes encountered (Appendix Table C-5).

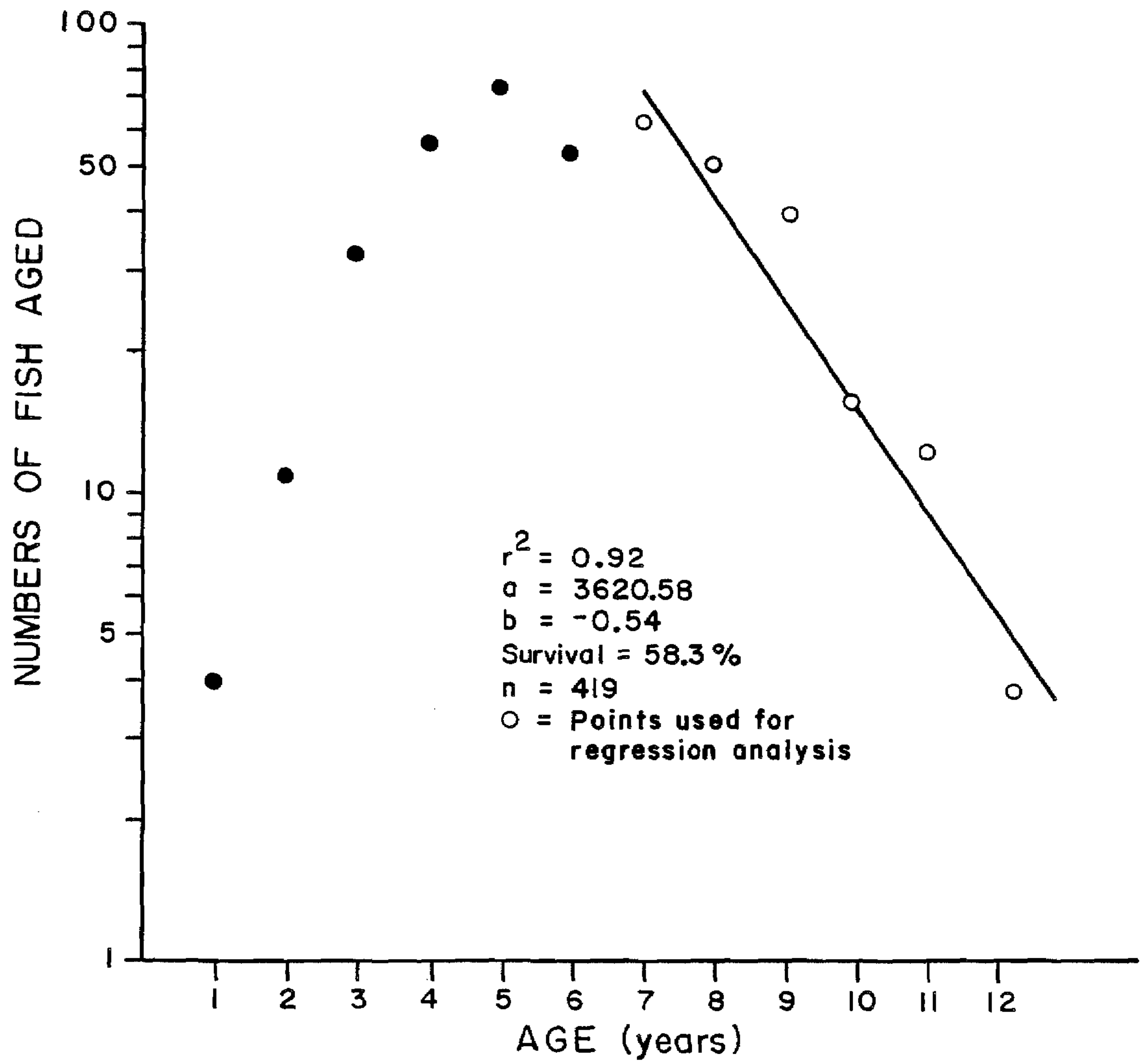
Appendix Table C-3. Round whitefish age-length relationships on the Susitna River between the Chulitna River confluence and Devil Canyon, May to October 1983. Fish aged were captured by boat electrofishing.

		Length (mm)			
Age (years)	Total No. of Fish Sampled	Mean	Standard Deviation	95% Confidence Intervals	Range
1	4	102	4.57	95 - 109	95 - 105
*1	41	89	11.90	85 - 93	67 - 110
2	11	152	15.94	141 - 163	135 - 187
3	33	187	22.34	179 - 195	154 - 265
4	56	222	20.13	217 - 227	174 - 271
5	74	262	20.74	257 - 267	184 - 302
6	52	290	42.67	278 - 302	248 - 332
7	61	311	21.65	305 - 317	260 - 366
8	53	332	19.15	327 - 337	276 - 386
9	42	342	19.44	336 - 348	282 - 390
10	16	362	19.70	352 - 372	327 - 384
11	13	376	19.45	364 - 388	388 - 403
12	4	382	23.96	344 - 422	346 - 397
*Total	456	267			67 - 403

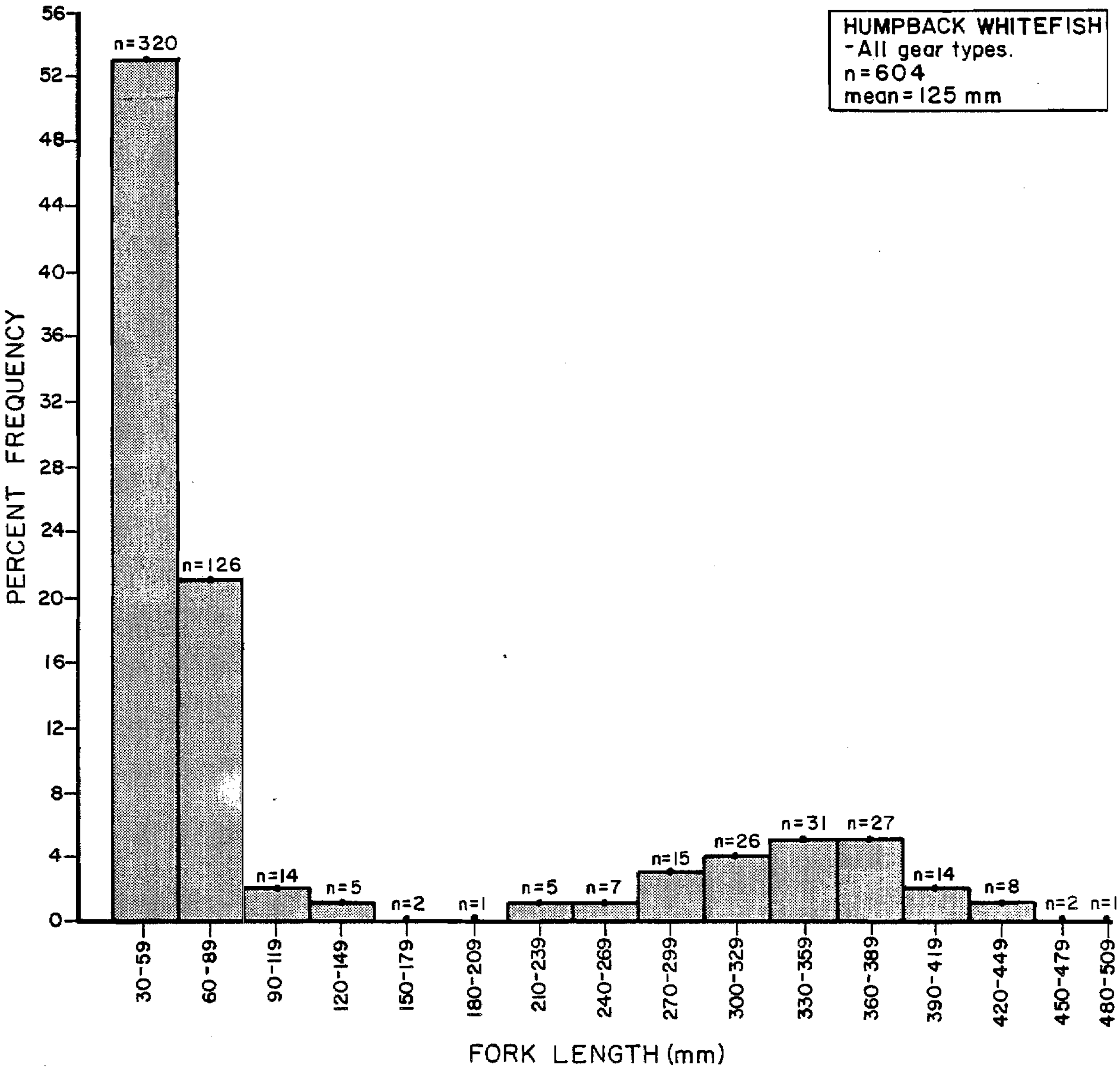
* Aged fish caught by all sampling methods.



Appendix Figure C-13. Age and length relationships for round whitefish captured in the Susitna River between the Chulitna River confluence and Devil Canyon, May to October 1983.



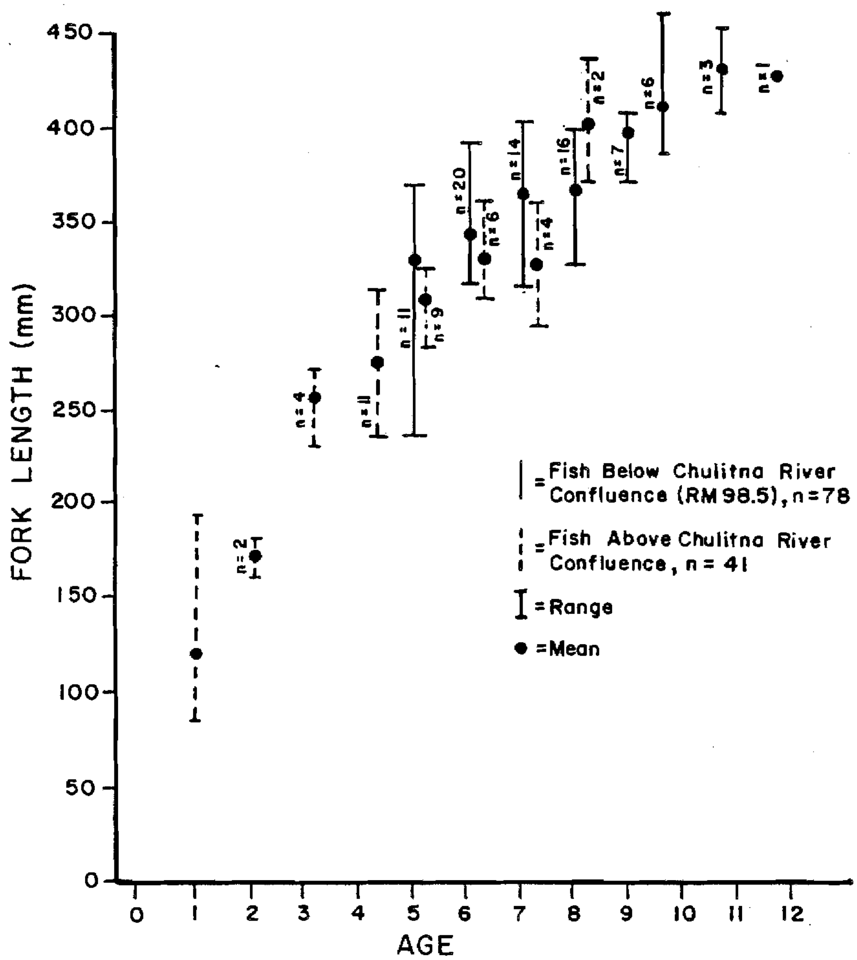
Appendix Figure C-14. Survival rate curve for round whitefish captured in the Susitna River between the Chulitna River confluence and Devil Canyon, 1983.



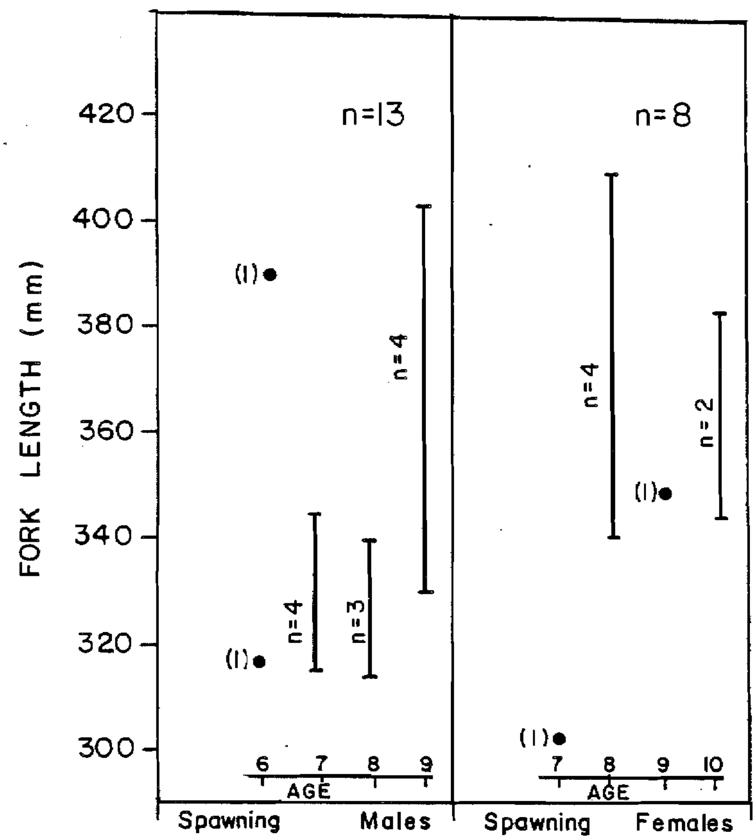
Appendix Figure C-15. Length frequency composition of humpback whitefish captured in the Susitna River between Cook Inlet and Devil Canyon by all gear types, May to October 1983.

Appendix Table C-4. Humpback whitefish age-length relationships on the Susitna River between Cook inlet and Devil Canyon, May to October 1983. Fish aged were captured by all sampling methods.

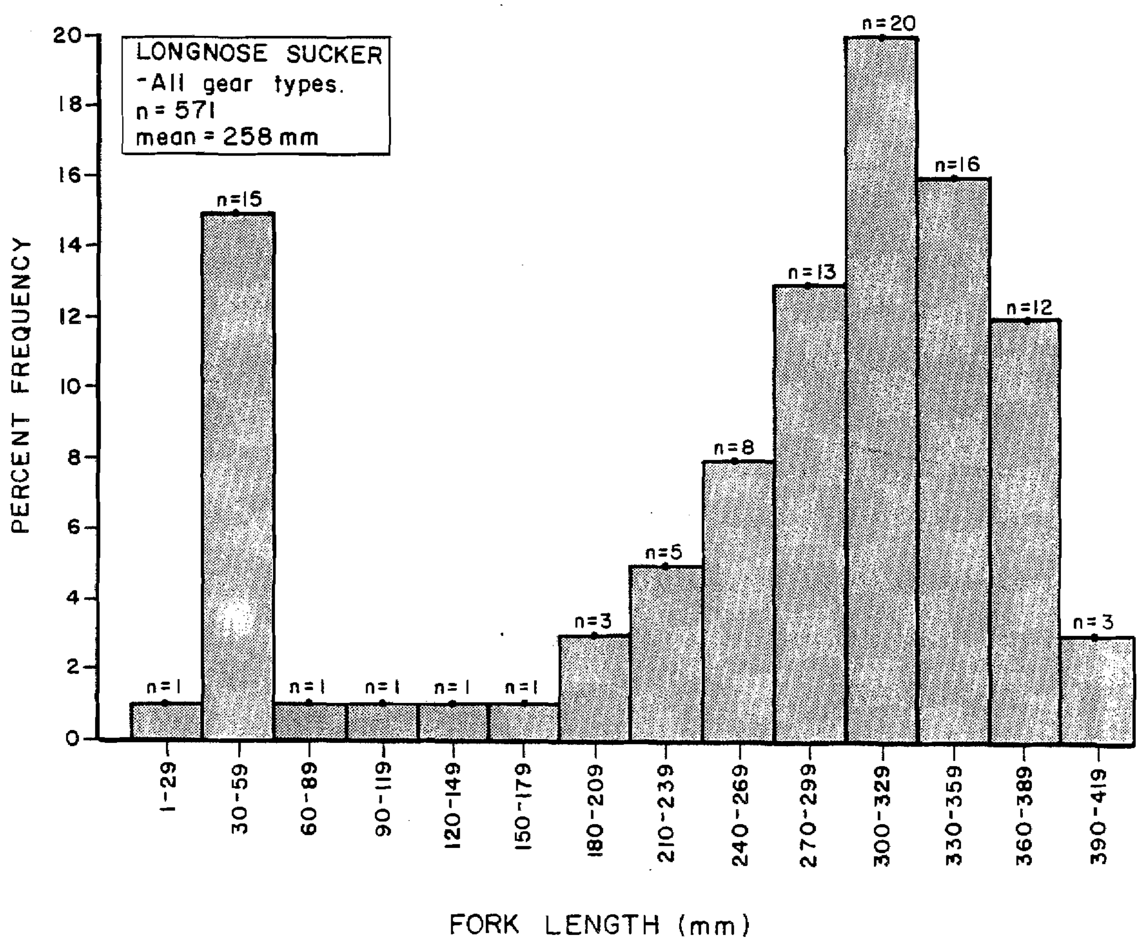
	Yentna River (TRM 4.0)					Chulitna Confluence to Devil Canyon					Yentna River to Devil Canyon				
	Total No.	Length (mm)				Total No.	Length (mm)				Total No.	Length (mm)			
Age (years)	of fish Sampled	Mean	Standard Deviation	95% Confidence Intervals	Range	of fish Sampled	Mean	Standard Deviation	95% Confidence Intervals	Range	of fish Sampled	Mean	Standard Deviation	95% Confidence Intervals	Range
1						3	121	60.72	0 - 272	77 - 190	3	121	60.72	0 - 272	77 - 190
2						2	159	10.07	69 - 249	153 - 165	2	159	10.07	69 - 249	153 - 165
3						4	251	18.96	221 - 281	228 - 268	4	251	18.96	221 - 281	228 - 268
4						11	270	22.04	255 - 285	236 - 311	11	270	22.04	255 - 285	236 - 311
5	11	334	25.08	317 - 351	286 - 363	9	303	13.82	292 - 314	281 - 322	20	320	25.54	308 - 332	281 - 363
6	20	348	22.74	337 - 359	316 - 390	6	330	18.23	311 - 349	303 - 358	26	343	22.80	334 - 352	303 - 390
7	14	367	25.51	352 - 382	318 - 404	4	322	29.18	276 - 368	288 - 356	18	350	31.82	334 - 366	288 - 404
8	16	367	22.25	355 - 379	329 - 400	2	402	49.50	0 - 847	367 - 437	18	371	26.63	358 - 384	329 - 437
9	7	397	22.22	376 - 418	369 - 410						7	397	22.22	376 - 418	369 - 410
10	6	416	31.06	383 - 449	377 - 458						6	416	31.06	383 - 449	377 - 458
11	3	430	20.03	380 - 480	409 - 449						3	430	20.03	380 - 480	409 - 449
12	1	419									1	419			
Total	78	367			286 - 458	41	279			77 - 437	119	337			77 - 458



Appendix Figure C-16. Age and length relationship for humpback whitefish captured in the Susitna River between Cook Inlet and Devil Canyon, May to October 1983.



Appendix Figure C-17. Age and length relationships for spawning longnose suckers captured in the Susitna River between the Chulitna River confluence and Devil Canyon, May to October 1983.



Appendix Figure C-18. Length frequency composition of longnose suckers captured in the Susitna River between the Chulitna River confluence and Devil Canyon by all gear types, May to October 1983.

Appendix Table C-5. Longnose sucker age-length relationships on the Susitna River between the Chulitna River confluence and Devil Canyon, May to October 1983. Fish aged were captured by all methods.

Age (years)	Total No. of Fish Sampled	Length (mm) Mean	Standard Deviation	95% Confidence Intervals	Range
1	3	81	11.37	53 - 109	68 - 90
2	2	127	10.28	35 - 219	120 - 133
3	7	196	18.51	179 - 213	168 - 219
4	2	244	3.54	212 - 276	241 - 246
5	10	245	23.97	228 - 262	208 - 282
6	16	291	21.74	279 - 303	256 - 321
7	32	320	25.90	311 - 329	276 - 370
8	34	347	27.60	337 - 357	307 - 408
9	17	364	24.36	351 - 377	330 - 407
10	10	363	20.72	348 - 378	336 - 403
11	3	372	16.26	332 - 412	360 - 383
Total	136	312			68 - 408

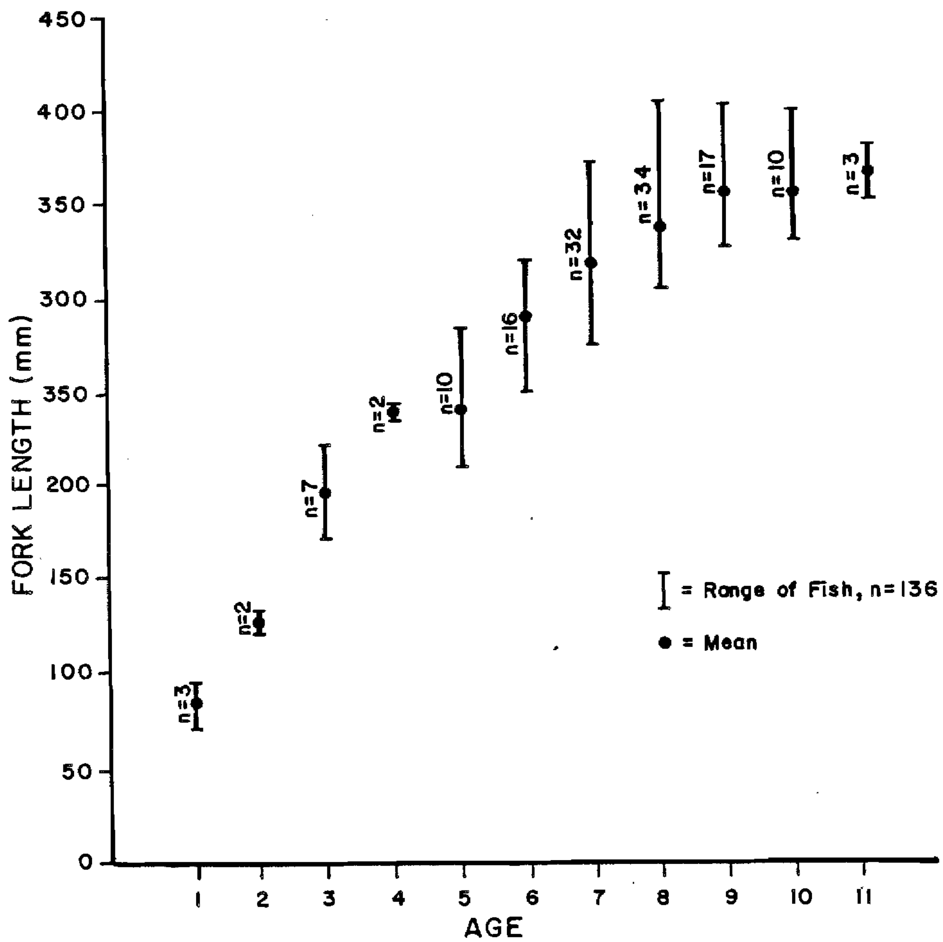
Appendix Figure C-19 shows that the growth rate of longnose suckers in the Susitna River between the Chulitna River confluence and Devil Canyon is relatively slow.

Dolly Varden

Seventeen Dolly Varden were captured on the Susitna River in 1983. Eight fish were captured by boat electrofishing and seven by the downstream migrant traps at RM 103.0. The downstream migrant traps Dolly Varden catches were all juveniles ($<$ 200 mm). Fork lengths of boat electrofishing Dolly Varden catches ranged from 146-320 mm.

Threespine Stickleback

Five hundred and seventy-four threespine stickleback were captured by the downstream migrant traps at RM 103.0 in 1983. Total lengths of these threespine stickleback ranged from 11-93 mm with a mean of 31 mm.



Appendix Figure C-19. Age and length relationship for longnose suckers captured in the Susitna River between the Chulitna River confluence and Devil Canyon, May to October 1983.

APPENDIX D

Population Estimates

During the course of the 1983 Resident Fish Studies, biases and assumptions relating to the population estimates of resident fish were identified. These biases fall into two general categories, those caused by behavior or other attributes of the biology of the fish and those caused by the sampling technique (Appendix D-1). The biases for each of the population estimates made were shown to be different depending on the species, area, and gear type used for sampling, or by a combination of these three factors.

The major bias associated with the rainbow trout population estimate in Fourth of July Creek (RM 131.1) was behavioral, the avoidance of recapture. After a fish was captured and marked, the capture probability of that fish decreased substantially since it learned to avoid the lure. This was observed during the second and third occasion of sampling. Although the lure was put before the marked fish, it did not strike. To correct for this bias, a behavioral model (a type of removal model) which allowed for decreases in capture probabilities was used in calculating the population estimate.

A secondary bias of the population estimate for rainbow trout at Fourth of July Creek was the size selectivity of sampling gear, resulting in variations in individual capture probabilities. Smaller fish have been reported to have a smaller capture probability than larger ones in other population estimates (ADF&G 1983d). This was also true for rainbows in Fourth of July Creek; angling was ineffective in capturing fish under 151 mm in fork length.

The population estimate of 107 rainbows in Fourth of July Creek therefore pertains only to rainbow trout over 150 mm.

Similar biases were shown at a mainstem site between RM 138.9-140.1 where a burbot population estimate was made. Since no burbot were recaptured at this site during the four day sampling period, a removal model was used to generate a population estimate. Other tag and recapture data from 1981-83 have also shown that burbot evidently learn to avoid recapture since less than ten have been recaptured during three years of sampling.

A secondary bias of size selectivity as found for rainbow trout in Fourth of July Creek, for the population estimate of burbot was evident since no burbot under 300 mm total length were captured. The population estimate of burbot in this reach of the mainstem river should therefore be applicable only to burbot over 300 mm in length.

To minimize the effects of in- or outmigration, sampling for rainbow trout was done in July. Electrofishing during July and August 1982 captured few rainbow trout in the mainstem indicating that rainbow trout are residing in the tributaries during this time period.

To minimize the possibility of in- or outmigration for burbot, sampling was done in July because catch results from 1981-82 and radio tagged burbot data from 1982 show that burbot move only from September to March.

Appendix Table D-1 Biases, corrections, and assumptions which affect the resident fish population estimates below Devil Canyon, 1983.

Bias:	Lack of randomness of mark or recapture effort.
Correction:	Stratification of habitat location by habitat type.
Assumption:	Random mark and recapture effort.
Bias:	Unequal recapture probability due to time between censusing.
Correction:	Use of multiple census estimator during a short time period.
Assumption:	Time does not affect recapture probability.
Bias:	Population is open geographically.
Correction:	Use of July and August data only; period of minimal movement.
Assumption:	Population is closed geographically.
Bias:	Heterogeneity; variance in the probability of capture and recapture between age classes.
Correction:	Stratification of age class for entire population, develop correction factor for populations.
Assumption:	Population estimates limited to Age IV and older fish due only to insufficient sample sizes of smaller fish.

Although population estimates were generated for burbot in the mainstem Susitna, problems were incountered with calculating population estimates for other resident species in the mainstem during 1983. For instance, catch information shows the major biases associated with the population estimates made at Slough 8A (RM 125.3) were probably that the fish migrated in and out of the site during the sampling (not a closed population) and that there was an avoidance of fish to electrofishing which was the method of capture used in Slough 8A. Sampling was done at this site during only a 72 hour period (twice a day for three days) to correct for the geographical bias, however, failed. The resultant population estimate, for example, of round whitefish at this site was believed inaccurate since the estimate was 896 but had a standard error of 294.43 using the population model selected by the computer as best fitting the data. The low catch of round whitefish at Slough 8A on two occasions compared to the other four occasions (25, 3, 38, 28, 28, and 8) showed that fish were moving in and out of the slough during at least these two time periods.

The movements of round whitefish as well as other species during these two time periods, meanwhile, were probably due to the changing turbidity in Slough 8A during the sampling period. The mainstem river was approximately 0.5 feet lower on those two occasions compared to the other four occasions. As the mainstem water decreased, the slough became clearer. The decreased round whitefish catches on these two occasions suggests that the fish moved into the mainstem when the water in the slough was no longer turbid enough to provide adequate cover.

Resident fish also appeared to avoid electrofishing and this avoidance was not anticipated prior to conducting the estimates. Of 130 round whitefish captured in Slough 8A during six occasions only nine (6.9%) were recaptured. Similar recapture percentages and speculation on fish avoidance to boat electrofishing were reported by Jacobs and Swink (1982). They found, however, that differences in turbidities did not affect capture efficiencies, although this may have been due to their study area not having as large changes in turbidities as our study did. They further point out that use of electrofishing alone for mark and recapture estimates in large rivers are generally unsuccessful because not enough fish are recaptured.

In order to make accurate population estimates for resident fish other than burbot in the mainstem Susitna River, methods have to be changed from those used in 1983. Jacobs and Swink (1982) suggested using boat electrofishing coupled with rotenone but this is not applicable to the Susitna River. Electrofishing coupled with baited trapnets may prove more successful, or large seining nets could be used to block the ends of channels and sloughs . Another more difficult method would be the use of population estimate models that allow for in- and outmigration (open population models).

Population estimates for resident fish in tributaries to the Susitna River can be made if enough fish of a given species are captured. Population estimates of rainbow trout in Fourth of July Creek succeeded because relatively large numbers of rainbow trout were captured and recaptured and because there was little or no in- or outmigration during the sampling period. The time period of sampling was very important at Fourth of July Creek. Sampling was conducted during mid-July because the flows were extremely low and no adult salmon were in the tributary (Estes and Vincent-Lang 1984). Biologists, therefore, had easy access along the stream and the fish were easily caught because less food in the form of salmon eggs was present in the system.

PART 6

Resident Fish Habitat Studies

RESIDENT FISH HABITAT STUDIES

1984 Report No. 2, Part 6

by Paul M. Suchanek, Richard L. Sundet and Mark N. Wenger

Alaska Department of Fish and Game
Susitna Hydro Aquatic Studies
2207 Spenard Road
Anchorage, Alaska 99503

ABSTRACT

The macrohabitat distribution and microhabitat suitability for rainbow trout, Arctic grayling, round whitefish, and longnose suckers in the Susitna River drainage between the Chulitna River confluence and Devil Canyon were evaluated using electrofishing, beach seine, and hook and line catch data and habitat data collected at radio telemetry relocation sites (rainbow trout and burbot) and spawning sites (round whitefish).

Turbidity had important effects on distribution of both adult and juvenile resident fish. Longnose suckers and juvenile round whitefish were found in highest numbers in turbid water. Adult rainbow trout, Arctic grayling, and round whitefish found clear water more suitable, but used turbidity for cover. Suitability criteria for velocity, depth, and object cover were fit to the distribution of resident fish. The location of radio tagged rainbow trout among macrohabitat types varied greatly by season.

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1.0 INTRODUCTION

The Resident Fish Study was initiated in the fall of 1980 to gather preliminary data concerning the following general objectives described in 1979 by the Alaska Department of Fish and Game for the Susitna Hydroelectric project:

A. Define seasonal distribution and relative abundance of resident fish in the Susitna River between Cook Inlet and Devil Canyon.

B. Characterize the seasonal habitat requirements of selected resident fish species within the study area.

During 1981, the primary emphasis was placed upon gathering seasonal distribution and relative abundance data. In 1982, more effort was placed upon characterizing the seasonal habitat requirements. During the 1983 field season, the resident fish studies were refined. We attempted to quantify the important habitat parameters associated with spawning and rearing (growth) of selected resident fish species and measure fish density in spawning and rearing habitats to provide an estimate of habitat quality.

There can be positive or negative effects upon fisheries after the construction of a hydroelectric dam (MDFW&P 1983). Postproject effects may include changes in water temperature, flow, and turbidity. Preproject baseline fisheries data and their correlation to habitat conditions, therefore, are necessary to evaluate the overall potential impact to these fisheries. One of these impacts can be the effect on rearing fish.

Successful rearing of resident fish in the Susitna River is dependent upon a variety of habitat conditions that may be substantially altered under postproject flow regimes (ADF&G 1983c; 1983d). Four major macrohabitats influenced by the mainstem were identified as possible rearing areas in the Susitna River for resident fish (ADF&G 1983e). These four major habitat types are tributary mouths, side sloughs, upland sloughs, and mainstem channels or side channels. Macrohabitat information reported in this report supplements ADF&G (1983e) as much less boat electrofishing was done in 1983.

Microhabitat suitability criteria are one means of quantifying the relationship of a life stage of a fish species to its habitat. The present work develops preliminary suitability criteria by species and river reach for application in incremental simulations of rearing habitat as a function of mainstem flows (see Part 7 of this report). Preliminary data presented for rainbow trout, Arctic grayling, round whitefish, and longnose suckers are univariate functions for cover type, percent cover, depth, and velocity. Frequency distributions by habitat attribute were not generated for other resident fish species such as burbot due to small catches. Differences between distributions in low and high turbidity water were detailed as data permitted.

2.0 METHODS

A two man crew conducted sampling on the Susitna River between the Chulitna River confluence and Devil Canyon from May to October 1983 to capture resident fish for micro- and macrohabitat studies (Figure 1). Sampling was performed largely from a river boat, with occasional use of helicopters. The primary sampling methods were boat electrofishing and hook and line. Habitat data collected included water depth and velocity, cover, substrate, and water chemistry parameters.

2.1 Study Locations

2.1.1 Macrohabitat studies

Relative abundances of selected resident fish species were determined by boat electrofishing at various macrohabitats in the Susitna River from May to October. These macrohabitats included mainstem channels and side channels, upland sloughs, side sloughs, and tributary mouths in the reach of river between the Chulitna River confluence and Devil Canyon.

Also, 26 radio tagged rainbow trout were located in four major macrohabitats in 1983. These macrohabitats included tributaries, upland and side sloughs, tributary mouths, and the mainstem. Radio tagged fish were located at these sites in the Susitna River between RM 100.7 and RM 148.8 from May 19 to October 21, 1983.

2.1.2 Microhabitat studies

Thirteen adult resident microhabitat study sites were sampled from July to October to develop habitat suitability curves. These sites were located between the Chulitna River confluence and Devil Canyon and included six tributary mouths, three tributaries, three side sloughs, and one upland slough (Table 1).

Nine sites at sloughs and tributary mouths were selected for sampling by boat electrofishing because relatively high numbers of adult resident fish exist in these areas (ADF&G 1983b). The nine sites were sampled with boat electrofishing gear twice a month from mid-July to October. The upper reaches of four tributaries were irregularly sampled by hook and line in conjunction with rainbow trout population estimates or studies of radio tagged rainbow trout. (Presented in Part 5 of this report).

Juvenile and a few adult resident fish were captured incidentally at 35 sites sampled during the juvenile anadromous studies reported in parts 2 and 3 of this report.

Microhabitat was also measured at relocation sites of 24 radio tagged rainbow trout and burbot. These data were recorded at tributary mouths, sloughs and sites in the mainstem Susitna River between RM 100.8 and RM 148.7 and at three tributaries.

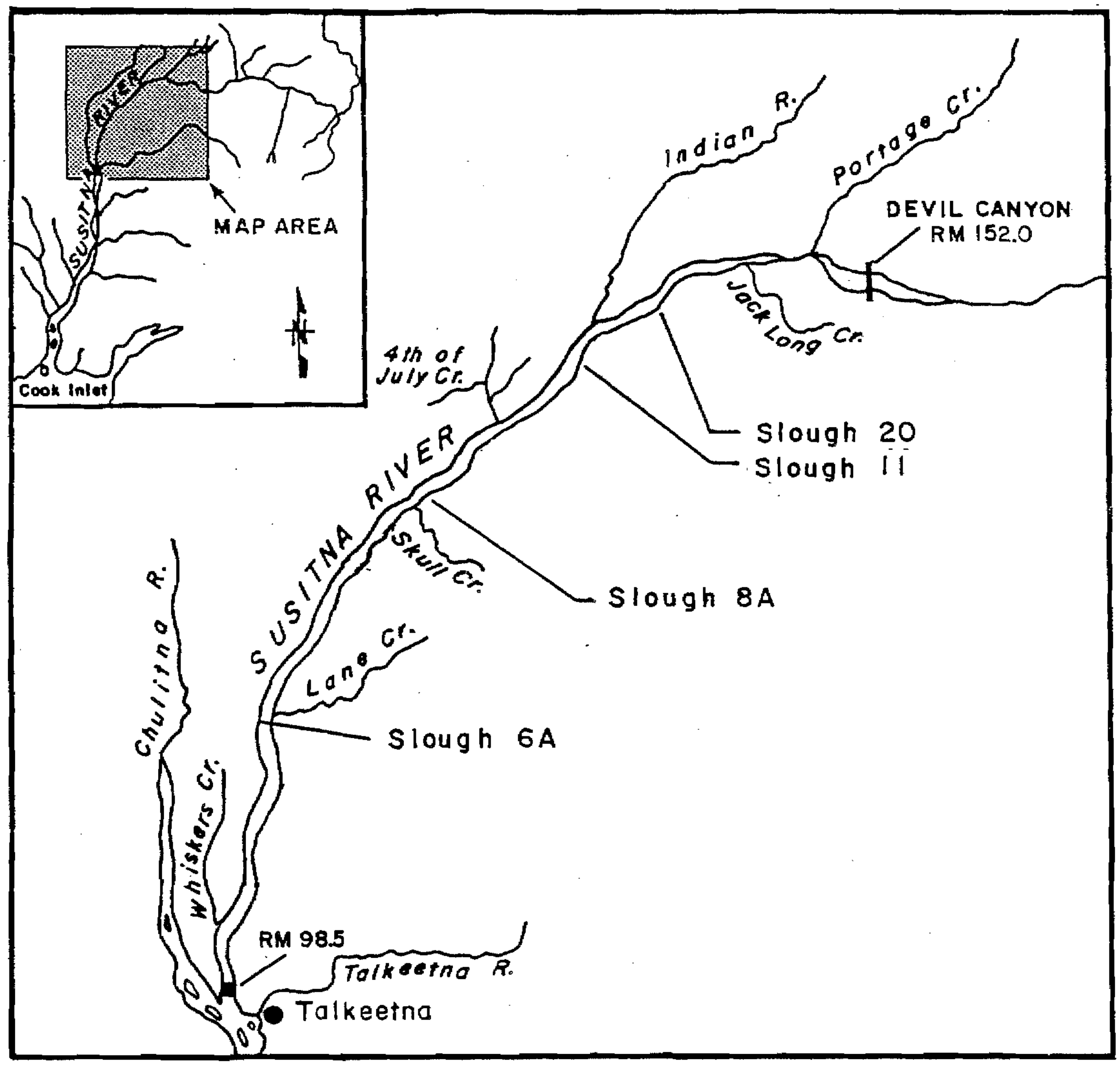

Figure 1. Map of the Susitna River from the Chulitna River confluence to Devil Canyon showing major tributaries and sloughs, 1983.

Table 1. Adult resident fish microhabitat study sites on the Susitna River between the Chulitna River confluence and Devil Canyon, 1983.

Location	River Mile (RM)	Sampling Method: Hook & line	Sampling Method: Boat Electro-fishing
Whiskers Creek Slough	101.2		X
Whiskers Creek - Mouth	101.4	X	
Slough 6A	112.3		X
Lane Creek - Mouth	113.6		X
Lane Creek - TRM [a] 0.6	113.6	X	
Slough 8A - Mouth	125.3		X
Fourth of July Creek - Mouth	131.1		X
Fourth of July Creek - TRM 0.8	131.1	X	
Slough 11 - Mouth	135.3		X
Indian River - Mouth	138.6		X
Indian River - TRM 1.5	138.6	X	
Jack Long Creek - Mouth	144.5		X
Portage Creek - Mouth	148.8		X

a/TRM = tributary river mile

2.2 Field Data Collection

2.2.1 Biological

Adult and a few juvenile (under 200mm) resident fish were captured at accessible locations in the Susitna River with a boat mounted electrofishing unit. Electrofishing equipment consisted of a Coffelt, model VVP-3E, boat electrofishing unit powered by a 2500 watt Onan portable generator. Boat electrofishing procedures are described in ADF&G (1983a). Adult resident fish were also captured by hook and line in tributaries. Juvenile resident fish at upland slough, side slough, mainstem and tributary sites were collected with beach seines and backpack electroshockers.

All resident fish were identified to species. Biological data collected included length, sex, and sexual maturity. Ages were determined by reading scale samples. All healthy adult resident fish were tagged with a Floy anchor tag and released in continuance of a resident fish migrational study described in part 5 of this report. Spawning sites of resident fish species were determined when captured female fish expelled eggs upon slight palpation of the abdomen.

Juvenile resident fish were captured incidentally during juvenile anadromous sampling of cells and grids located at a greater diversity of sites. Techniques differed somewhat as beach seining and backpack electrofishing were used (see Part 2 of this report for details on collection methods).

Microhabitat data were collected from relocations of four burbot and 20 rainbow trout radio tagged in 1983. Tagging techniques are presented in ADF&G (1981, 1983a) and part 5 of this report. Radio tagged fish were tracked from airplanes and boats. A summary of capture and tracking locations of the tagged fish are presented in Part 5 of this report. Habitat measurements were taken after a radio tagged fish was relocated by boat to an area of no greater than 30 feet by 30 feet. In some cases, radio tagged fish were observed.

2.2.2 Habitat

Each microhabitat study location was divided into one to three grids. Grids were located so that the water quality within them was as uniform as possible and so that the grids would encompass a variety of habitat types. At tributary mouths, one grid was located in the mainstem Susitna River above the confluence of the tributary, another grid was set up within or below the confluence where the tributary was the primary water source, and a third grid was situated where the mainstem and tributary waters mixed (Figure 2). Sites located in sloughs and tributaries had one to three grids depending on the water quality within the slough. Since grid location was dependent upon specific hydraulic characteristics, grid locations were redetermined during each sampling trip based on differences in turbidity and water chemistry readings.

Grids were subdivided into cells. Cells were rectangular and the length and width of each cell varied. The length boundaries of cells within

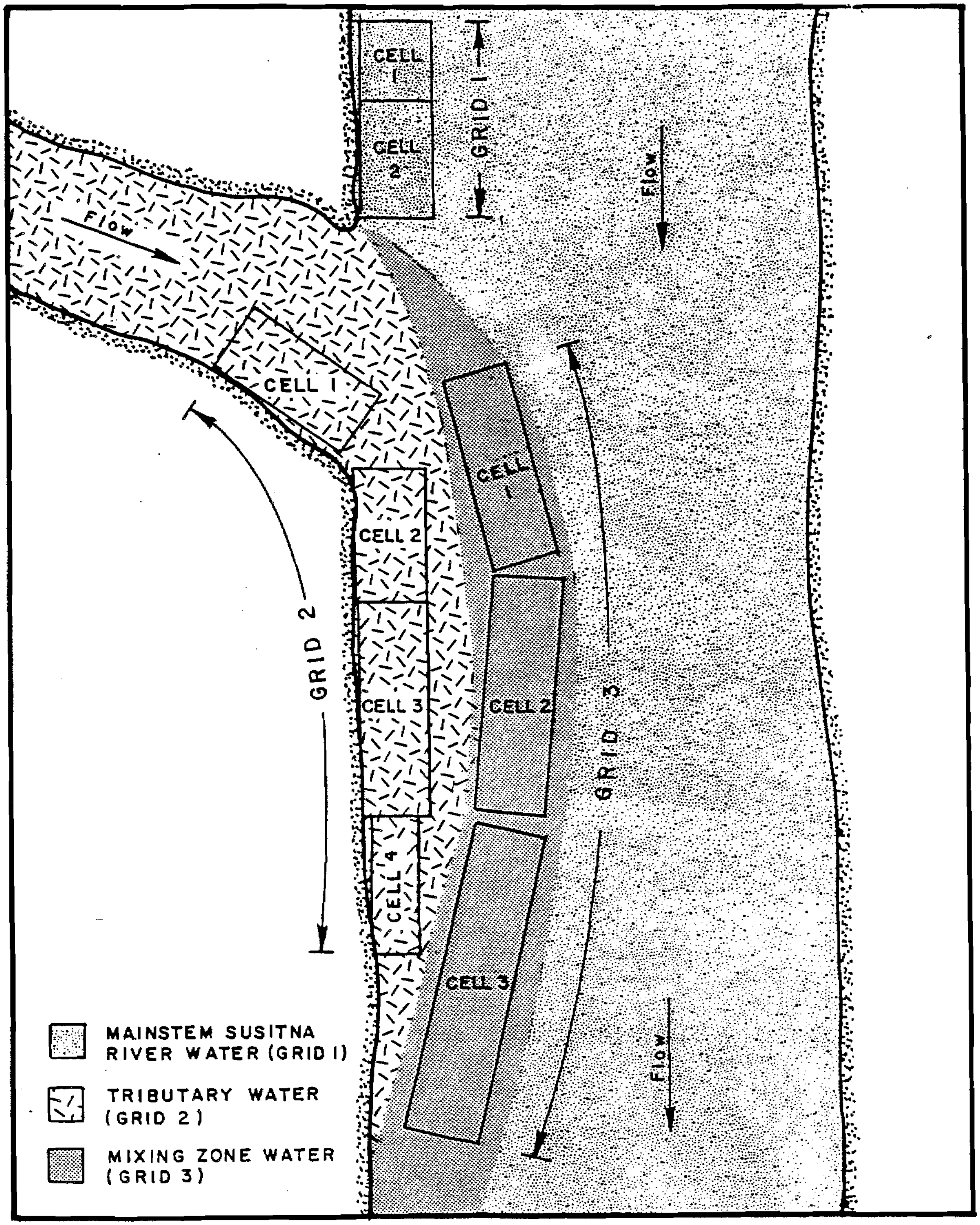

Figure 2. Arrangement of grids and cells at a hypothetical adult resident fish macrohabitat study site.

each grid were marked with orange flagging prior to sampling. The width of cells in tributaries, which were sampled by hook and line, was the width of the stream. Cell widths at sloughs and tributary mouths, which were sampled by boat electrofishing, were determined to be five feet or a multiple of five feet. Five feet was chosen as a standard cell width because it is the average effective capture width of the boat electrofishing equipment used.

This method of sampling was designed to approximate the method that the "instream flow incremental methodology" uses to generate estimates of usable habitat (Bovee 1982, also see Part 7 of this report). The correlation of fish occurrence in cells with a particular set of physical parameters can be compared with the calculated usability of the habitat.

Habitat parameters measured within cells and at radio tagged fish relocations included dissolved oxygen, specific conductance, pH, turbidity, water temperature, water velocity, and water depth. Substrate type, cover type, and percent cover were estimated (Table 2). Intragravel temperatures were also recorded at all spawning sites.

Table 2: Substrate, cover, and percent cover classifications used for resident fish microhabitat studies.

Substrate	Cover Type	% Cover
Silt	No Cover	0 - 5%
Sand	Emergent Vegetation	6 - 25%
Small Gravel (1/8" - 1")	Aquatic Vegetation	26 - 50%
Large Gravel (1" - 3")	Debris/Deadfall	51 - 75%
Rubble (3" - 5")	Overhanging Riparian	76 - 95%
Cobble (5" - 10")	Undercut Banks	96 - 100%
Boulder (> 10")	Large Gravel 1" - 3"	
	Rubble 3" - 5"	
	Cobble or Boulder > 5"	

The mean depth of cells and radio tagged fish relocation sites was measured to the nearest tenth of a foot with a topsetting wading rod. The mean velocity was measured with a Price Model AA velocity meter. Turbidity measurements were made with an HF Instrument Model DRT-15 turbidometer in Nephelometric Turbidity Units (NTU's). Water quality measurements were taken with a Hydrolab model 4001 multi parameter meter.

Habitat parameters were recorded for each cell at resident fish microhabitat study sites. However if the water quality within a grid were relatively constant, only one measurement was taken to represent all cells within that grid. Specific data collection methodology is summarized in ADF&G (1984).

2.3 Data Analysis

2.3.1 Macrohabitat studies

Biological and catch per unit effort (CPUE) data were compiled by macrohabitat type from boat electrofishing sampling data recorded in conjunction with distribution and relative abundance studies presented in Part 5 of this report. Macrohabitat CPUE data were also compiled by pooling the catch from all the cells at microhabitat study sites sampled by boat electrofishing. The macrohabitat type of radio tagged fish relocation sites was also recorded.

Catch data recorded by Juvenile Anadromous Habitat Study (JAHS) crews were also compiled by macrohabitat type for incidentally captured juvenile resident fish. Mean CPUE's were calculated by macrohabitat type, summed, and then each CPUE by type was expressed as a percentage of the total to equalize sampling effort. These percentages were then used to analyze distribution by macrohabitat type. Macrohabitat types were defined with the discharge based classification scheme discussed in Part 2 of this report.

An analysis of variance (ANOVA) was run to determine whether macrohabitat type had a significant effect on the relative abundance of juvenile round whitefish (see Part 2 of this report for further details).

2.3.2 Microhabitat studies

2.3.2.1 Adult resident fish

Biological, habitat and catch data were recorded at microhabitat study sites according to ADF&G (1984). Adult fish microhabitat studies used two gear types, boat electrofishing and hook and line. Hook and line was used in tributaries, while boat electrofishing was used elsewhere. Hook and line data were analyzed separately from boat electrofishing data since the area each gear type sampled was very different in water quality and habitat characteristics.

Values of habitat attributes measured had to be pooled for analysis because of small sample sizes. Groupings for the boat electrofishing and hook and line data are detailed in Table 3. Groupings for the rainbow trout hook and line catch data were somewhat different than the boat electrofishing data because of small sample sizes and different cover types sampled.

Turbidity values were also grouped into three categories to determine the effects of low, moderate and high turbidities on resident fish distribution. The three turbidity groupings used were: 1 to 9 NTU, 10 to 30 NTU and greater than 30 NTU. Turbidity inflection points at 9 NTU and at 30 NTU were used because light penetration changes considerably at these points in other glacial systems in Alaska (Jeffery Koenings, pers. comm.) and because chinook salmon fry used turbidities of greater than 30 NTU for cover (see Part 3 of this report).

Table 3. Habitat attribute groupings for analysis of boat electrofishing and hook and line data.

Boat Electrofishing Habitat Attribute Groupings

No.	Velocity Grouping (ft/sec)	Depth Grouping (ft)	Percent Cover	Cover type	Substrate
1	0	0.7-2.0	0-5%	No cover	Silt - 1"
2	0.2-1.0	2.1-2.9	6-25%	Emergent or aquatic vegetation	1-3"
3	1.1-2.0	3.0-4.4	26-50%	Debris or overhanging riparian vegetation	3-5"
4	2.1-3.0	4.5 +	51+%	Large gravel (1-3")	5"+
5	3.1 +			Rubble (3-5")	
6				Cobble or boulder (5"+)	

Hook and Line Habitat Attribute Groupings

No.	Velocity Grouping (ft/sec)	Depth Grouping (ft)	Cover type
1	0-0.5	0.5-1.0	No cover
2	0.6-1.0	1.1-2.0	Debris, under cut banks or overhanging riparian vegetation
3	1.1-1.5	2.1 +	Cobble or boulder (5"+)
4	1.6 +		

Percent cover and substrate groupings same as for boat electrofishing data.

After habitat attribute values were grouped, Kendall rank-order correlation coefficients were calculated between the habitat attributes and catch for the resident species for both the boat electrofishing and hook and line data. Since cells varied significantly in size, catch was put on an area basis as catch per 1000 ft^2 of surface area. Density of fish was assumed to be a function of catch per 1000 ft^2. Suitability of habitat was reflected by this number as fish density can be assumed to reflect fish habitat suitability.

The distributions of mean catches by species were examined for the habitat attributes of velocity, depth, cover type, and percent cover. Velocity was thought to be an important determinant of distribution and therefore suitability criteria were fit by hand using professional judgement to the distributions of catch by grouped velocity interval for all four species. Since we had no data for velocities greater than 4.3 ft/sec, we assumed that suitability for all species was 0 for velocities greater than 4.5 ft/sec.

Depth was not thought to be as important a determinant of distribution and therefore we did not fit suitability criteria to any of the depth distributions. Depth, however, may be important in limiting distribution on the shallow end. Wesche (1976), for example, reported that adults of three trout species preferred depths greater than 0.5 ft. Raleigh et al. (1984) reported that rainbow trout found depths of less than 1.5 ft less suitable than greater depths. We conservatively set depth suitability to 1.0 for all depths greater than 0.6 ft and suitability to 0 for depths less than 0.5 ft.

Percent cover and cover type both were believed to have potential importance in determining adult fish distribution, however, sample sizes limited us to consider only cover type. We believed the cover type data were most reliable and also these data showed clear differences in usability of the different cover types. Since the turbidity data indicated that as turbidity increased, suitability of no cover cells increased, we integrated these data into suitability indices for cover type by turbidity level. Cover type suitability indices for both clear (< 10 NTU) and turbid (> 30 NTU) conditions were developed. The suitability of "no cover" cells (cells without object cover) at these two levels was different. The suitability of the "no cover" cells was set as a minimum, therefore if other cover types had mean catches less than those of the no cover cells then suitability for these types were changed to the suitability value for the no cover cells. Since there were no boat electrofishing data for the cover type, undercut banks, we assumed that undercut banks had a suitability equal to that for overhanging riparian vegetation and debris which provide a somewhat similar type of cover.

2.3.2.2 Juvenile resident fish

Only round whitefish juveniles were captured in sufficient numbers at the juvenile salmon study sites to warrant development of microhabitat suitability indices. The habitat attributes of velocity, depth, percent cover and cover type were examined for criteria development. Beach seining data from water over 30 NTU in turbidity were used in the analysis as catches were highest for this gear type at this turbidity level.

Due to small sample sizes, groupings of velocity values were by 0.3 ft/sec increments and depths by 0.5 ft increments. Cover type analysis was only qualitative due to small sample sizes and the inefficiency of beach seines in different cover types. Round whitefish suitability was measured as mean catch per cell, as this number was assumed to reflect density because cell size was constant at 300 ft^2. In general, analysis was the same as that used to develop criteria for juvenile chinook salmon in turbid water (see Part 3 of this report).

An analysis of variance (ANOVA) was run to determine the effect of the site parameters: mean depth, mean velocity, mean percent cover, water temperature, and turbidity on the relative abundance of juvenile round whitefish (see Part 2 of this report for further details on the methods used).

3.0 RESULTS

3.1 Macrohabitat Distribution

3.1.1 Adult resident fish

Boat electrofishing catch and catch per unit effort (CPUE) for five resident fish species in three types of macrohabitats was determined in 1983 (Table 4). Since sampling was not as intensive in 1983 as in 1982, the category "sloughs" includes both upland sloughs and side sloughs. Sampling effort in 1983 (45.9 boat electrofishing hours) was small in comparison to 1982 efforts (177.6 total boat electrofishing hours, with 63.9 hours above the Chulitna River confluence).

Radio telemetry was used to study movements of rainbow trout among macrohabitat types. Movements of adult rainbow trout in the Susitna River can be placed into three major categories based on their annual life history, those associated with spawning (April-June), those associated with summer rearing (July-September) and those associated with overwintering (October-March). Distribution of radio tagged rainbow trout in or at the mouths of tributary streams and at mainstem areas changed with season (Figure 3). Radio tagged rainbow trout were located in tributaries and at tributary mouths more often during spawning and summer rearing periods than during the winter. Between April and June, 67% of the radio tagged rainbow trout locations were associated with tributaries, the majority being in tributaries (52%). During July through September, 61% of the radio tagged rainbow trout were associated with tributaries, the minority being located in tributaries. By October 1, all radio tagged rainbow trout had outmigrated from tributaries and sloughs into mainstem influenced areas. About 33% of the radio tagged rainbow trout remained at tributary mouths from October to December. Besides the high incidence of rainbows using tributaries from April to September, about 10% used Slough 9 (RM 128.3), Slough 8A (RM 125.3), Slough A (RM 124.7), and Moose Slough (RM 123.5) during July through September.

Often radio tagged rainbow trout moved from one tributary or slough to another tributary or slough (refer to Part 5 of this report for individual trout movements). For example, five radio tagged rainbow trout migrated 7.5 miles downriver from the mouth of Indian River (RM 138.6), to the mouth of Fourth of July Creek (RM 131.1). In addition, a rainbow trout moved 6.5 miles upriver from the mouth of Skull Creek (RM 124.7) to the mouth of Fourth of July Creek, and then 2.6 miles downriver to Slough 9. Another rainbow trout spent over one week in two different sloughs (8A and A) before holding in Moose Slough for over three weeks. Finally, a rainbow trout outmigrated from Fourth of July Creek (TRM 1.5) and moved 7.5 miles upriver to Indian River where it was last located at TRM 4.5.

3.1.2 Juvenile resident fish

Incidental catches of juvenile and a few adult resident fish were made during juvenile anadromous habitat study (JAHS) sampling (Table 5). Large differences in the distribution of juvenile fish by macrohabitat

Table 4. Boat electrofishing catch and catch per unit effort (CPUE) of five resident fish species by three types of macrohabits. Resident fish species sampled are rainbow trout, burbot, Arctic grayling, round whitefish, and longnose suckers. CPUE is in parentheses, and the units are catch per minute.

MACROHABITAT TYPE	MAY 16-31	JUN 1-15	JUN 16-30	JUL 1-15	JUL 16-31	AUG 1-15	AUG 16-31	SEP 1-15	SEP 16-30	OCT 1-15	TOTAL
RAINBOW TROUT											
MAINSTEM	6(.0)	5(.0)	1(.0)	0(0.0)	1(.0)	0(0.0)	----(----)	7(.0)	13(.0)	8(.0)	41(.0)
SLOUGH	4(.1)	2(.0)	1(.0)	1(.0)	3(.0)	1(.0)	1(.1)	0(0.0)	1(.1)	2(.1)	16(.0)
TRIBUTARY MOUTH	7(.0)	7(.1)	9(.1)	4(.1)	11(.2)	3(.0)	4(.3)	19(.2)	16(.2)	14(.2)	94(.1)
TOTAL	17(.0)	14(.0)	11(.1)	5(.0)	15(.1)	4(.0)	5(.2)	26(.1)	30(.1)	24(.1)	151(.1)
BURBOT											
MAINSTEM	6(.0)	3(.0)	0(0.0)	0(0.0)	4(.0)	1(.0)	----(----)	9(.0)	7(.0)	1(.0)	31(.0)
SLOUGH	1(.0)	0(0.0)	0(0.0)	4(.1)	6(.0)	1(.0)	0(0.0)	1(.0)	1(.1)	0(0.0)	14(.0)
TRIBUTARY MOUTH	0(0.0)	2(.0)	3(.0)	0(0.0)	3(.1)	8(.1)	0(0.0)	0(0.0)	0(0.0)	1(.0)	17(.0)
TOTAL	7(.0)	5(.0)	3(.0)	4(.0)	13(.0)	10(.0)	0(0.0)	10(.0)	8(.0)	2(.0)	62(.0)
ARCTIC GRAYLING											
MAINSTEM	63(.2)	78(.4)	40(1.1)	0(0.0)	28(.3)	32(.6)	----(----)	99(.4)	195(.7)	19(.1)	554(.4)
SLOUGH	23(.3)	22(.4)	1(.0)	1(.0)	5(.0)	1(.0)	5(.3)	4(.1)	17(1.3)	2(.1)	81(.2)
TRIBUTARY MOUTH	50(.3)	26(.2)	31(.3)	18(.3)	56(.9)	24(.2)	7(.5)	66(.6)	87(1.1)	14(.2)	379(.4)
TOTAL	136(.3)	126(.4)	72(.4)	19(.1)	89(.3)	57(.2)	12(.4)	169(.4)	299(.8)	35(.1)	1014(.4)

\- = No effort.
.0 = Trace.

Table 4 continued.

MACROHABITAT TYPE	MAY 16-31	JUN 1-15	JUN 16-30	JUL 1-15	JUL 16-31	AUG 1-15	AUG 16-31	SEP 1-15	SEP 16-30	OCT 1-15	TOTAL
ROUND WHITEFISH											
MAINSTEM	25(.1)	82(.4)	21(.6)	0(0.0)	31(.3)	20(.4)	----(----)	147(.6)	101(.4)	78(.4)	505(.4)
SLOUGH	7(.1)	11(.2)	3(.1)	45(.6)	142(1.0)	8(.2)	3(.2)	15(.4)	7(.5)	8(.4)	249(.5)
TRIBUTARY MOUTH	26(.2)	45(.4)	36(.4)	61(1.2)	71(1.2)	72(.5)	5(.3)	108(1.0)	66(.8)	75(1.0)	565(.6)
TOTAL	58(.1)	138(.4)	60(.4)	106(.7)	244(.8)	100(.4)	8(.3)	270(.7)	174(.5)	161(.6)	1319(.5)
LONGNOSE SUCKER											
MAINSTEM	1(.0)	3(.0)	5(.1)	0(0.0)	29(.3)	13(.2)	----(----)	65(.3)	16(.1)	3(.0)	135(.1)
SLOUGH	2(.0)	13(.2)	9(.3)	33(.4)	51(.4)	16(.4)	0(0.0)	7(.2)	4(.3)	0(0.0)	135(.3)
TRIBUTARY MOUTH	0(0.0)	4(.0)	15(.1)	4(.1)	10(.2)	56(.4)	0(0.0)	18(.2)	23(.3)	2(.0)	132(.1)
TOTAL	3(.0)	20(.1)	29(.2)	37(.3)	90(.3)	85(.4)	0(0.0)	90(.2)	43(.1)	5(.0)	402(.1)

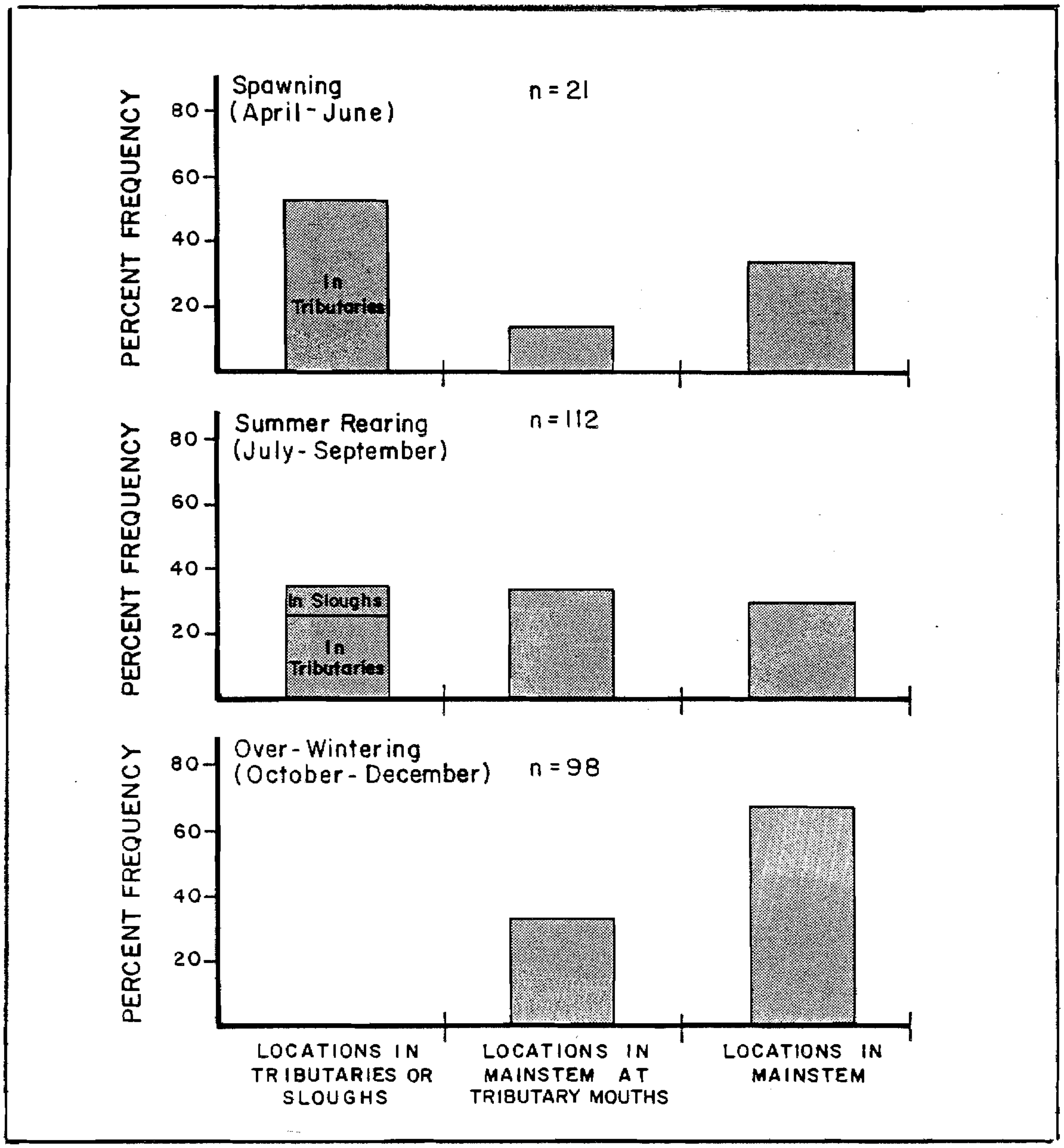

Figure 3. Frequency distribution of radio tagged rainbow trout locations in tributaries, at tributary mouths, and in the mainstem Susitna River during 1983.

Table 5. Incidental catch of juvenile resident fish in cells by macrohabitat sites on a mainstem discharge basis during Juvenile Anadromous Habitat Study sampling.

Species	Tributaries	Upland Sloughs	Side Sloughs	Mainstem Side-channels	Total
Rainbow trout	6	3	1	1	11
Arctic grayling	1	-	-	20	21
Round whitefish	1	20	7	601	629
Longnose sucker	-	20	33	66	119
Dolly Varden	21	-	-	-	21
Burbot	9	3	-	6	18
Humpback whitefish	-	-	-	11	11
Effort (cells fished)	236	131	455	463	

Table 6. Percent catch per unit effort (CPUE) by macrohabitat type on a mainstem discharge basis for juvenile resident fish species for which at least 20 specimens were captured.

	Tributaries	Upland Sloughs	Side Sloughs	Mainstem Side-channels
Arctic grayling (n=21)	8.9%	0.0%	0.0%	91.1%
Round whitefish (n=629)	0.3%	10.4%	1.0%	88.3%
Longnose sucker (n=119)	0.0%	41.5%	19.7%	38.8%
Dolly Varden (n=21)	100.0%	0.0%	0.0%	0.0%

type are evident in this table. The analysis of variance of round whitefish distribution showed that macrohabitat type does have a significant ($p < 0.01$) effect on distribution. In order to adjust for differences in sampling effort among the macrohabitat types, CPUE on a percentage basis was calculated for the four species for which more than 20 individuals were captured (Table 6). Arctic grayling and round whitefish juveniles were most numerous at mainstem side channels while Dolly Varden were captured only in tributaries. Longnose suckers were distributed primarily in upland sloughs and mainstem side channels although they were also caught in side sloughs.

3.2 Microhabitat Suitability

3.2.1 Adult resident fish

Boat electrofishing catches of rainbow trout, Arctic grayling, round whitefish, and longnose suckers were sufficient to be analyzed for microhabitat suitability criteria development. Hook and line catches of rainbow trout were also sufficient. Total catches by species and number of cells fished are listed in Table 7. Additional measurements of microhabitat were taken at telemetry locations of 20 rainbow trout and four burbot and these are available at the ADF&G Susitna Hydro Aquatic Studies office. These telemetry data cannot be used for criteria development but they supplement our knowledge of microhabitat use.

Kendall rank-order correlation coefficients between grouped habitat attributes and fish catches are listed in Table 8. Since substrate is partially a subset of cover type and also was highly correlated (tau=0.61) with velocity, it was dropped from consideration for further analysis.

Turbidity was the habitat attribute most highly correlated with longnose sucker mean catch. Graphs of turbidity level versus mean catch indicated turbidity has an influence on distribution of rainbow trout, round whitefish, Arctic grayling, and longnose suckers (Figure 4). Plots of catch in the "no cover" cells by turbidity value also suggest that these four species use turbidity for cover. Mean rainbow trout, Arctic grayling, and round whitefish catches per 1000 ft^2 were lower in turbid waters, however.

3.2.1.1 Rainbow trout

Rainbow trout were typically captured by boat electrofishing in cells with water velocities less than 1.5 ft/sec (Figure 5). Favored cover types included rocks with diameters over 3", and secondarily, debris and overhanging riparian vegetation. Rainbow trout used cells with 6 to 25% and greater than 50% object cover in the highest densities.

Hook and line sampling data suggested that rainbow trout preferred pools with velocities less than 0.5 ft/sec and depths greater than 2.0 ft (Figure 6). Rainbow trout captured by hook and line sampling used debris, undercut banks, and riparian vegetation more than they did cobble or boulders. An abundance of cover also appeared to be tied to rainbow distribution.

Table 7. Catches and effort for boat electrofishing and hook and line sampling of adult resident fish.

Boat electrofishing sampling

No. of cells sampled = 176

Species	Catch
Rainbow trout	44
Arctic grayling	138
Round whitefish	384
Longnose sucker	157
Burbot	18
Humpback whitefish	15
Dolly Varden	2

Hook and line sampling

No. of cells sampled = 79

Species	Catch
Rainbow trout	99
Arctic grayling	2

Table 8. Kendall correlation coefficients (tau) between grouped habitat variables and resident fish catches.

Boat Electrofishing Data (n = 176)

	Turbidity	Percent Cover	Cover Type	Velocity	Depth	Substrate	Rainbow Trout	Arctic Grayling	Longnose Sucker
Percent cover	-0.07	1.00							
Cover type	-0.22**	0.45**	1.00						
Velocity	-0.08	0.10*	0.45**	1.00					
Depth	-0.27**	0.16**	0.43**	0.34**	1.00				
Substrate	-0.16**	0.33**	0.61**	0.54**	0.32**	1.00			
Rainbow Trout	-0.14*	0.21**	0.22**	0.11	0.11	0.20**	1.00		
Arctic grayling	-0.13	0.18**	0.36**	0.33**	0.27**	0.29**	0.20**	1.00	
Longnose sucker	0.34**	0.19**	-0.15*	-0.25**	-0.22**	-0.25**	-0.04	-0.07*	1.00
Round whitefish	0.05	0.19**	0.20**	0.10	0.11	0.10	0.15*	0.34**	0.18**

Hook and Line Data (n = 79)

	Percent Cover	Cover Type	Velocity	Depth	Substrate
Cover type	-0.10				
Velocity	-0.30**	0.38**			
Depth	0.59**	-0.09	-0.42**		
Substrate	-0.04	0.53**	0.28**	-0.02	
Rainbow Trout	0.42**	0.04*	-0.29**	0.35**	0.08

* Significantly different from 0 at $p < 0.05$
** Significantly different from 0 at $p < 0.01$

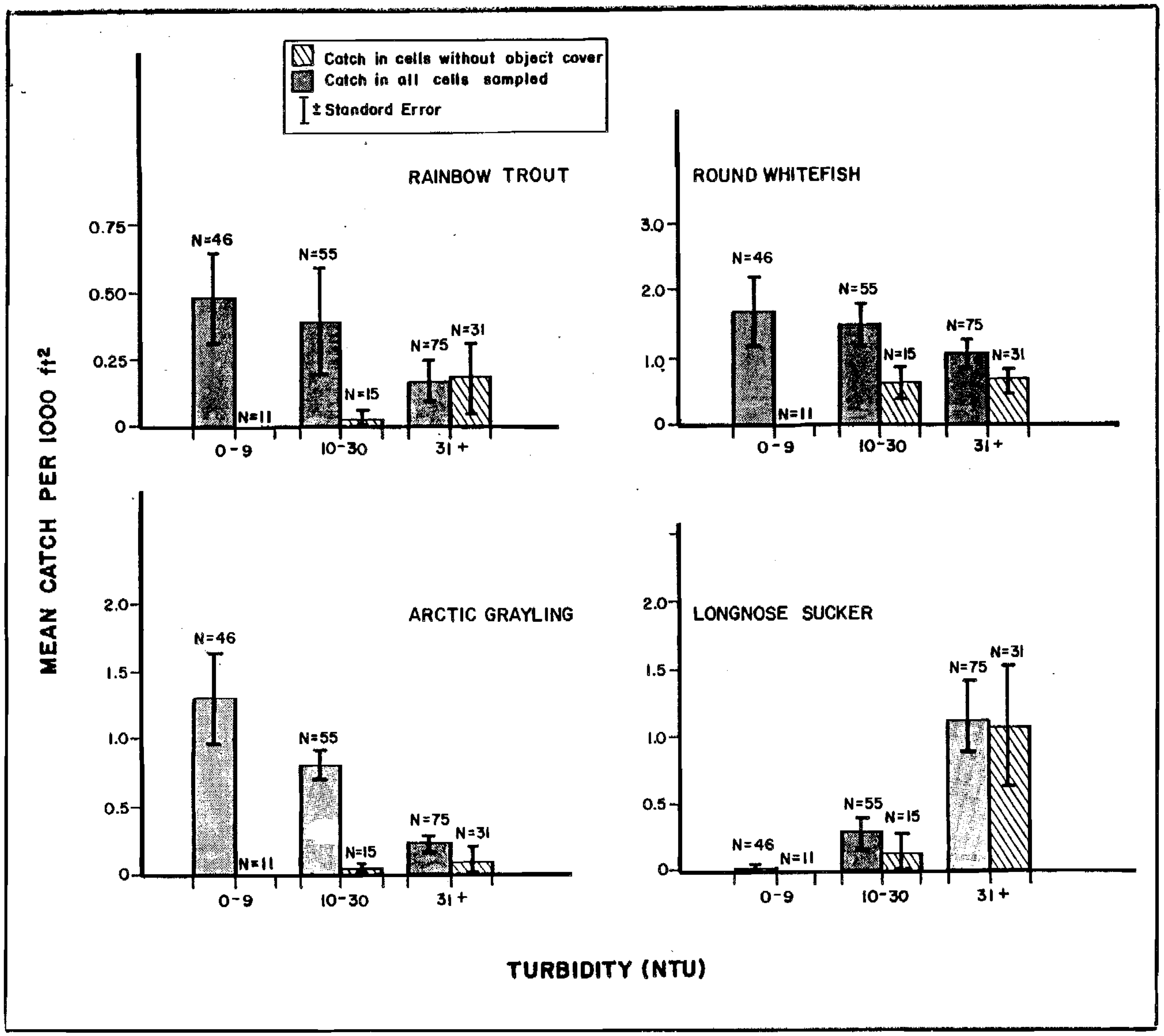

Figure 4. Rainbow trout, round whitefish, Arctic grayling, and longnose sucker boat electrofishing mean catch per 1000 ft² in cells without object cover and all cells sampled by turbidity

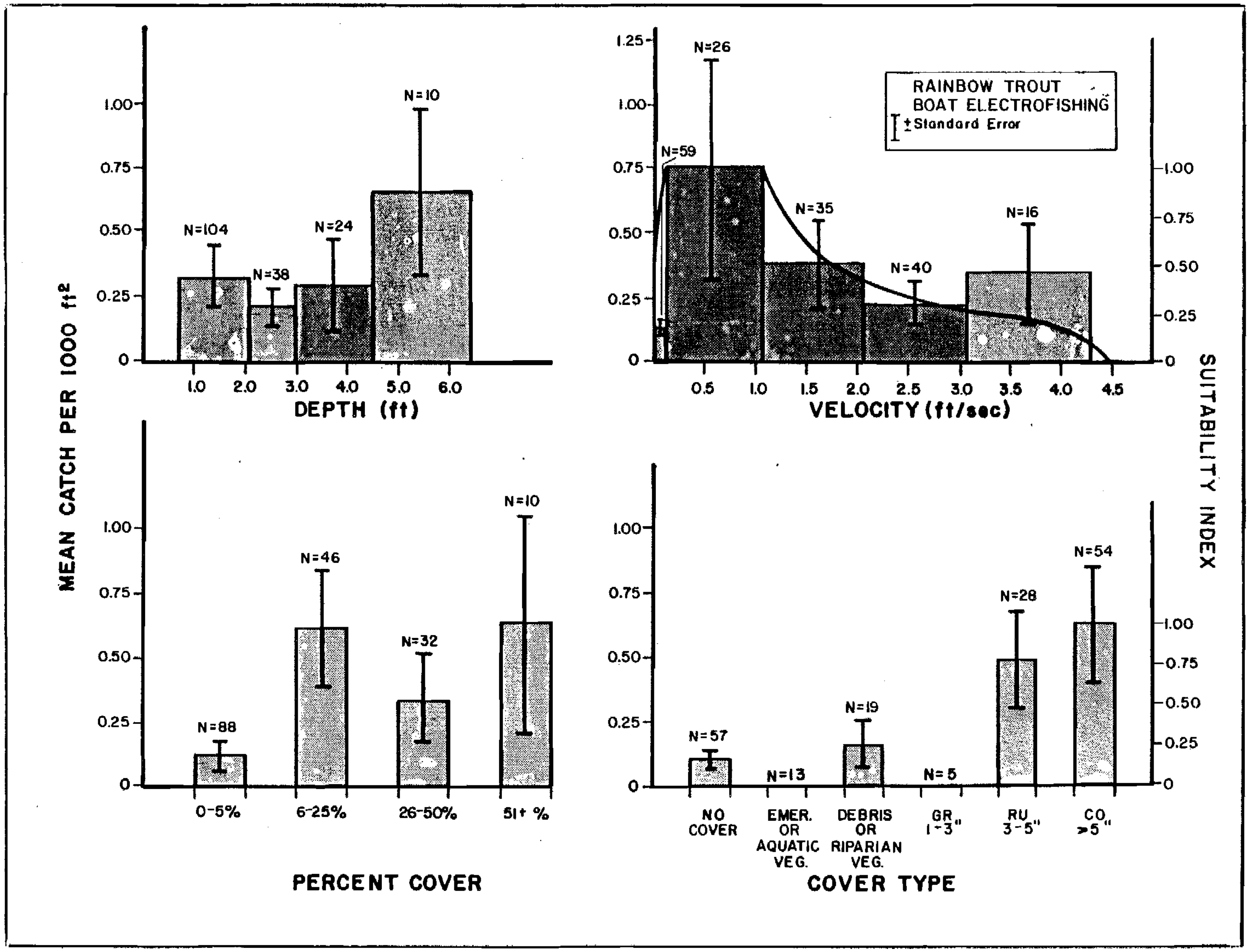

Figure 5. Rainbow trout boat electrofishing mean catch (bars) per 1000 ft² by habitat attribute values of depth, velocity, percent cover, and cover type. Suitability index (line) for velocity

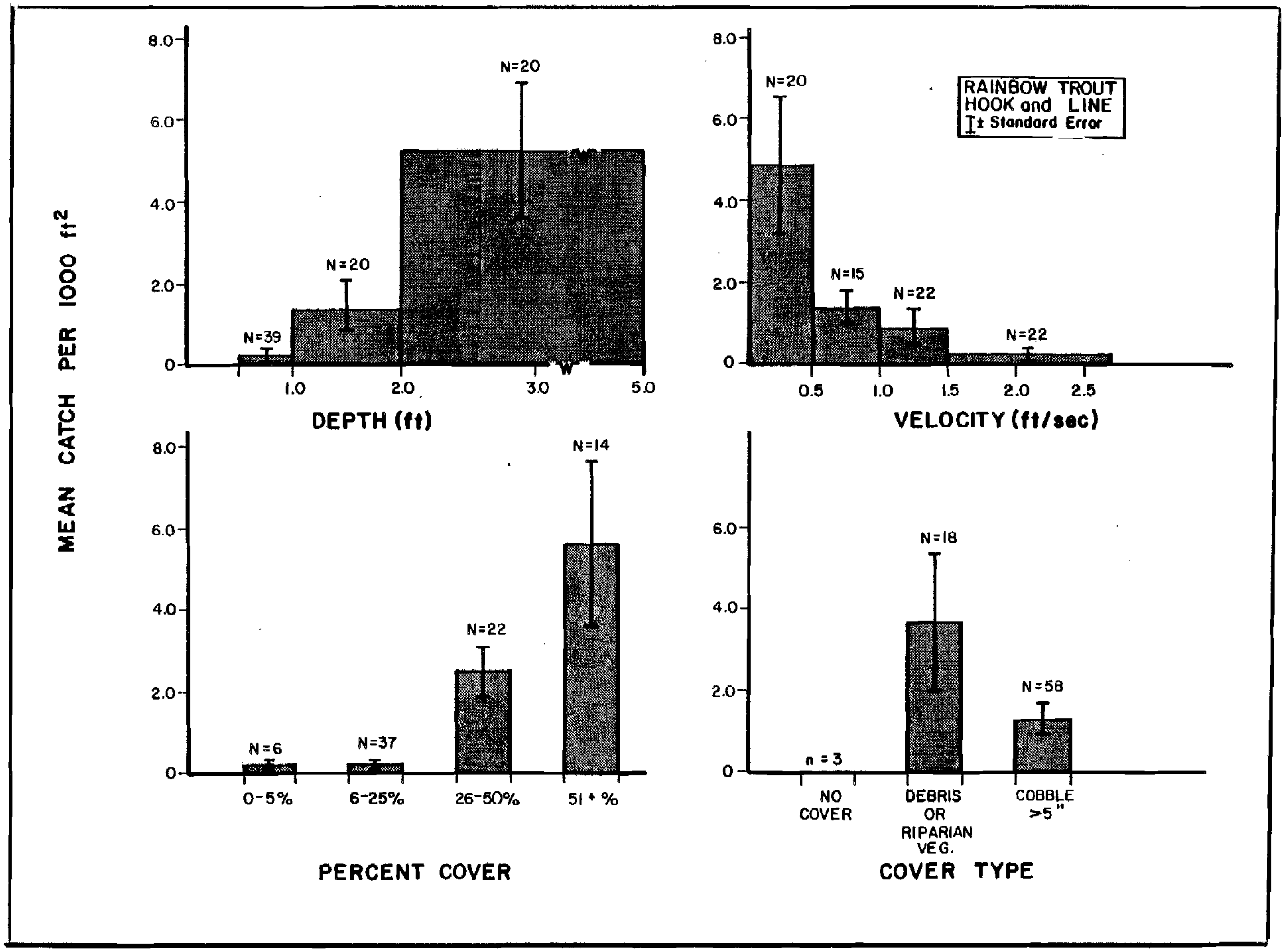

Figure 6. Rainbow trout hook and line mean catch per 1000 ft² by habitat attribute values of depth, velocity, percent cover, and cover type.

Since electrofishing data were collected at more cells in a wider variety of habitat types, velocity and cover type suitability indices were fit to the boat electrofishing data (Figure 4). Since the hook and line data suggested that cover types of debris, overhanging riparian vegetation, and undercut banks were more suitable than cobble or boulders (Figure 5), suitabilities for these cover types were changed to the suitability of cobble and boulders which was 1.0. A listing of suitability criteria point values for rainbow trout (along with all other suitability criteria developed in this report) is contained in Appendix Table A-1.

3.2.1.2 Arctic grayling

Adult Arctic grayling often used rocks for cover and water with high velocities and deep depths (Figure 7). Arctic grayling may avoid high turbidity waters and make little use of turbidity for cover (Figure 4). Suitability criteria were fit to the velocity and cover type distributions of catch (Figure 7 and Appendix Table A-1).

3.2.1.3 Round whitefish

Distribution of round whitefish was influenced by turbidity as they used it for cover (Figure 4). Round whitefish also used object cover in the form of cobble or boulders, debris, and overhanging riparian vegetation most highly (Figure 8). The hydraulic attribute of velocity was not strongly tied to distribution, although optimum velocities ranged from two to three ft/sec. Suitability criteria were fit to the velocity and cover type distributions of catch (Figure 8 and Appendix Table A-1).

Seven spawning sites for round whitefish were found in October 1983. Three of the sites were at tributary mouths while the other four sites were in the mainstem. Microhabitat data collected at these sites are presented in Appendix B, along with a brief discussion of round whitefish spawning in the Susitna River.

3.2.1.4 Longnose suckers

Longnose suckers often used turbid water for cover (Figure 4), but they also used emergent or aquatic vegetation, debris and overhanging riparian vegetation cover (Figure 9). Shallow depths and waters of low velocity were most suitable for longnose suckers. Suitability criteria were fit to the velocity and cover type distributions of catch (Figure 9 and Appendix Table A-1).

3.2.1.5 Burbot

Burbot prefer areas of moderate to high turbidities since catch data show they are always in the mainstem during the summer (ADF&G 1983e). Telemetry data also showed they were always found in the mainstem. While in these mainstem areas, radio tagged burbot appeared to prefer low velocities (under 1.5 fps) and shallow depths (approximately 2.5 feet). They also appeared to prefer areas with rubble or cobble substrate, however, nearly all of the mainstem river between the Chulitna River confluence and Devil Canyon, where the radio tagged fish were found, has a predominately rubble or cobble substrate.

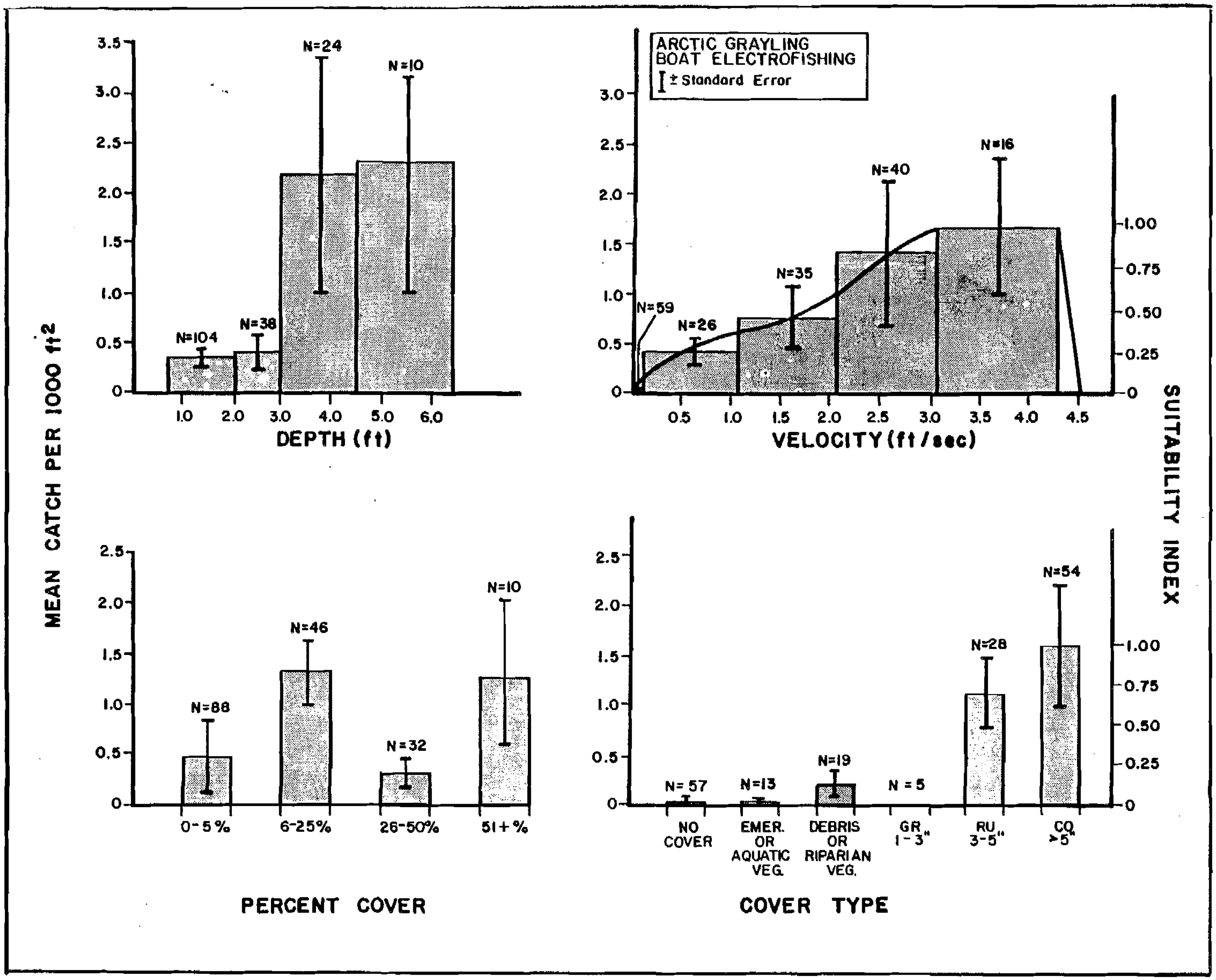

Figure 7. Arctic grayling boat electrofishing mean catch (bars) per 1000 ft² by habitat attribute values of depth, velocity,

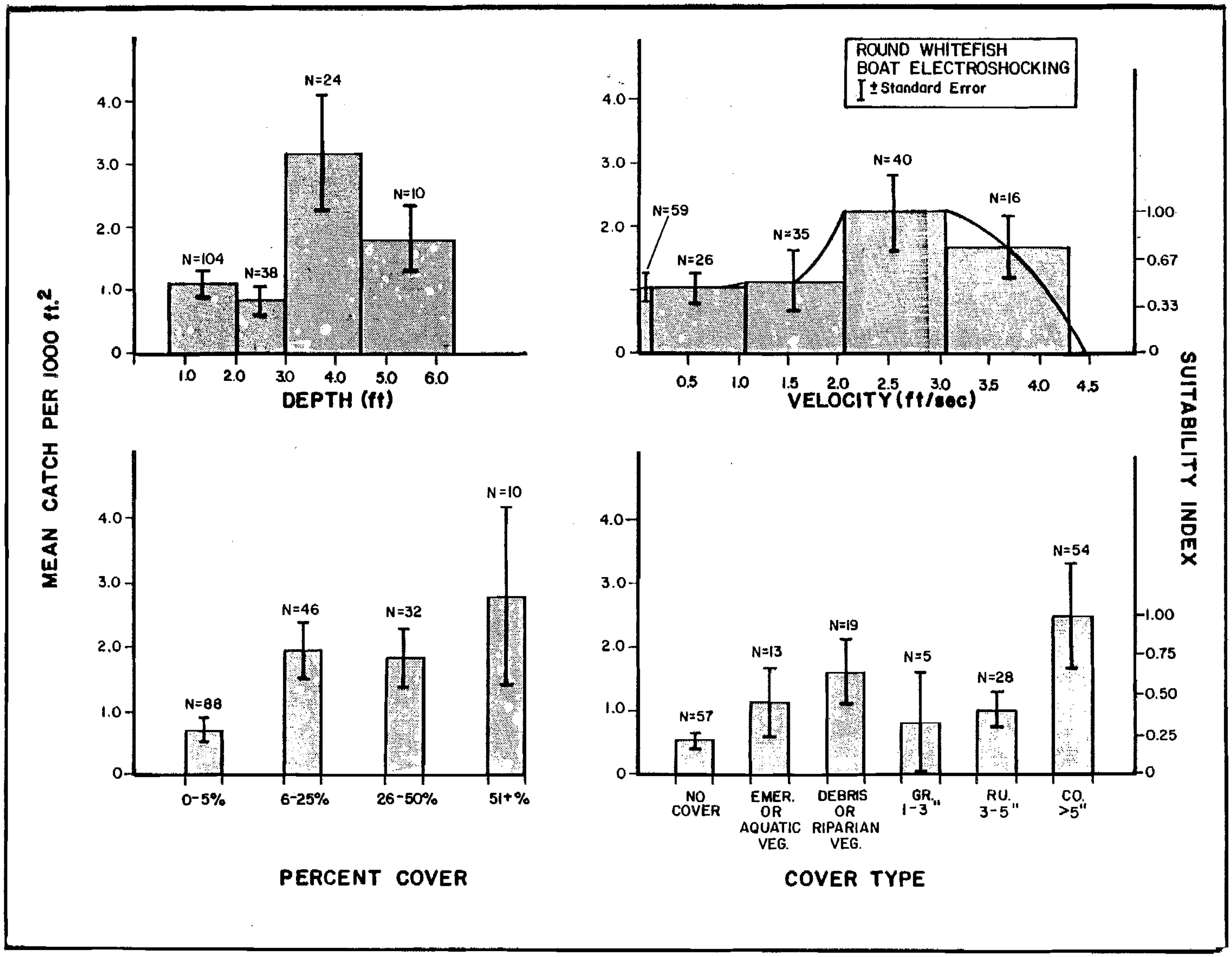

Figure 8. Round whitefish boat electrofishing mean catch (bars) per 1000 ft² by habitat attribute values of depth, velocity, percent cover, and cover type. Suitability index (line) for

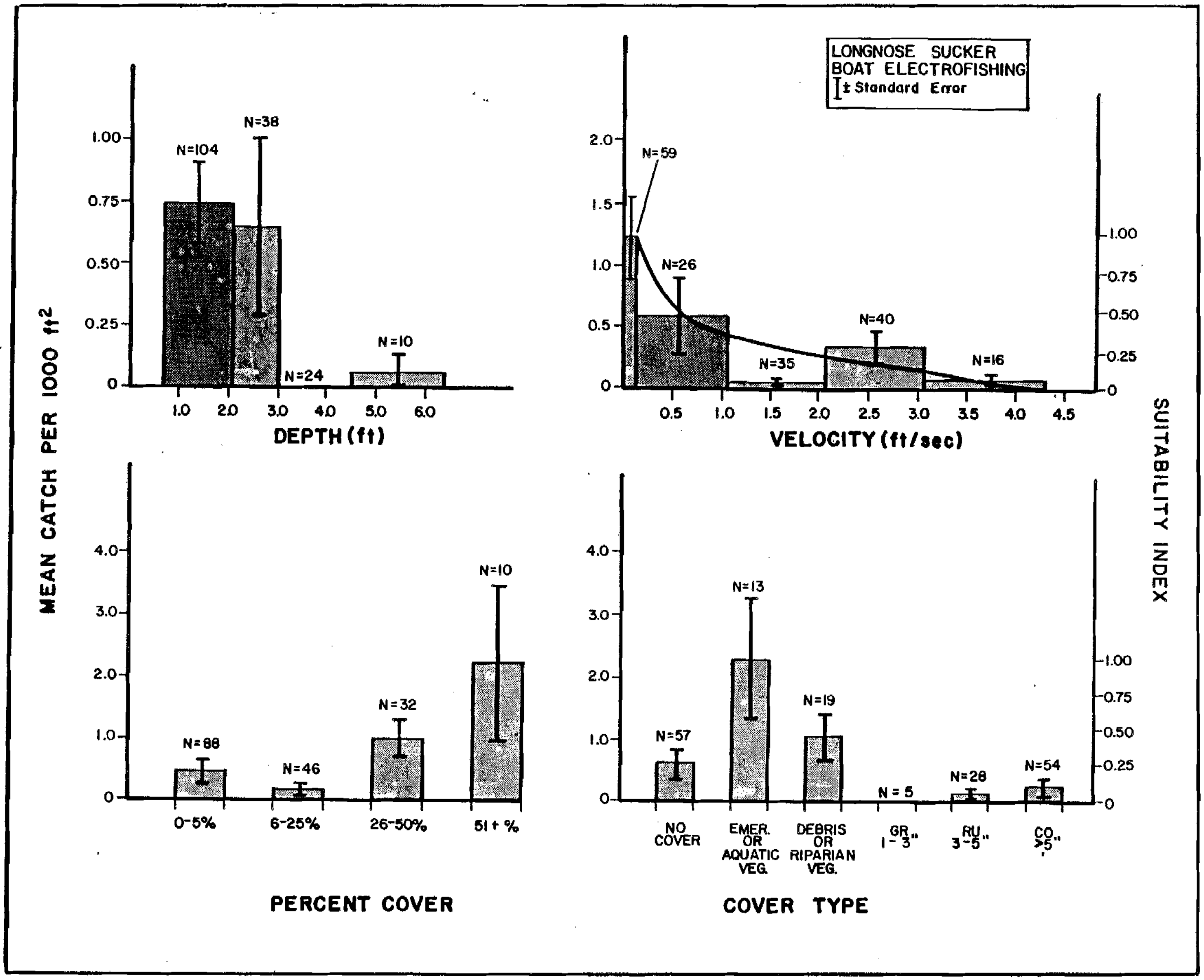

Figure 9. Longnose sucker boat electrofishing mean catch (bars) per 1000 ft² by habitat attribute values of depth, velocity,

3.2.2 Juvenile resident fish

The analysis of variance showed that turbidity had a significant ($p < 0.01$) effect on the relative abundance of juvenile round whitefish. Catch rates in water with a turbidity less than 30 NTU were extremely low.

The total catch of round whitefish by beach seines in turbid (greater than 30 NTU) water was 569, and most of these were 0+ juveniles. Mean catches by velocity, depth and percent cover interval suggest that velocity had the largest effect on distribution in the 320 cells fished (Figure 10). Juvenile round whitefish greatly preferred water without a significant velocity. Catches in cells with little object cover were higher than in cells with large amounts of cover. This suggests that object cover is not very significant in influencing round whitefish habitat use. Beach seining efficiency is greatly reduced, however, by the amount and type of cover present, and therefore catch distribution by cover type has not been presented. The data suggest that round whitefish fry also find shallow depths most suitable.

A suitability index was fit to both the depth and velocity catch distributions by hand using professional judgement. Pearson correlation coefficients between the fitted suitability criteria for depth, velocity, and (depth x velocity) and juvenile round whitefish catch by cell were calculated. The correlations between juvenile round whitefish catch and depth, velocity, and (depth x velocity) were 0.23, 0.42, and 0.50 ($n=320$, $p < 0.001$ for all three), respectively. Since depth was correlated with catch, we decided to use depth as fitted in subsequent habitat modelling. Suitability for turbid water for all cover types was set to 1.0 and suitability for all cover types in clear water was set to 0 (Appendix Figure A-1).

Catches were insufficient for any other species of juvenile resident fish to be analyzed for criteria development.

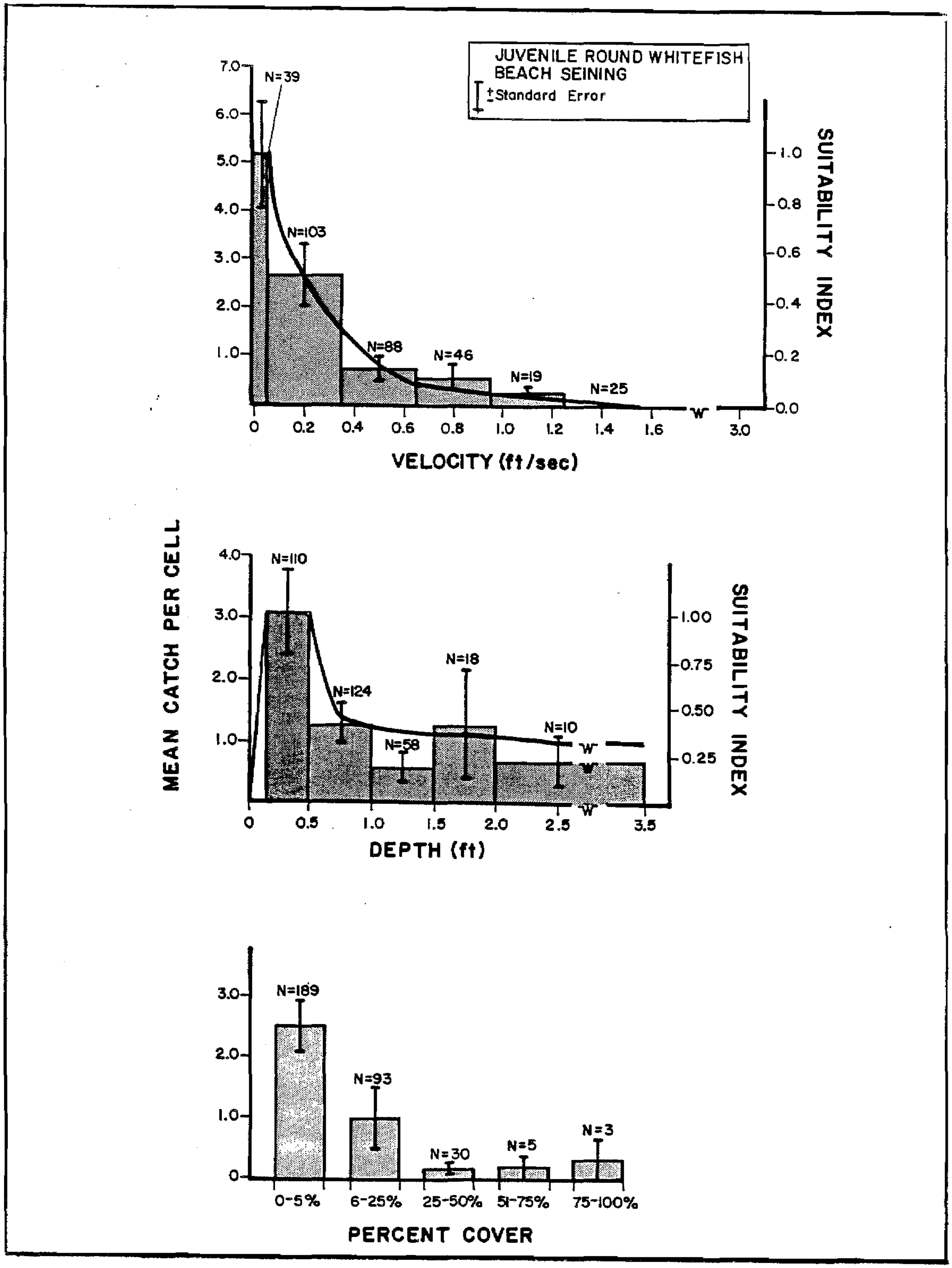

Figure 10. Juvenile round whitefish beach seining mean catch (bars) by habitat attribute values of velocity, depth, and percent cover. Suitability indices (lines) for depth and velocity were fit by hand using professional judgement.

4.0 DISCUSSION

4.1 Adult Resident Fish

Boat electrofishing and hook and line sampling have provided a limited set of data by habitat attribute which were used to generate suitability criteria for adult resident fish. These suitability criteria are preliminary as sampling effort was limited. Since most sampling was done by boat electrofishing a bias toward the capture of large fish was probable. There may have also been some bias in the capture rates of fish in clear versus turbid water because of differences in boat electrofishing efficiency between these two habitat types but it did not appear to be large. The boat electrofishing microhabitat suitability data were collected near tributary and slough mouths during July to October and therefore are applicable only during the open water season. Additional information about rainbow trout and burbot microhabitat distribution was also collected during radio telemetry locations of tagged fish and these data were used to supplement the other data because they were free of sample efficiency bias.

Use of macrohabitats at tributaries and slough mouths could be due to food input in the form of salmon eggs, fry or invertebrates drifting out of the sloughs or tributaries. Species interactions could also play a role in distribution as each species competes best within a niche. All the species showed different responses to the habitat variables and this may be due to these interactions rather than an actual preference. Intercorrelations among habitat variables might also cause apparent preferences as fish might actually be selecting for something else.

Turbidity was an important habitat attribute which had large effects on adult resident fish distribution. Rainbow trout, Arctic grayling, and round whitefish apparently avoided turbid water. Longnose suckers avoided clear water. Turbidity also provided cover for all species and therefore was desirable from this aspect.

Analysis of radio tagged rainbow trout distribution among the macrohabitats of the Susitna River provided insights not obtainable by other sampling methods. These data are not subject to the collection gear bias inherent in other collection methods. Rainbow trout apparently ascend tributary streams from mid-May through early June to spawn. Some rainbow trout remain in the tributaries but others outmigrate to mainstem influenced macrohabitats. Tributary mouths are used heavily for summer rearing especially during periods of salmon spawning. Rainbow trout may also ascend tributaries and move into sloughs while following spawning salmon. Rainbow trout were observed being chased from spawning redds by male chum salmon while presumably feeding on salmon eggs. One radio tagged rainbow trout in Slough A[1] and another in Lane Creek were observed milling around spawning pink and chum salmon. The mainstem, per se, is probably used mainly as a migration path between tributaries and sloughs at this time. By mid-September, however, all radio tagged trout which had been in tributaries had descended to the mouths. The occurrence of this outmigration during a short time period makes rainbow trout in the upper Susitna River extremely vulnerable to sport fishing. Local anglers take advantage of the outmigration at the mouth of Indian River (RM 138.6) each fall. As the Susitna River basin continues to develop, the rainbow trout population may suffer from the increased fishing pressure. Most adult rainbow trout apparently overwinter in the mainstem.

Rainbow trout distribution within microhabitat was correlated with velocity and cover (Figures 5 and 6). Lewis (1969) found that rainbow trout populations in pools were most highly correlated with higher velocities, rather than the amount of cover. Shirvell and Dungey (1983) found velocity to be the most important factor determining brown trout position choice but that positions were chosen with optimum combinations of depth and velocity. Observations of radio tagged fish, however, revealed that rainbow trout distribution within microhabitat may be dependent upon food source. In areas where rainbow trout were feeding on salmon eggs, rainbow trout were closely associated with the spawning salmon and therefore used shallow water riffles with cobble substrate for cover. In other areas where there were no adult salmon, rainbow trout were presumably feeding primarily on aquatic insects. In these areas they were found in plunge pools or deep pools using turbulent water and depth, along with rubble/cobble substrate and debris as cover. Turbulent water in plunge pools was observed to be excellent cover.

4.1.2 Juvenile Resident Fish

Juvenile resident fish use of macrohabitat present on the Susitna River during the ice free months was found to vary greatly by species (Tables 5 and 6). Juvenile Dolly Varden, for example, were found only in tributaries while round whitefish juveniles were found most abundantly in mainstem side channels. The tributary sites are not influenced by mainstem discharge so Dolly Varden rearing would be little affected by changes in discharge. Round whitefish, on the other hand, might be affected by changes in discharge. Juveniles of this species apparently find turbid, mainstem conditions most suitable as they infrequently occur in sloughs when the heads are not overtopped. Large numbers of rearing juvenile Arctic grayling and round whitefish have been found during previous Susitna studies to prefer mainstem mixing zones of either sloughs or tributaries and secondarily mainstem waters (ADF&G 1983d). Longnose suckers were found in mainstem waters primarily but data collected during 1983 indicate that juvenile longnose suckers also find upland and side sloughs suitable for rearing.

Turbidity is the one factor which most distinguishes side slough habitats from mainstem side channel habitats and turbid water increases the suitability of mainstem side channels for such species as juvenile Arctic grayling and round whitefish. Turbidity provides suitable cover in environments which lack large amounts of object or overhead cover. If lack of suitable cover limits rearing of juvenile fish, major decreases in the amount of turbid rearing areas may adversely affect habitat used by juvenile Arctic grayling, round whitefish, and possibly longnose suckers.

Round whitefish fry find turbid, mainstem side channels as the preferred macrohabitat. Within these side channels, they use shallow, slow moving microhabitats. Apparently the turbid water provides all the cover necessary. Little, if any, literature is available concerning juvenile round whitefish rearing microhabitat needs.

Very little data are available concerning the microhabitat preferences of other resident species which make use of mainstem influenced environments for rearing. Juvenile Arctic grayling under 200mm perhaps have microhabitat preferences similar to that of chinook salmon fry or other salmonids. Juvenile longnose suckers probably use microhabitat very similar to that used by juvenile round whitefish as adult longnose suckers also prefer shallow, slow moving, turbid habitats.

5.0 CONTRIBUTORS

Field data were collected by Rich Sundet and Mark Wenger. Larry Dugan, Paul Suchanek, Dave Sterritt, and Bob Marshall collected the juvenile round whitefish data. Dana Schmidt provided the study design.

Data processing was done by Allen Bingham, Gail Heinemann, Donna Buchholz, Kathrin Zosel and Alice Freeman. Figures were drafted by Carol Kerkvliet, Carol Riedner, and Sally Donovan. The typing was done by Skeers Word Processing Services.

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APPENDIX A

Suitability Indices for Resident Fish Species for Cover, Velocity, and Depth

Appendix Table A-1. Suitability indices for resident fish species for cover, velocity, and depth.

Cover Suitability

Cover type	PHABSIM Code	Adult: Rainbow trout clear	Adult: Rainbow trout turbid	Adult: Arctic grayling clear	Adult: Arctic grayling turbid	Adult: Round whitefish clear	Adult: Round whitefish turbid	Adult: Longnose suckers clear	Adult: Longnose suckers turbid	Juvenile: Round whitefish clear	Juvenile: Round whitefish turbid
No cover	1.	0	0.29	0	0.07	0	0.26	0	0.47	0	1.00
Emergent vegetation	2.	0	0.29	0	0.07	0.47	0.47	1.00	1.00	0	1.00
Aquatic vegetation	3.	0	0.29	0	0.07	0.47	0.47	1.00	1.00	0	1.00
Debris/ deadfall	4.	1.00	1.00	0.14	0.14	0.65	0.65	0.46	0.47	0	1.00
Overhanging riparian vegetation	5.	1.00	1.00	0.14	0.14	0.65	0.65	0.46	0.47	0	1.00
Undercut banks	6.	1.00	1.00	0.14	0.14	0.65	0.65	0.46	0.47	0	1.00
Large gravel (1-3")	7.	0	0.29	0	0.07	0.33	0.33	0	0.47	0	1.00
Rubble (3-5")	8.	0.77	0.77	0.69	0.69	0.41	0.41	0	0.47	0	1.00
Cobble or boulder (> 5")	9.	1.00	1.00	1.00	1.00	1.00	1.00	0	0.47	0	1.00

VELOCITY

Adult: Velocity (ft/sec)	Rainbow trout suitability	Velocity (ft/sec)	Arctic grayling suitability	Velocity (ft/sec)	Round whitefish suitability	Velocity (ft/sec)	Longnose sucker suitability	Juvenile: Velocity (ft/sec)	Round whitefish suitability
0.00	0.18	0	0.04	0	0.45	0	1.00	0	1.00
0.05	1.00	0.55	0.25	0.55	0.46	0.05	1.00	0.05	1.00
1.05	1.00	1.55	0.46	1.55	0.51	0.55	0.47	0.20	0.52
1.55	0.50	2.55	0.86	2.05	1.00	1.55	0.31	0.50	0.16
2.55	0.33	3.05	1.00	3.05	1.00	2.55	0.20	0.80	0.07
3.55	0.20	4.30	1.00	3.55	0.70	3.55	0.10	1.10	0.04
4.50	0.00	4.50	0.00	4.50	0.00	4.3	0.00	1.40	0.00

DEPTH

Adult: Depth (ft)	All resident fish suitability	Juvenile: Depth (ft)	Round whitefish suitability
0	0	0	0.00
0.5	0	0.15	1.00
0.6	1.00	0.50	1.00
10.0	1.00	0.75	0.42
		1.25	0.35
		1.75	0.33
		2.50	0.31
		10.0	0.31

APPENDIX B

Round Whitefish Spawning Microhabitat Data

Since 1981, nine locations have been determined to be spawning sites for round whitefish. In 1981 and 1982 one site was found each year at RM 100.8 and RM 102.6, respectively. In 1983 seven sites were found including four mainstem sites: RM 102.0, RM 114.0, RM 142.0 and RM 147.0; and three tributary mouth sites: Lane Creek (RM 113.6), Indian River (RM 138.6) and Portage Creek (RM 148.8) (Appendix Table B-1).

While catch data and the incidence of sexually ripe fish suggest that spawning of round whitefish might occur nearly anywhere in the mainstem, selection of spawning sites may not be random. Anchor ice, water fluctuations and ice cover can all limit egg survival. Due to these reasons, round whitefish in the Susitna River may seek out areas which have adequate ground water. Habitat data taken at one mainstem site (RM 147.0 in 1983) where eight sexually ripe males and females were captured support this hypothesis. Specific conductance was relatively high, 160 umhos/cm, in this area, indicating an area of upwelling. Chum salmon, another mainstem spawning species in the Susitna River, also seek areas of upwelling for spawning (ADF&G 1983c).

Appendix Table B-1. Physical and chemical habitat characteristics of spawning round whitefish in the Susitna River during October 1983.

Area, River Mile	Date	Site	Water depth	Velocity 0.2	Velocity 0.8	Velocity x/0.6	Substrate Primary	Substrate Secondary	Water quality: Turbidity	Water quality: intra-gravel temp	Water quality: sur-face temp	Water quality: pH	Water quality: DO	Water quality: specific conduct-ance
Lane Creek (RM 113.6)	Oct 7	1	3.2	1.8	1.6		cobble(5"-10"),	rubble(3"-5")	12.0	-	0.4	-	-	-
		2	2.2			1.5	rubble(3"-5"),	gravel(1"-3")	12.0	-	0.4	-	-	-
Portage Creek (RM 148.8)	Oct 5	1	4.2	1.4	1.2		rubble(3"-5"),	cobble(5"-10")	4.2	-	1.2	7.5	15.1	133
		2	2.2			0.4	rubble (3"-5"),	silt	2.0	-	1.7	7.4	13.7	104
Mainstem (RM 147.0)	Oct 5	1	2.1			0.7	silt,	cobble (5"-10")	14.0	0.6	0.0	7.5	15.1	159.0
		2	1.9			0.7	silt,	cobble (5"-10")	14.0					
		3	2.3			0.7	silt,	cobble (5"-10")	14.0	0.6	0.0	7.5	15.0	160.0
		4	2.2			0.7	silt,	cobble (5"-10")	14.0					
		5	1.8			1.2	cobble(5"-10"),	boulder(over 10")	14.0	0.6	0.0	7.5	15.0	161.0
		6	1.7			1.2	cobble(5"-10"),	boulder(over 10")	14.0					

PART 7

Modelling Of Juvenile Salmon And Resident Fish Habitat

MODELLING OF JUVENILE SALMON AND RESIDENT FISH HABITAT

Report Series No. 2, Part 7

by Stephen S. Hale, Paul M. Suchanek, and Dana C. Schmidt

Alaska Department of Fish and Game
Susitna Hydro Aquatic Studies
2207 Spenard Road
Anchorage, Alaska 99503

ABSTRACT

Output from the Instream Flow Group hydraulic models of rearing habitat for juvenile salmon and resident species at seven sites in the Chulitna River confluence to Devil Canyon reach of the Susitna River leads to similar conclusions as those drawn from a habitat model developed by the Susitna Hydro Aquatic Studies group for six additional sites. Overtopping of side slough heads by mainstem discharge causes abrupt changes in rearing habitat which are of positive benefit for some species/life stages and negative for others. Rearing habitat for chinook salmon at the study sites is greatest when the head of the site is slightly overtopped, thus providing turbid water for cover and moderate water velocities. The portions of this reach which are directly influenced by the mainstem provide only limited rearing habitat for coho and sockeye salmon during the open water season, but are likely to be of major importance for all overwintering species. Resident species are associated with levels of turbidity, velocity, and food supply and in general are not abundant in side sloughs when the head is closed unless a tributary is present.

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1.0 INTRODUCTION

The effects of flow regulation on downstream fisheries have long been the subject of investigations whose goal was to predict the status of fisheries after development of hydro power or other types of instream flow regulation. The Instream Flow Incremental Methodology developed by the U.S. Fish and Wildlife Service (Bovee 1982) has gained wide acceptance and is the method most often applied to these types of studies. This method comprises the IFG (Instream Flow Group) PHABSIM (Physical Habitat Simulation System) and has been used in Alaska by Estes et al. (1980), Wilson et al. (1981), and ADF&G (1983a). The Susitna Hydro Aquatic Studies group has used this method for two seasons to simulate changes in available spawning habitat of chum and sockeye salmon as a function of mainstem discharge.

Beginning in the open water season of 1983, we used these IFG hydraulic models and another habitat model developed by ourselves (RJHAB) to investigate the effects of mainstem discharge variations on rearing habitat for juveniles of four species of salmon and juveniles and adults of several resident fish species in the Susitna River.

This paper presents the results of the IFG model habitat simulations for juvenile salmon and resident fishes, compares the IFG models with the RJHAB model (presented in Part 4 of this report), and discusses in general the usefulness and implications of these habitat models in understanding and predicting the effects of discharge changes on rearing habitat.

2.0 METHODS

2.1 Study Locations

Seven IFG model sites and six RJHAB sites located on the Susitna River reach extending from the Chulitna River confluence to Devil Canyon were modelled (Figure 1). Criteria used in IFG model site selection are detailed in Estes and Vincent-Lang (1984). Sloughs 8A, 9, and 21 were selected in 1982 to quantify the response of adult chum and sockeye salmon spawning habitat in sloughs to variations in mainstem discharge. These sloughs are representative of side sloughs in general and also contain critical spawning habitat. In 1983, four IFG side channel study sites were selected as representative sites for the study of responses of mainstem salmon spawning and rearing habitat to variations in mainstem discharge. The RJHAB sites were selected as representative or important juvenile salmon rearing sites (see Part 4 of this report).

Figure 2 shows the sites ordered by the mainstem discharge required to overtop the head of the sites. The two upland slough sites (Slough 5 and Slough 6A) are not included on this figure. It can be seen that, generally, sites which have heads overtopped more than 60% of the time have been named side channels; sites with less frequent overtopping have been called sloughs. All sites to the left of the vertical line were overtopped on more than half the days between June 1 and September 30. The mainstem discharge required to overtop the head of each site is as follows:

Site	Model	Overtopping Discharge [a]
Lower Side Channel 11	IFG-2	5,000
Side Channel 10A	RJHAB	9,000
Side Channel 21	IFG-4	9,000
Upper Side Channel 11	IFG-4	13,000
Slough 9	IFG-4	16,000
Slough 21	IFG-4	18,000 [b]
Side Channel 10	IFG-4	19,000
Slough 22	RJHAB	20,000
Whiskers Slough	RJHAB	22,000
Slough 8	RJHAB	25,000
Slough 8A	IFG-4	33,000
Slough 5	RJHAB	upland slough
Slough 6A	RJHAB	upland slough

a/ Cubic feet per second (cfs). Source: Estes and Vincent-Lang (1984).

b/ This is the discharge level at which a side channel entering the Slough 21 study site begins to convey mainstem water. The head of Slough 21 proper is not overtopped until a discharge level of 23,000 cfs.

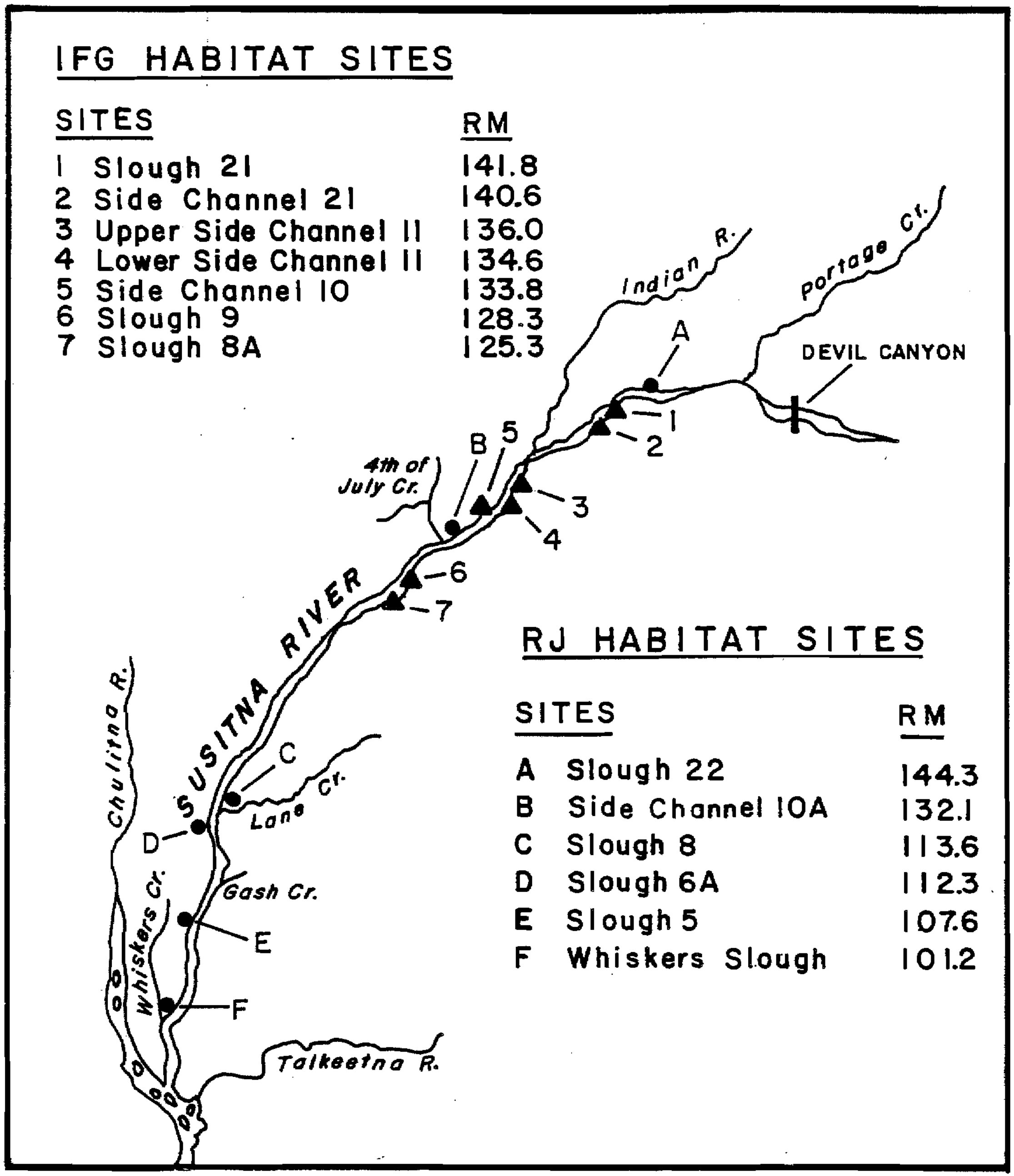


Figure 1. Location of IFG and RJHAB modelling sites.

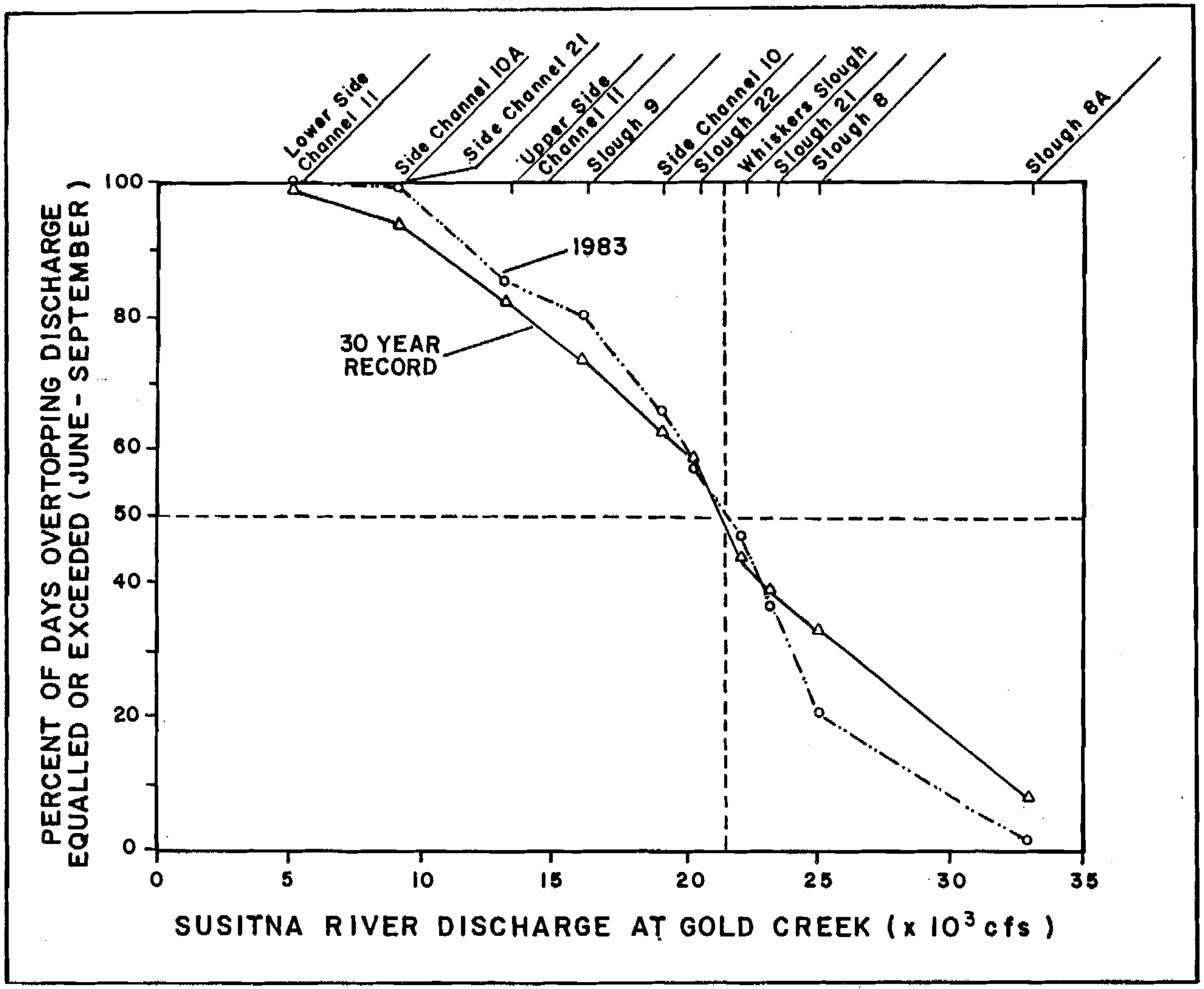


Figure 2. Percent of time that the heads of study sides were overtopped by mainstem discharge.
Sources: 30 year record - Bredthauer and Drage (1982); 1983 discharge - USGS provisional data.

2.2 Physical Habitat Modelling

The models used have been described in other reports (see below) and will only be summarized here. Basically, transects are established at a site and then measurements of depth, mean water column velocity, and cover are made across the transects. Also, the top width of the wetted surface at each transect is measured so that wetted area may be calculated. This is done on three or four different occasions over a range of flows and the information is then input to the models. Output from the models provides either simulated physical parameters and habitat values (IFG) or interpolated habitat values (RJHAB) for any level of discharge over a wide range of discharge.

2.2.1 Instream Flow Group (IFG) PHABSIM Models

Two hydraulic simulation models were used by the Aquatic Habitat section and E. Woody Trihey and Associates during the 1983 open water season (Estes and Vincent-Lang 1984). The IFG-4 model simulates depth and mean water column velocity across horizontal transects at a site over a discharge range from 40% of the lowest calibration flow to 250% of the highest calibration flow (Bovee and Milhous 1978). The IFG-2 model is a water surface profile model that provides the same information as the IFG-4 model but which requires less field data. The IFG-4 model was used for all of the sites except for Lower Side Channel 11, where the IFG-2 model was used.

The models also allow the input of substrate data. However, cover data rather than substrate information were input because it was determined that cover was more important than substrate in influencing the distribution of juvenile salmon (see Part 3 of this report). Substrate was frequently the primary cover type in the cover coding. Consistently good cover data were not obtained at the IFG model sites because most of the sites were primarily intended to be used for simulating habitat for adult spawners. Consequently, cover for some of the transects had to be estimated and may therefore lead to some error in the weighted usable area (WUA) predictions. The cover values on these transects will be obtained during the open water season of 1984 and the output modified accordingly.

2.2.2 RJ Habitat Model (RJHAB)

The RJ Habitat Model, which modelled juvenile salmon habitat at six sites, was described in Part 4 of this report. Transects were established at these sites but, rather than using detailed depth and mean column water velocity measurements across each transect, as do the IFG models, these models use the average depth and average mean water column velocity of 300 sq ft (6 ft wide by 50 ft long) cells which were established along each transect. Usually, there were three cells per transect, but sometimes only two when the channel became too narrow (less than 18 ft in width). This model does not simulate hydraulic characteristics of the site as do the IFG models; instead, it estimates weighted usable area for shoreline and mid-channel portions of the site for those discharge levels at which physical habitat attributes were measured. Estimates of WUA for other discharges are then interpolated.

2.3 Suitability Criteria

The suitability criteria for juvenile salmon input into the models were developed in Part 3 of this report. Suitability indices for cover, velocity, and depth input into the PHABSIM models are presented in Appendix Table A-1 of Part 3. The PHABSIM models linearly interpolate between the point values for depth and velocity input. The cover suitability indices were put into the model in place of substrate; these indices reflect both amount and type of cover. Depth was not thought to be as important as cover and velocity in affecting distribution; therefore, suitability for depth for all species was fixed at 1.00 (i.e., it had no effect on the results) except when depth was less than 0.14 ft and then suitability was fixed at 0.00.

Velocity suitability criteria input into the RJHAB models differed slightly from those input to the IFG models. Suitability indices were constant over an interval of 0.3 ft/sec for velocity. This grouping was made because the limited number of velocity measurements was only an index to hydraulic conditions present and finer resolution was deemed unnecessary. Depth suitability for the RJHAB model was set to 1.0 because depths less than 0.2 ft did not occur.

Suitability criteria for resident fish input into the IFG models were developed and presented in Part 6 of this report. Habitat of juvenile round whitefish and adult rainbow trout, Arctic grayling, round whitefish, and longnose suckers was modelled. The RJHAB models were not run for any resident species. Because of limited data collection, the suitability functions for resident fish are only preliminary.

2.4 Weighted Usable Area Projections

The PHABSIM system can be used to describe the mosaic of physical features of a stream which includes substrate or cover and hydraulic parameters such as depth and velocity. The HABTAT program of PHABSIM incorporates the physical model and the suitability criteria to produce weighted usable area, the habitat potential for a given life stage of a species. Weighted usable area (WUA) is calculated (Bovee 1982) by:

$$WUA = C_{i,s} \times A_i$$

where: $C_{i,s}$ = the composite weighting factor (sometimes called the joint preference factor) for cover, velocity, and depth of the cell (i) for the species and life stage (s)

A_i = the surface area of the cell

The WUA for the study site at a given discharge was calculated by totalling all the individual cell WUA's. The composite weighting factor was calculated by multiplying the suitability indices for cover, velocity, and depth of the cell together. WUA's at each study site were calculated at 10 to 40 incremental flows over the recommended extrapolation range of the hydraulic model.

At RJHAB sites, WUA's were calculated for shoreline and mid-channel portions of the site each time the site was measured. Data were pooled to yield a discharge-specific site WUA instead of calculating individual cell WUA's as in the IFG PHABSIM models. WUA's calculated for the RJHAB sites are generated from habitat measurements which provide an index to conditions at the site. The IFG WUA is standardized to a 1000 ft reach while the RJHAB WUA is dependent on the size of the site.

The output from the IFG models consists of weighted usable area and total surface area predictions for incremental levels of site flow which was in turn related to mainstem discharge by rating curves provided by Estes and Vincent-Lang (1984). RJHAB provides the same information at measured discharges and then plots WUA as a function of discharge. All of the output from RJHAB was presented in Part 4 of this report.

We entered the output of the IFG models into a microcomputer worksheet program to perform additional manipulations of the data. First, plots were constructed of WUA as a function of mainstem discharge. Then we matched WUA predictions with each of the mean daily discharge levels observed from June 1 to September 30, 1983 to obtain a time series of WUA at each of the sites during the open water season. This time series was compared with the catch data at these sites and the outmigration timing data from the downstream migrant traps to better understand the relation between WUA and fish behavior.

All of the possible site/species combinations were run through the IFG models, but only certain ones are presented in this paper because of space limitations; all raw model output is available on request. With a few exceptions, the basic criterion used to select species/site combinations for presentation was that mean catch per cell for the species for the entire season at the site had to be greater than the mean catch per cell at all sites (Table 1). Hence, we are not including weighted usable area predictions for a species at those sites where very few individuals of the species were captured. There are some exceptions to this practice for resident species because the sampling methods used at the modelling sites were not intended for capture of adult resident fish. The species/life stages for which weighted usable area predictions are presented include juveniles of four salmon species (chinook, coho, chum, and sockeye), juvenile and adult round whitefish, and adult rainbow trout, Arctic grayling, and longnose suckers.

To make comparisons among sites which would be independent of the size of the site, we divided the site weighted usable areas at each level of discharge by the total surface area of the site when the mainstem discharge was 23,000 cfs (the area was interpolated from the PHABSIM output of total area as a function of flow). The 23,000 cfs figure was chosen because it is a typical mid-summer discharge (Bredthauer and Drage 1982; Klinger and Trihey 1984) and because it may be integrated with macrohabitat abundance information which was digitized from aerial photographs by E. Woody Trihey and Associates. The resulting habitat index is comparable to the habitat index calculated for the RJHAB sites in Part 4 of this report.

Table 1. Total catch and catch per unit effort of juvenile salmon at the IFG sites, open water season, 1983.

IFG Site	No. of Cells	Catch (catch/cell) Chinook 0+	Coho 0+	Chum	Sockeye 0+
Slough 21	86	91(1.1)*	1(0.0)	417(4.8)*	23(0.3)*
Side Channel 21	23	38(1.6)*	0(0.0)	0(0.0)	0(0.0)
Upper Side Channel 11	21	101(4.8)*	0(0.0)	0(0.0)	0(0.0)
Lower Side Channel 11	21	39(1.9)*	0(0.0)	0(0.0)	0(0.0)
Side Channel 10	62	279(4.5)*	0(0.0)	2(0.0)	0(0.0)
Slough 9	123	227(1.8)*	0(0.0)	74(0.6)*	30(0.2)*
Slough 8A	66	6(0.1)	26(0.4)	129(2.0)	24(0.4)
Sum of IFG sites	402	781	27	205	77
Mean of IFG sites		112(1.9)	4(0.1)	29(0.5)	11(0.2)
Mean of all sites sampled					
Backpack electrofishing		(3.4)	(2.3)	(1.3)	(0.9)
Beach seining		(3.4)	(0.3)	(0.0)	(0.5)

* = Site/species combination selected for presentation.

2.5 Model Verification

Data on fisheries abundance and distribution were collected at the sites; however, program constraints prevented intensive sampling efforts. Composite weighting factors were calculated for each 6 ft X 50 ft cell sampled for fish and this index was then correlated with fish catch in the cell. If cells with large composite weighting factors are associated with higher densities of fish, then it can be assumed that WUA does reflect habitat potential. Correlations or associations between catch and composite weighting factors at the RJHAB sites have been presented in Part 4 of this report. Data were available at the IFG sites for verification of composite weighting factors for juvenile salmon and round whitefish, but not for adult resident species.

The specific hypothesis tested was whether the correlation between a composite weighting factor and catch of chinook and coho salmon/cell [transformed by natural log (x+1)] was greater than zero (in other words, whether there was a significant positive relationship). For sockeye and chum salmon, the null hypothesis was that there was no association between the composite weighting factor and fish presence. Sampling occasions when less than three fish were captured in all cells within a site sampled during a day were deleted from the analysis. This was done because seasonal variations in outmigration from natal areas can lead to low fish density, even in areas that provide good rearing habitat, and inclusion of data from these times could lead to spurious correlations.

3.0 RESULTS

3.1 IFG Model Weighted Usable Area

Juvenile salmon catches and catch per unit effort (CPUE) varied greatly at the seven IFG modelling sites (Table 1). Since discharge levels of more than 33,000 cfs (the level required to overtop the head of the Slough 8A study site) occurred infrequently during the 1983 open water season, this site was not modelled for any species. Juvenile salmon at this slough were primarily caught below the modelling site. The Slough 8A IFG modelling site harbored few juvenile fish because access was restricted from below by several beaver dams and access was restricted from above because the head was only infrequently overtopped.

Juvenile coho catches and CPUE were very low at all the modelling sites and, therefore, no results for coho WUA's are presented. In general, WUA's calculated for coho salmon at the sites were less than 2% of the total surface area of the site. The primary reason for low coho density was the preference of cohos for non-turbid water and cover types infrequently found in the sites modelled (see Parts 2 and 3 of this report). All of the IFG modelling sites, with the exception of Slough 8A, harbored significant numbers of chinook salmon and results from these six sites are presented. Sockeye and chum WUA's are presented for sloughs 21 and 9 as these were the only two sites where these species were relatively numerous. Unfortunately, the four mainstem side channel sites were not sampled for fish density until July; most chum and large numbers of sockeye had moved down river by this time (see Part 1 of this report).

In the time series plots that follow, if a mean daily discharge exceeded the extrapolated range of the model, no WUA value was plotted. No weighted usable areas of zero occurred. If the discharge was less than the extrapolated range, then the WUA was set equal to the WUA value for the lowest discharge in the extrapolated range. WUA at four of the sites was extrapolated to some point below the overtopping flow. WUA did not change very much at flows less than the overtopping flow because the surface areas of the sites remained relatively constant, being affected mainly by site morphology and local hydrology. The lower end of the extrapolated range at Slough 9, Slough 21, and Lower Side Channel 11 was above the overtopping flow.

3.1.1 Chinook salmon

Weighted usable areas for six IFG modelling sites as a function of mainstem discharge and as projected over the June 1 to September 30 time period are presented in Figures 3 through 8. There were two different sets of suitability criteria for chinook salmon; one for a low turbidity level and one for a high turbidity level (Part 3 of this report). We used the low turbidity criteria when the head of a site was closed and the high turbidity criteria when the head was overtopped by mainstem flow. The point of overtopping was taken as the point when mainstem water just began to flow through the head, raising the turbidity level of the site. Chinook juveniles preferred the high turbidity condition when other cover types were not abundant. Therefore, the weighted

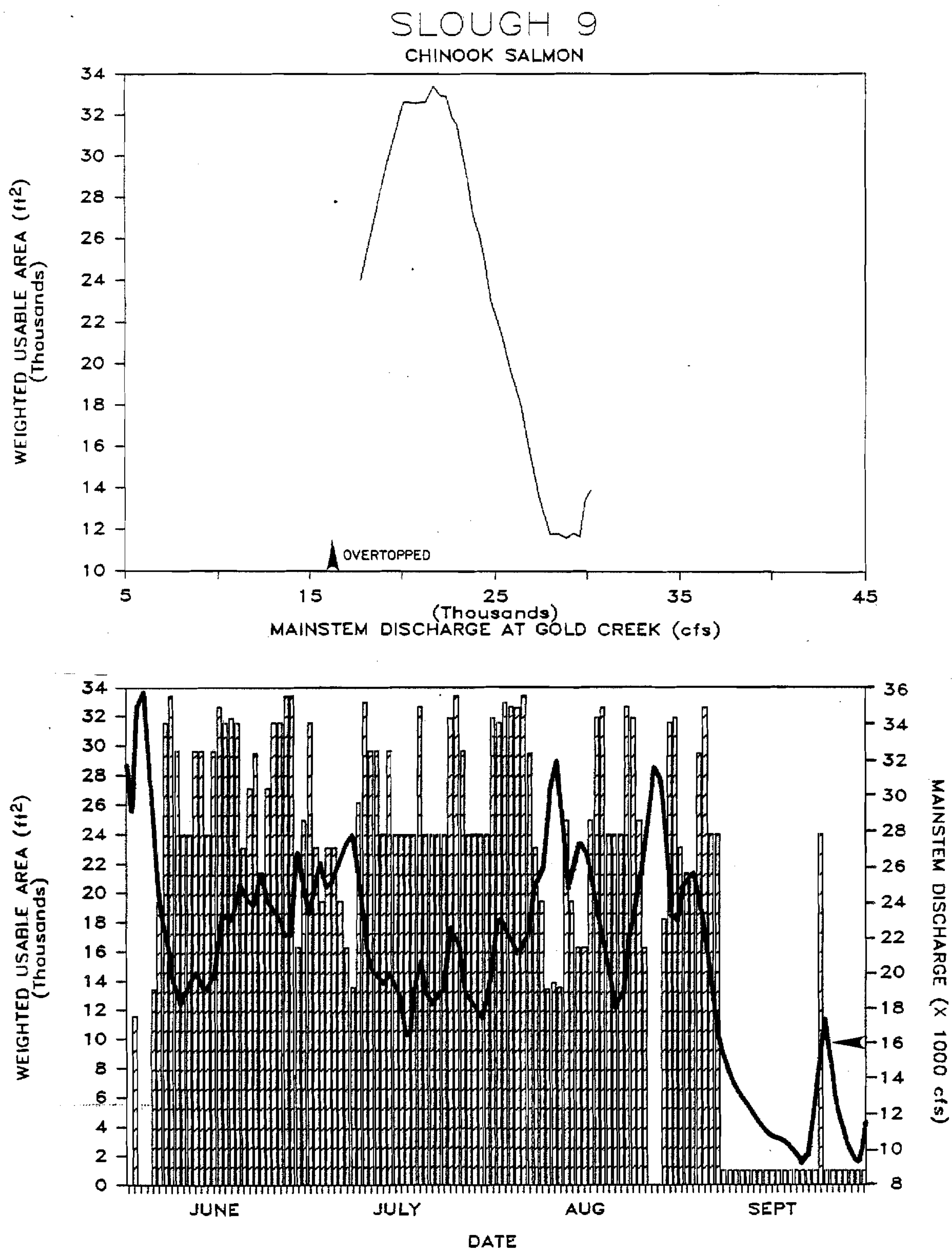


Figure 3. Weighted usable area for chinook salmon at the Slough 9 study site by level of mainstem discharge at Gold Creek and by date, 1983. In the lower graph, daily WUA's are plotted as bars. No WUA value is plotted if the mean daily discharge exceeded the extrapolated range of the model.

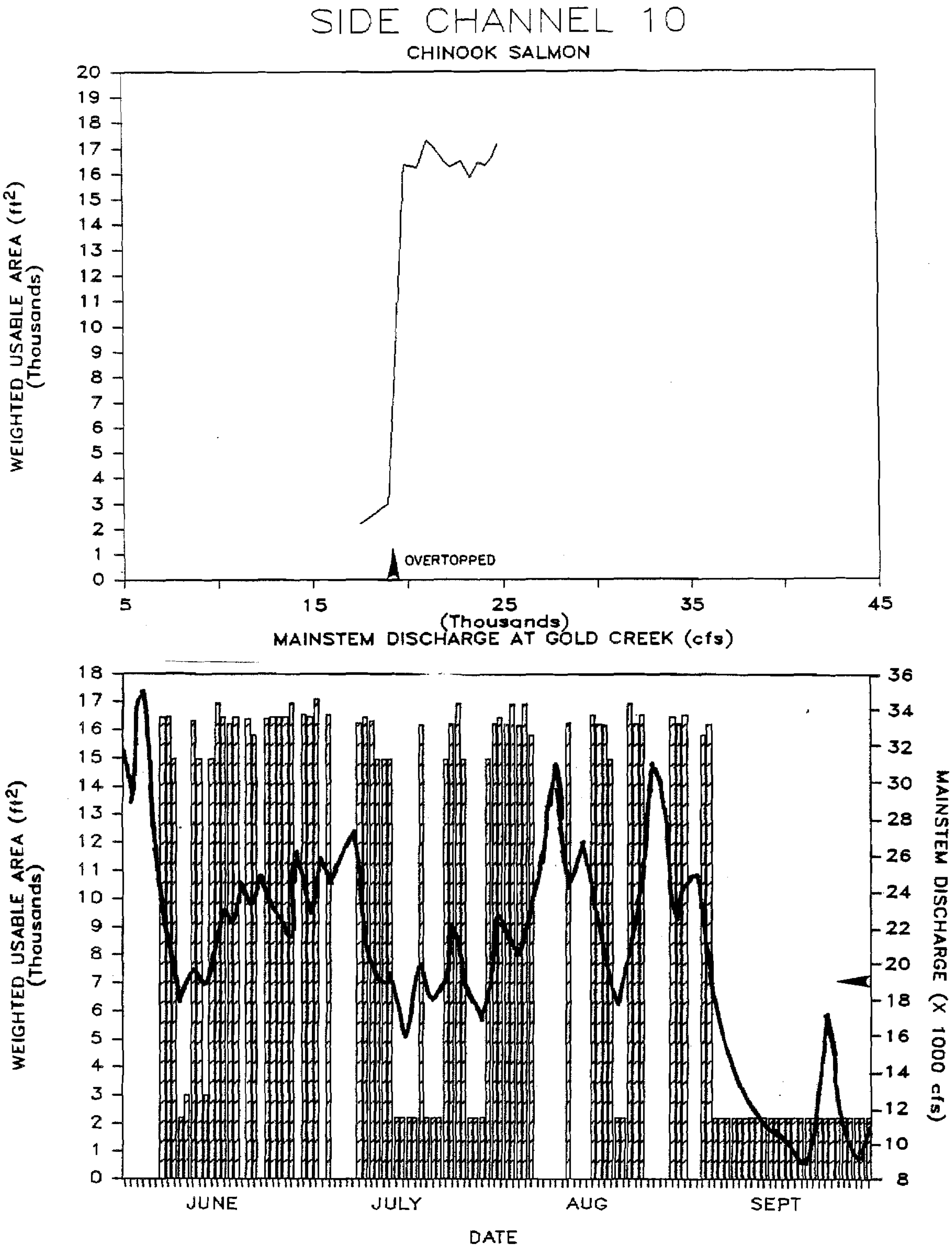


Figure 4. Weighted usable area for chinook salmon at the Side Channel 10 study site by level of mainstem discharge at Gold Creek and by date, 1983. In the lower graph, daily WUA's are plotted as bars. No WUA value is plotted if the mean daily discharge exceeded the extrapolated range of the model.

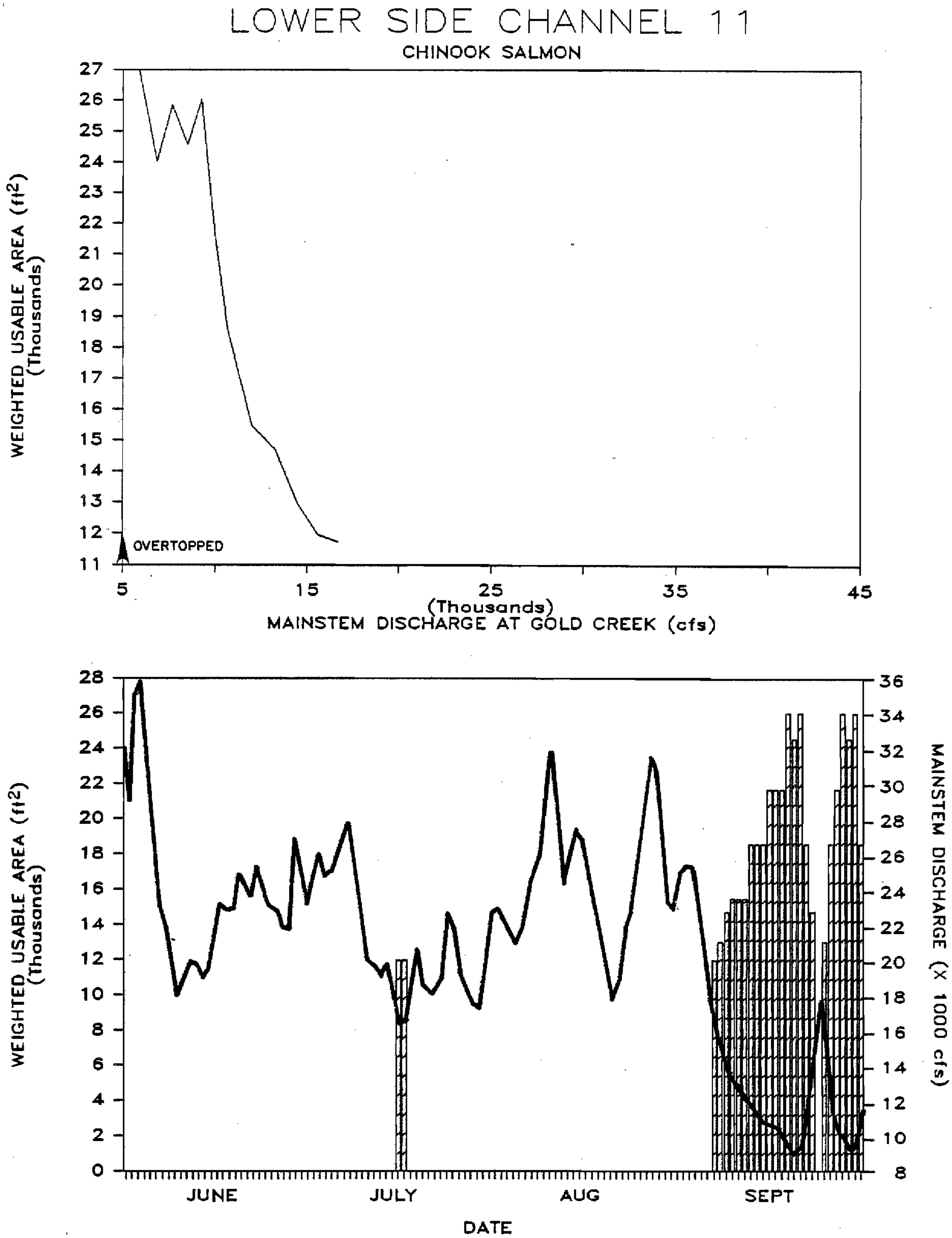


Figure 5. Weighted usable area for chinook salmon at the Lower Side Channel 11 study site by level of mainstem discharge at Gold Creek and by date, 1983. In the lower graph, daily WUA's are plotted as bars. No WUA value is plotted if the mean daily discharge exceeded the extrapolated range of the model.

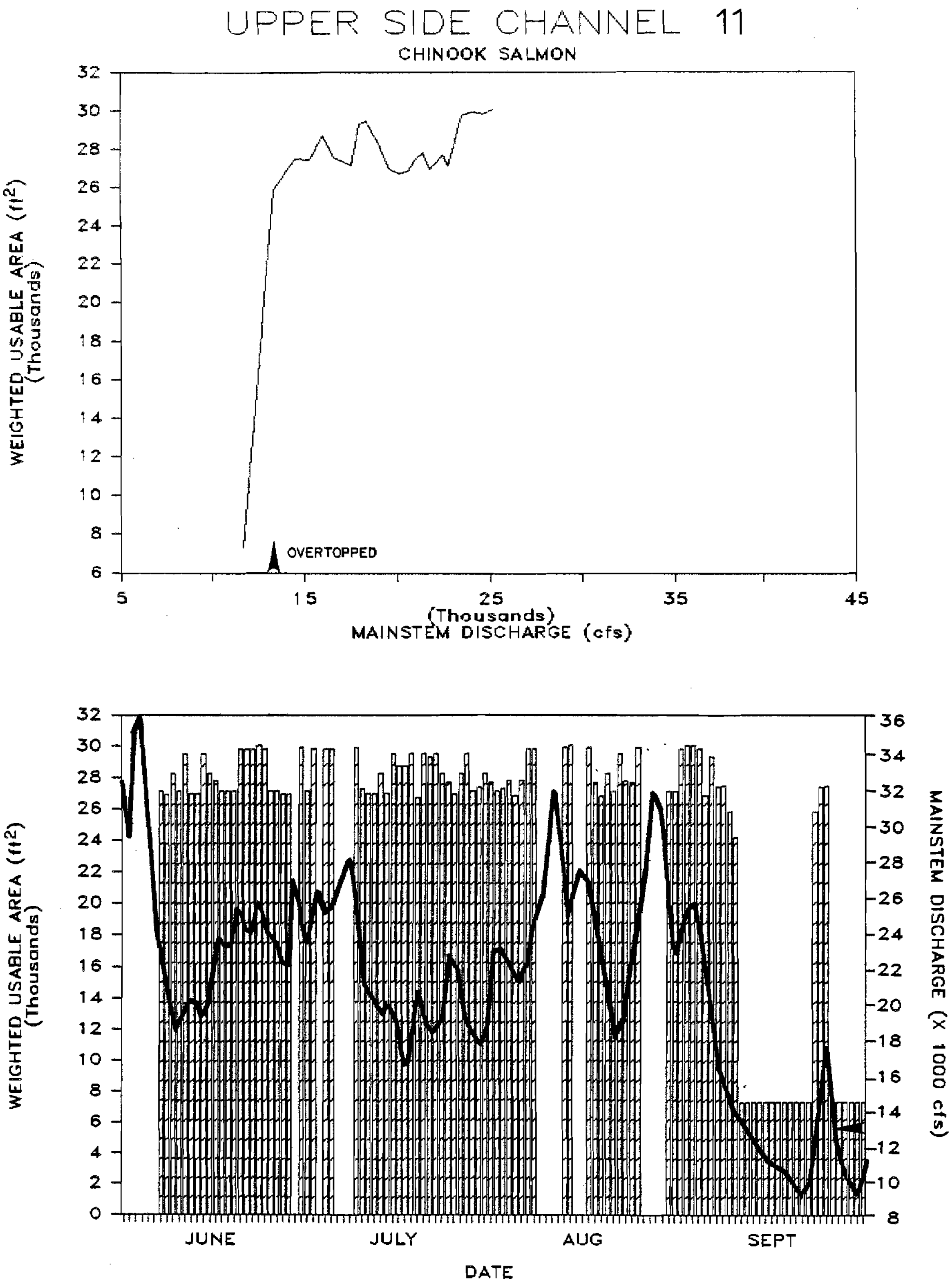


Figure 6. Weighted usable area for chinook salmon at the Upper Side Channel 11 study site by level of mainstem discharge at Gold Creek and by date, 1983. In the lower graph, daily WUA's are plotted as bars. No WUA value is plotted if the mean daily discharge exceeded the extrapolated range of the model.

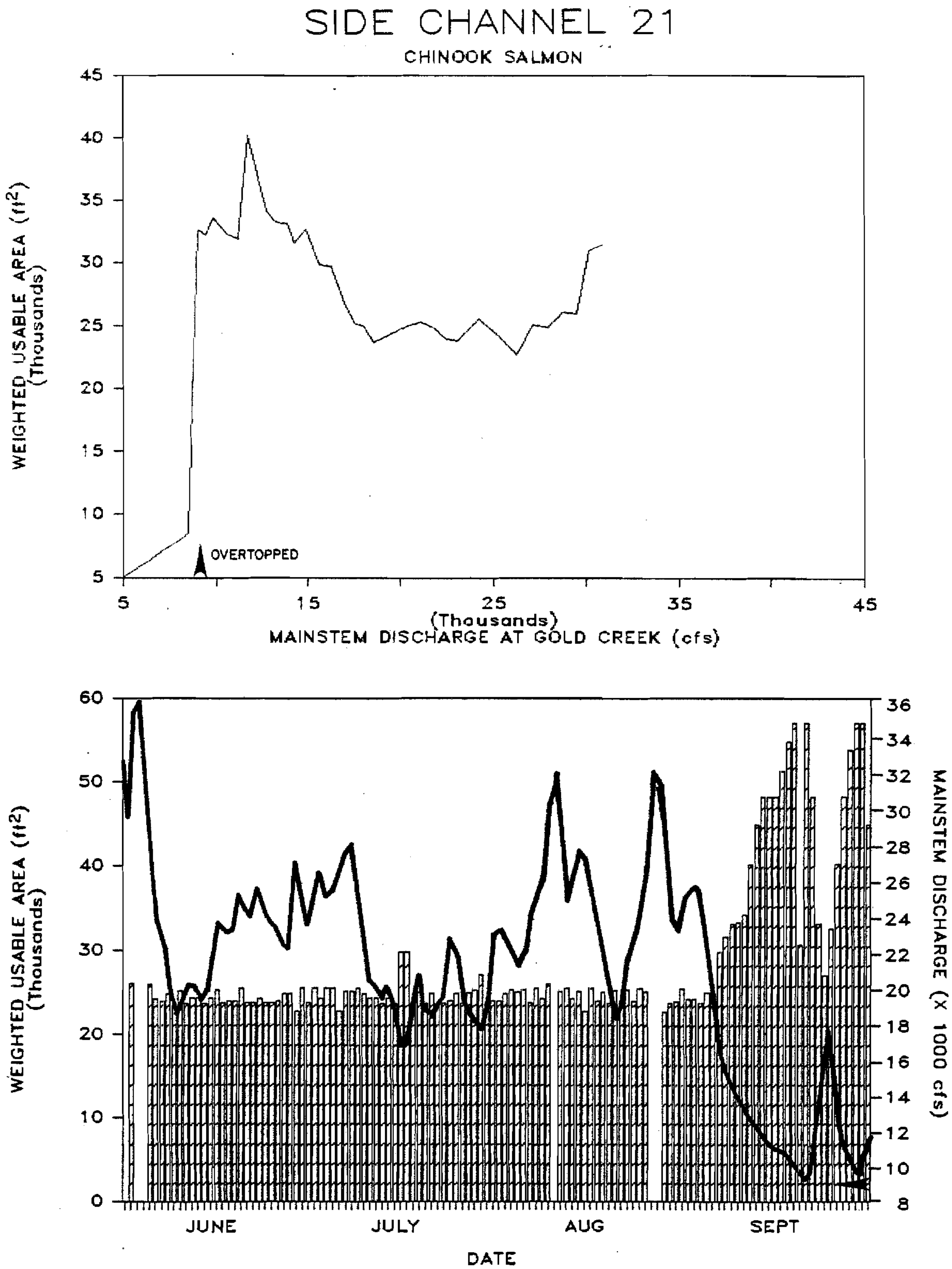


Figure 7. Weighted usable area for chinook salmon at the Side Channel 21 study site by level of mainstem discharge at Gold Creek and by date, 1983. In the lower graph, daily WUA's are plotted as bars. No WUA value is plotted if the mean daily discharge exceeded the extrapolated range of the model.

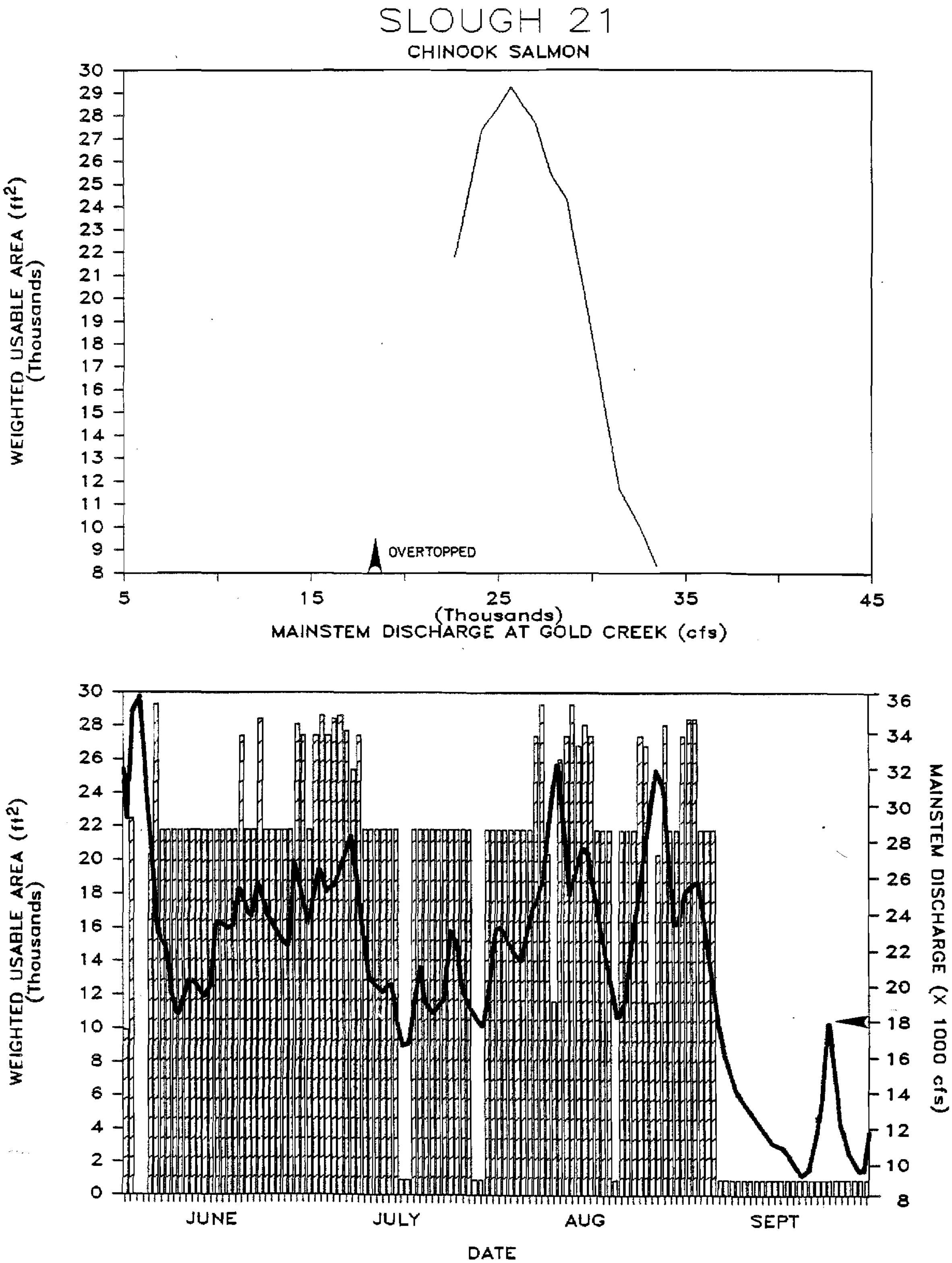


Figure 8. Weighted usable area for chinook salmon at the Slough 21 study site by level of mainstem discharge at Gold Creek and by date, 1983. In the lower graph, daily WUA's are plotted as bars. No WUA value is plotted if the mean daily discharge exceeded the extrapolated range of the model.

usable area for chinooks drops sharply when discharge levels become low enough so that the head of the site is no longer overtopped by turbid mainstem water. At mainstem discharges less than those required to overtop the head of the site, there is no strong relationship between slough flow and mainstem discharge unless groundwater flow is significantly related to discharge. Calibration ranges of the model at many of the sites limited the calculated responses of WUA to a small range of mainstem discharges. The three peak discharges which occurred in early June and in early and late August exceeded the calibration range of all the sites except for Slough 21.

Typically, peaks in weighted usable area were found at mainstem discharges slightly (within a few thousand cfs) greater than the overtopping discharges. The Slough 21 study site appears (Figure 8) to be an exception to this trend but in fact is not. A small side channel which entered the Slough 21 study site conveyed mainstem water at discharge levels greater than 18,000 cfs, but the amount of mainstem water entering the site did not become substantial until the head of Slough 21 proper became overtopped at 23,000 cfs.

The time when the WUA peaks occurred and, hence, the period when the site was theoretically able to support the maximum number of fish, can be seen from the time series plots. With a few exceptions, sites at which the overtopping flow occurred at a middle level of discharge provided more habitat during the open water season of 1983 than sites which had either a relatively low overtopping flow or a relatively high overtopping flow. With the exception of the two side channels which had low overtopping discharges (Lower Side Channel 11 and Side Channel 21), weighted usable area was low to all sites in September because low mainstem discharge (down to 9,000 cfs) led to reduced velocity, depth, and surface area at these study sites.

3.1.2 Chum and sockeye salmon

Plots of weighted usable area for chum and sockeye salmon as a function of mainstem discharge showed very similar trends (Figures 9 through 12). Chum and sockeye WUA plots were almost identical at both Slough 9 and Slough 21. At both sites, WUA's for chum and sockeye peaked rapidly with small increases in discharge, held constant over a range of approximately 5,000 cfs in mainstem discharge, and then decreased rapidly with further increases in mainstem discharge. At a given site, sockeye WUA's peaked slightly before chum WUA's because slightly lower velocities were more suitable to the sockeye salmon juveniles. Chum and sockeye salmon WUA at these two sites remained relatively high in September as compared to chinook WUA, because chum and sockeye salmon have a preference for lower velocities. However, the chum WUA in September is never used because this species has basically outmigrated from this reach by the end of July.

3.1.3 Resident Fish Weighted Usable Area

Only limited sampling for resident fish was conducted at the IFG modelling sites and, therefore, no site-specific data on adult resident use of the sites are available. Many of the sites are inaccessible to

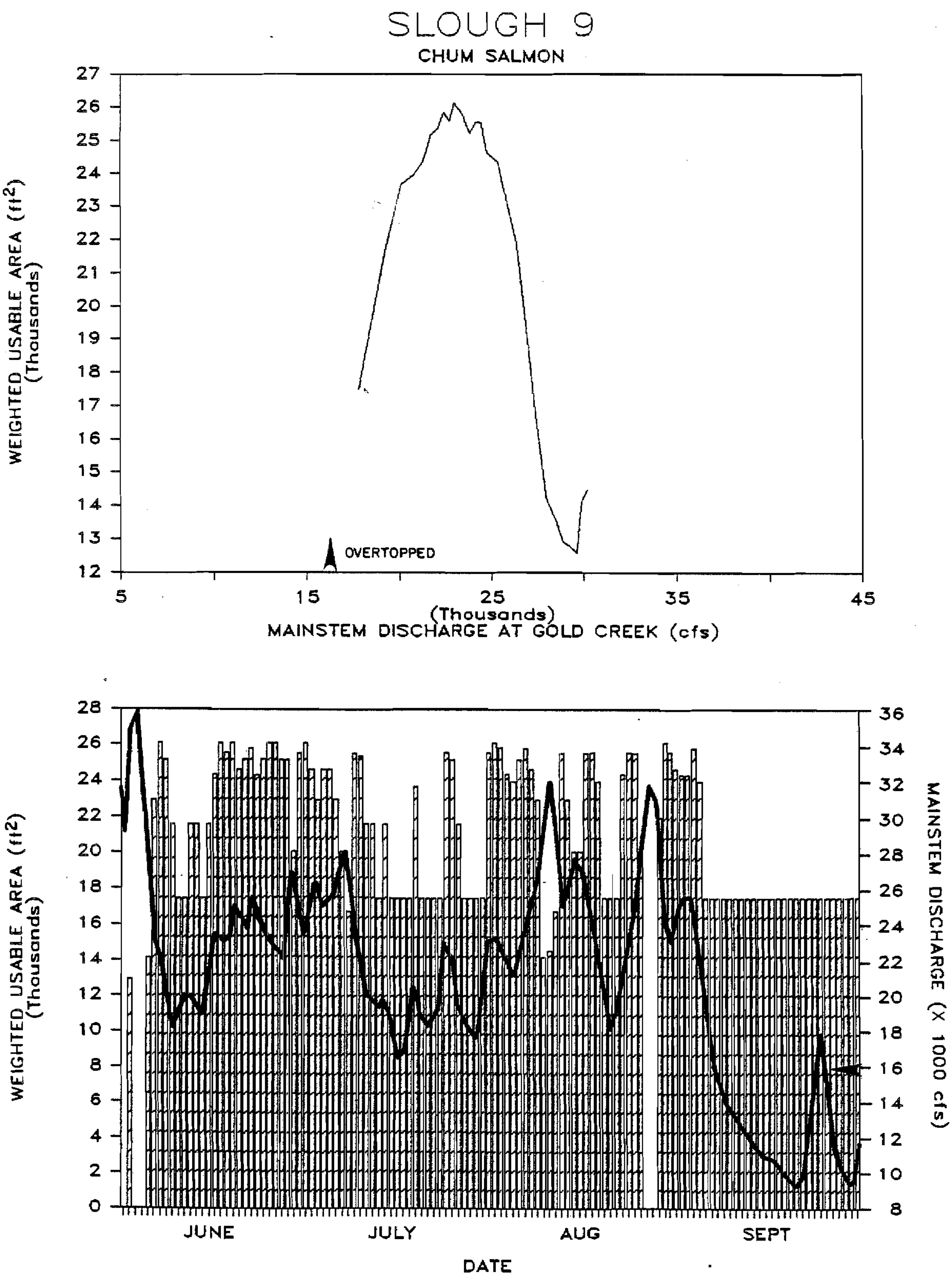
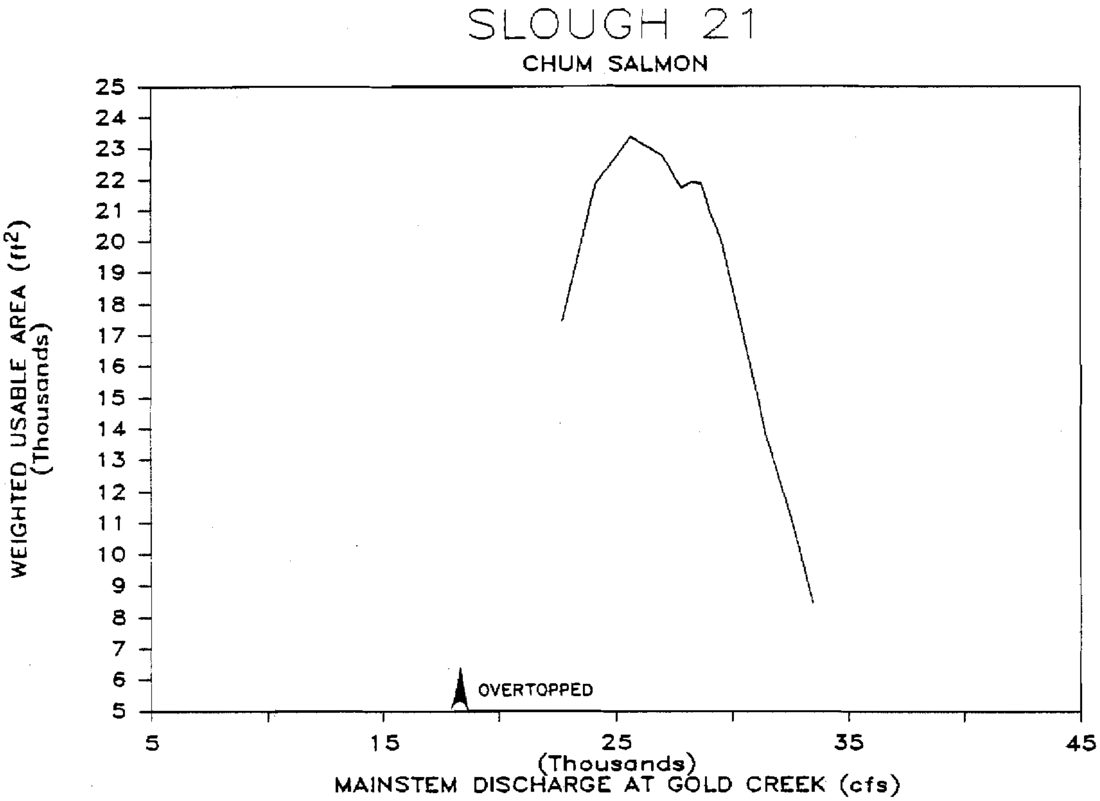


Figure 9. Weighted usable area for chum salmon at the Slough 9 study site by level of mainstem discharge at Gold Creek and by date, 1983. In the lower graph, daily WUA's are plotted as bars. No WUA value is plotted if the mean daily discharge exceeded the extrapolated range of the model.



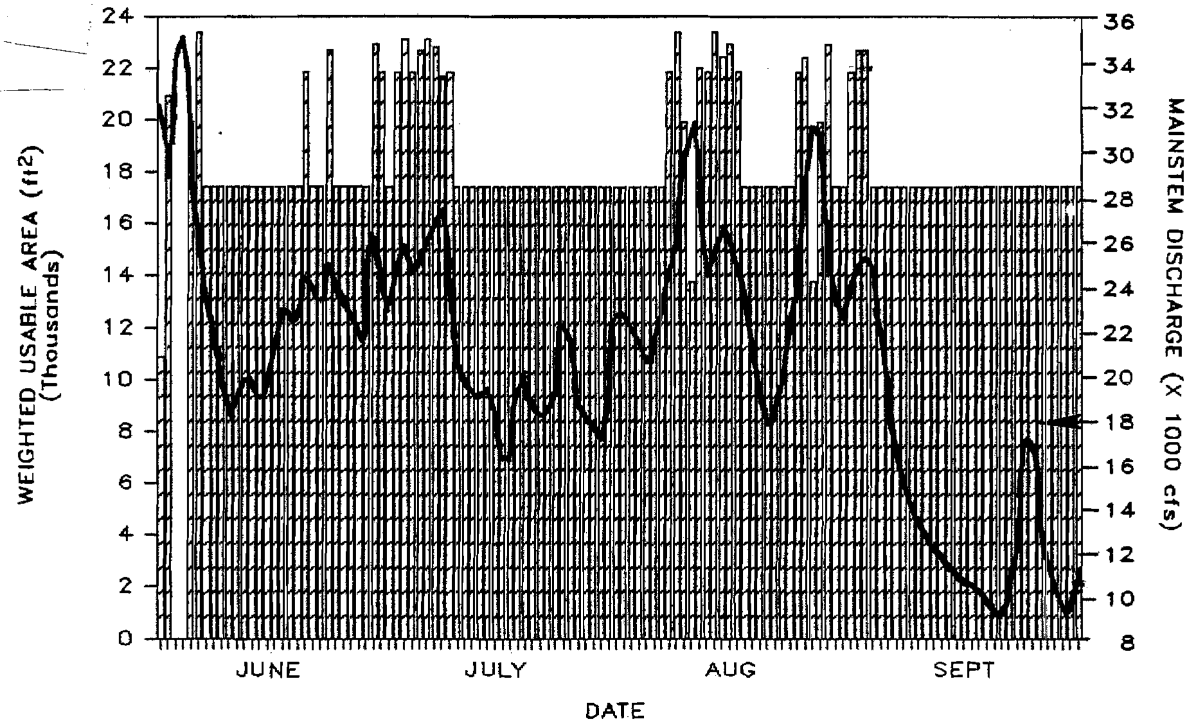


Figure 10. Weighted usable area for chum salmon at the Slough 21 study site by level of mainstem discharge at Gold Creek and by date, 1983. In the lower graph, daily WUA's are plotted as bars. No WUA value is plotted if the mean daily discharge exceeded the extrapolated range of the model.

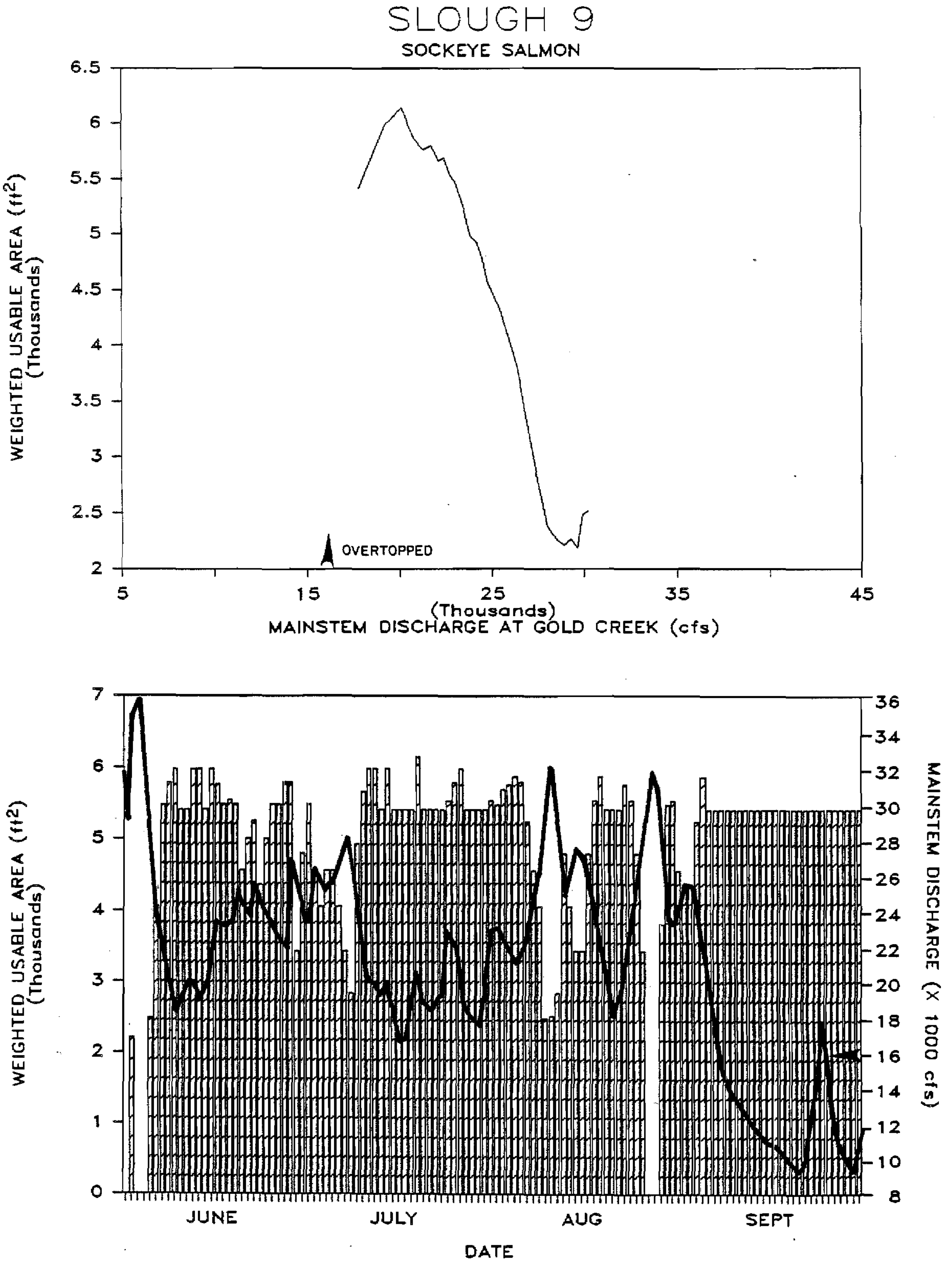


Figure 11. Weighted usable area for sockeye salmon at the Slough 9 study site by level of mainstem discharge at Gold Creek and by date, 1983. In the lower graph, daily WUA's are plotted as bars. No WUA value is plotted if the mean daily discharge exceeded the extrapolated range of the model.

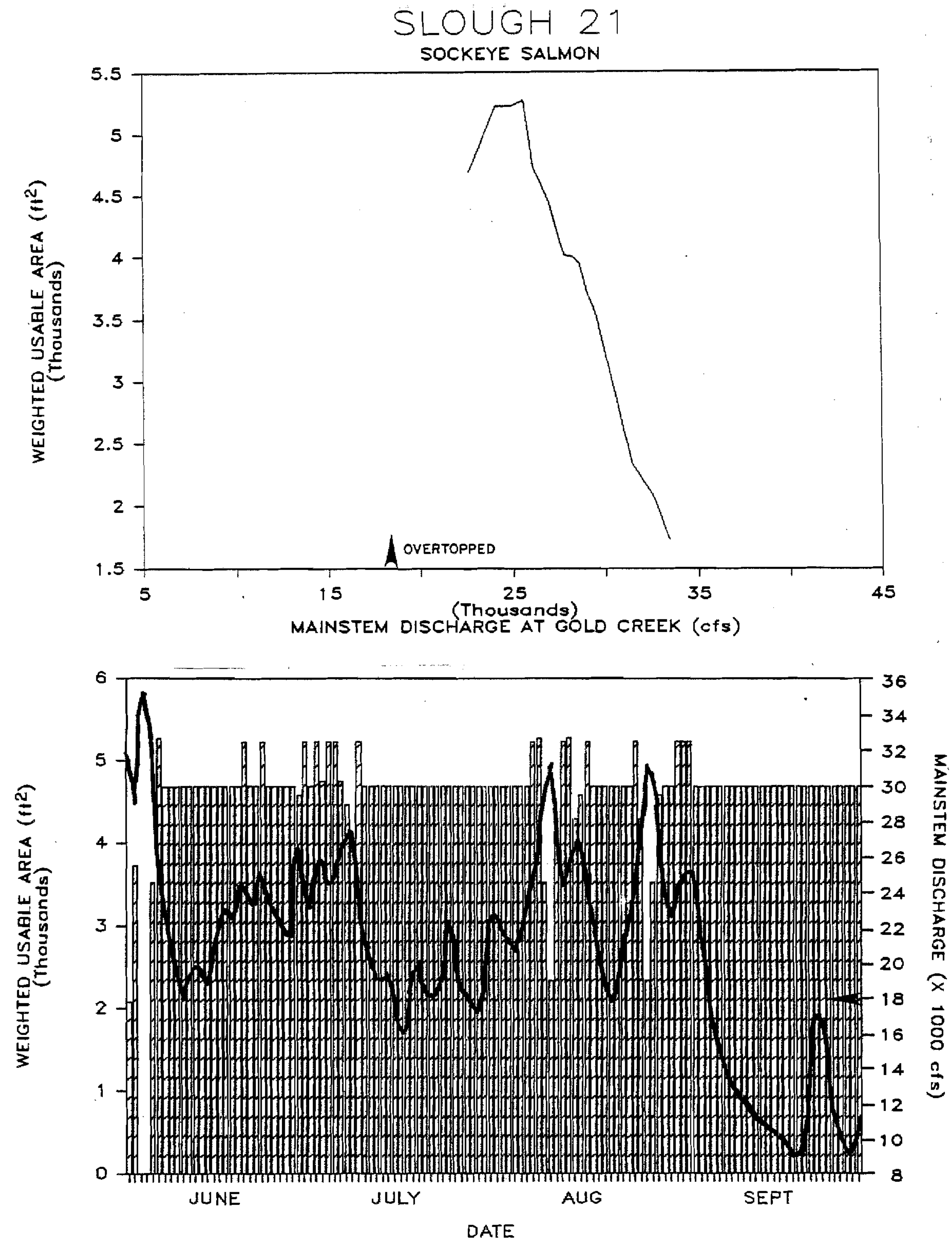


Figure 12. Weighted usable area for sockeye salmon at the Slough 21 study site by level of mainstem discharge at Gold Creek and by date, 1983. In the lower graph, daily WUA's are plotted as bars. No WUA value is plotted if the mean daily discharge exceeded the extrapolated range of the model.

electrofishing boats except during high mainstem discharges. Slough 21 was selected as a representative site to present responses of adult resident fish habitat to changes in mainstem discharge. The relationships between WUA and mainstem discharge for adult rainbow trout, Arctic grayling, round whitefish, and longnose suckers are shown in Figures 14 and 15. Since Arctic grayling are frequently found in side channels during the ice-free months, responses of WUA to mainstem discharge for Arctic grayling at Slough 9 and Side Channel 21 are also presented (Figure 13). Within the extrapolated flow ranges of the site or sites, WUA's for adult rainbow trout, Arctic grayling, and round whitefish increased with flow. WUA for longnose suckers, which prefer low velocities and turbid water, peaked with the overtopping of the site by mainstem discharge and then rapidly decreased with further increases in discharge.

At least 16 juvenile round whitefish were captured at every site with the exception of Slough 8A where none were captured. Results from WUA calculations for juvenile round whitefish are presented for six sites in Figures 16 to 18.

3.2 Model Verification

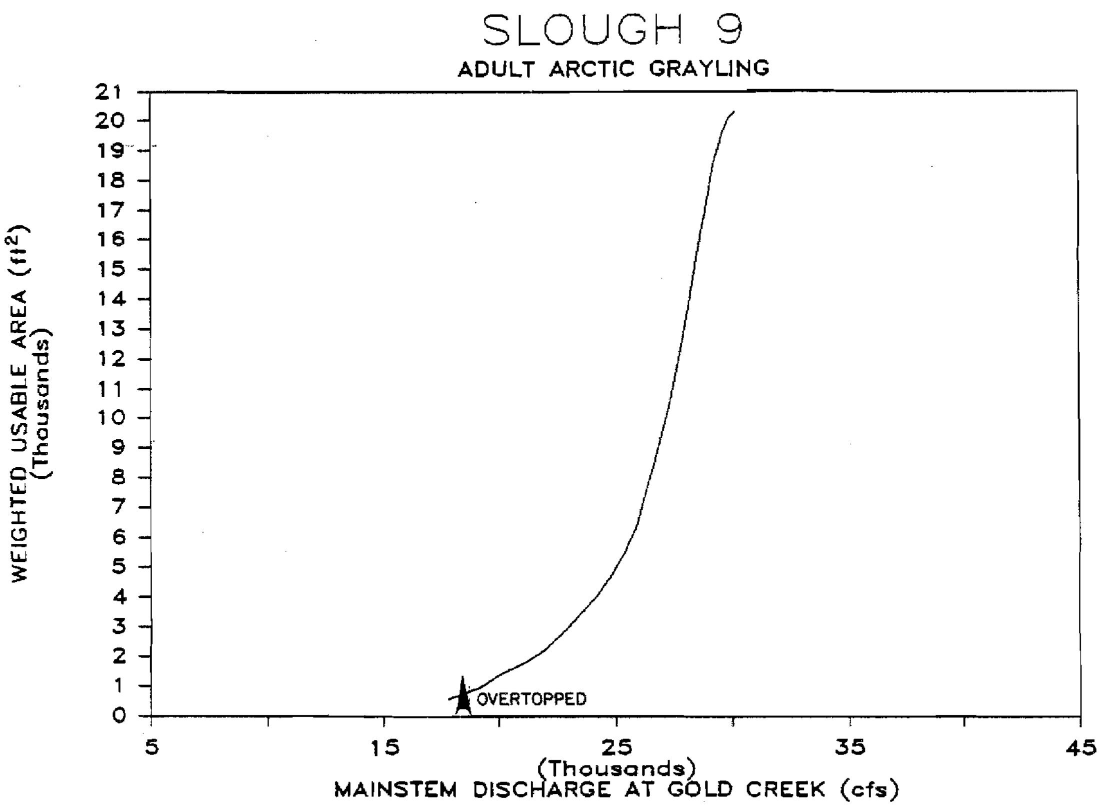
Slough 9 and Side Channel 10 were the only two IFG sites where both a relatively large amount of sampling and catch of juvenile chinook occurred. Correlations between chinook catch and composite weighting factor at Slough 9 and for all seven sites pooled for both clear and turbid conditions were significantly greater than 0.0 (Table 2). At Side Channel 10, however, there was no significant correlation between chinook catch in turbid water and the composite weighting factor.

Data from Sloughs 8A, 9 and 21 were pooled for chi-square contingency tests of chum and sockeye proportional presence by composite weighting factor interval (Table 3). Chum salmon presence was associated with larger composite weighting factors; however, sockeye salmon presence was not.

Correlations between round whitefish catch in turbid ($>$ 30 NTU) water and composite weighting factors were all significantly greater than 0.0 at the 0.01 level. The correlations were 0.35 (n = 54) at Side Channel 10, 0.46 (n = 63) at Slough 9, and 0.52 (n = 188) for all seven IFG sites pooled.

3.3 Habitat Indices

In order to compare modelling sites with one another and to compare IFG model results with RJHAB model results independently of site surface area, habitat indices were calculated by dividing WUA by the total surface area of the site at a mainstem discharge of 23,000 cfs. This discharge level was chosen because it represents typical mid-summer discharge conditions in this reach (Klinger and Trihey 1984).



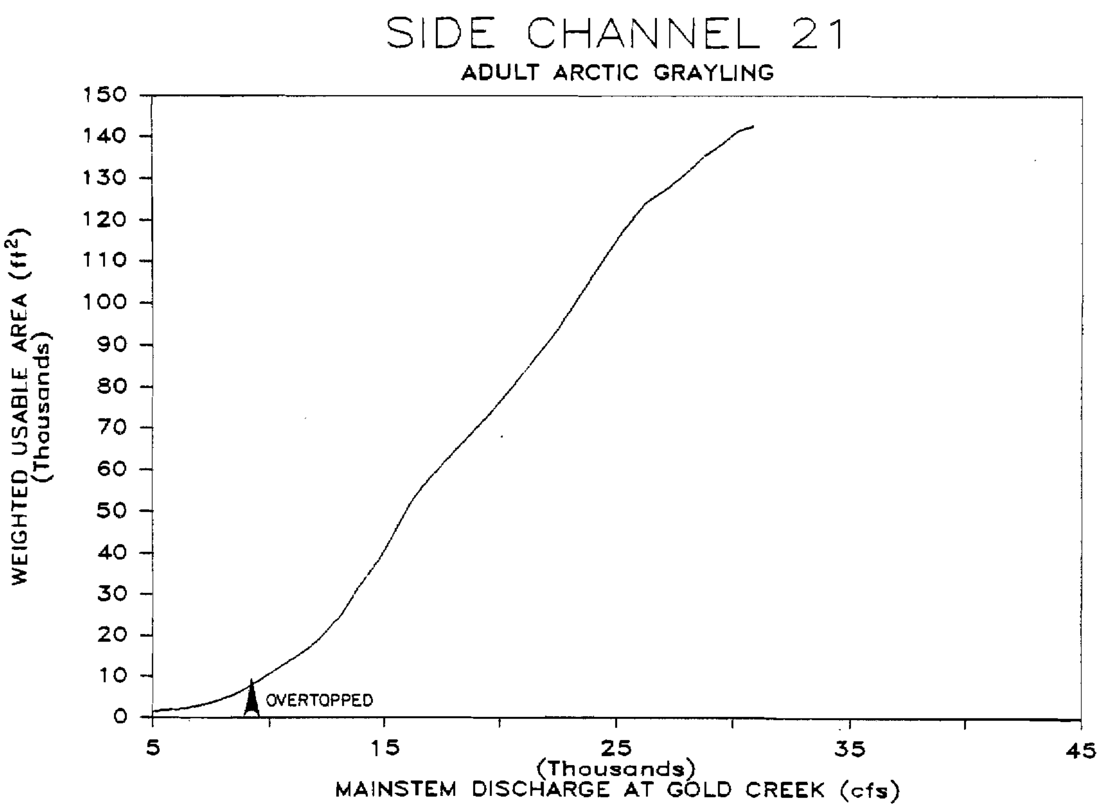


Figure 13. Weighted usable area for adult Arctic grayling at the Slough 9 and Side Channel 21 study sites.

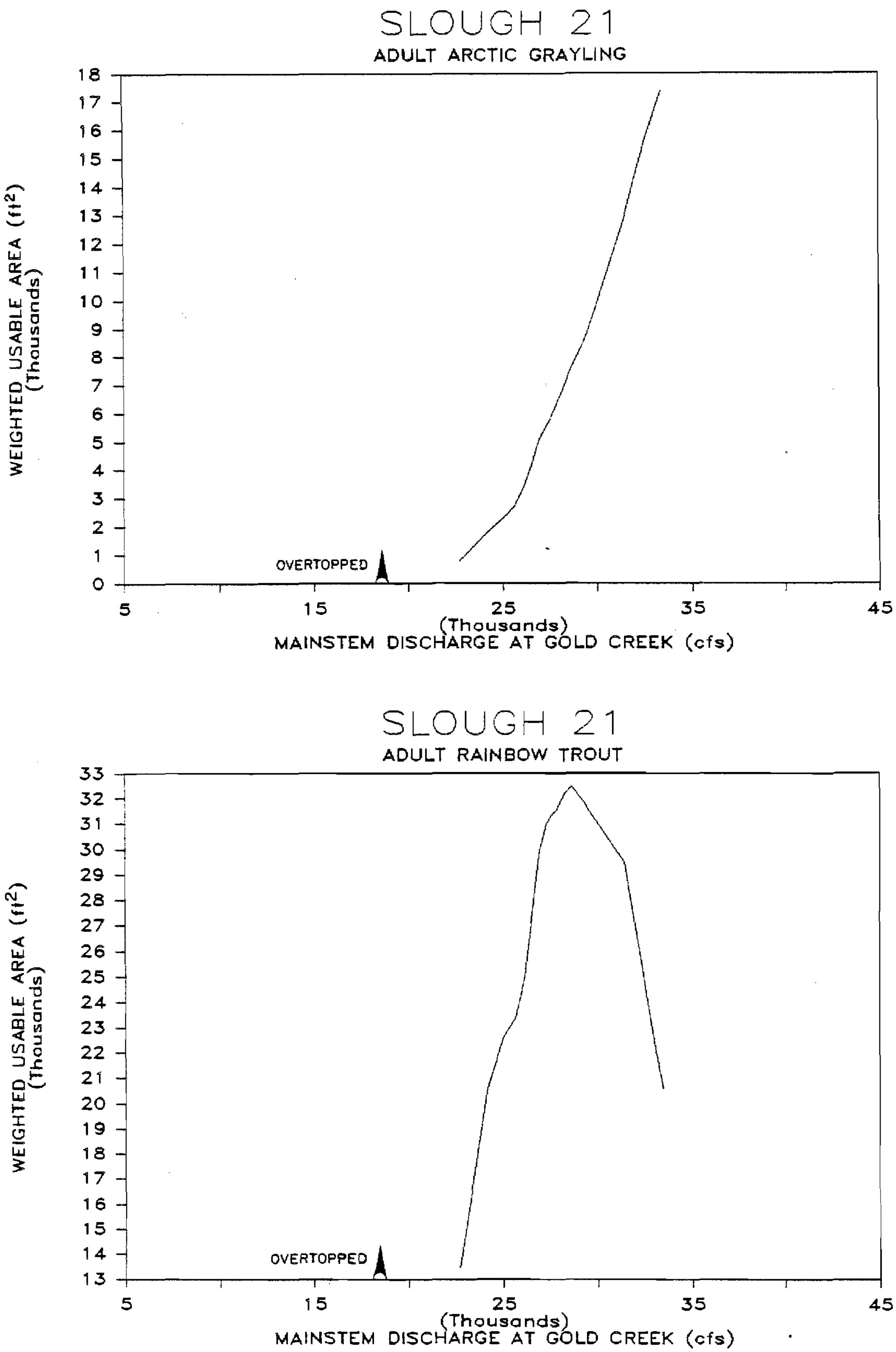
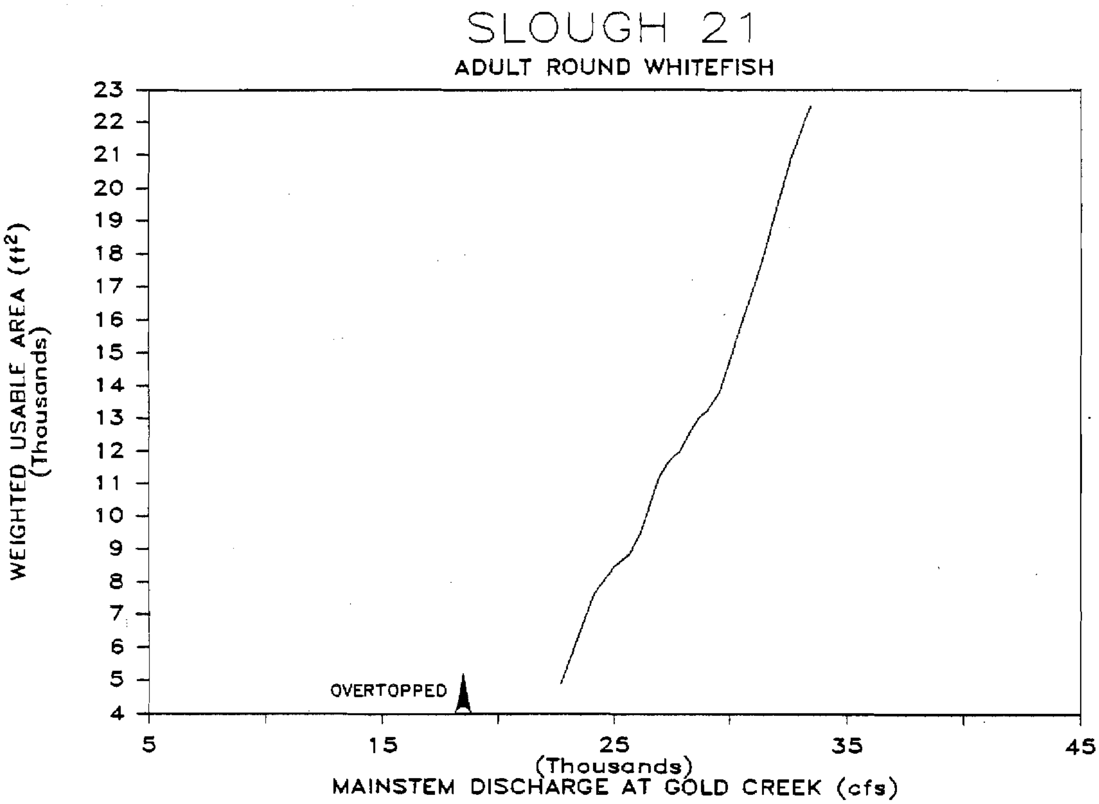


Figure 14. Weighted usable area for adult Arctic grayling and rainbow trout at the Slough 21 study site.



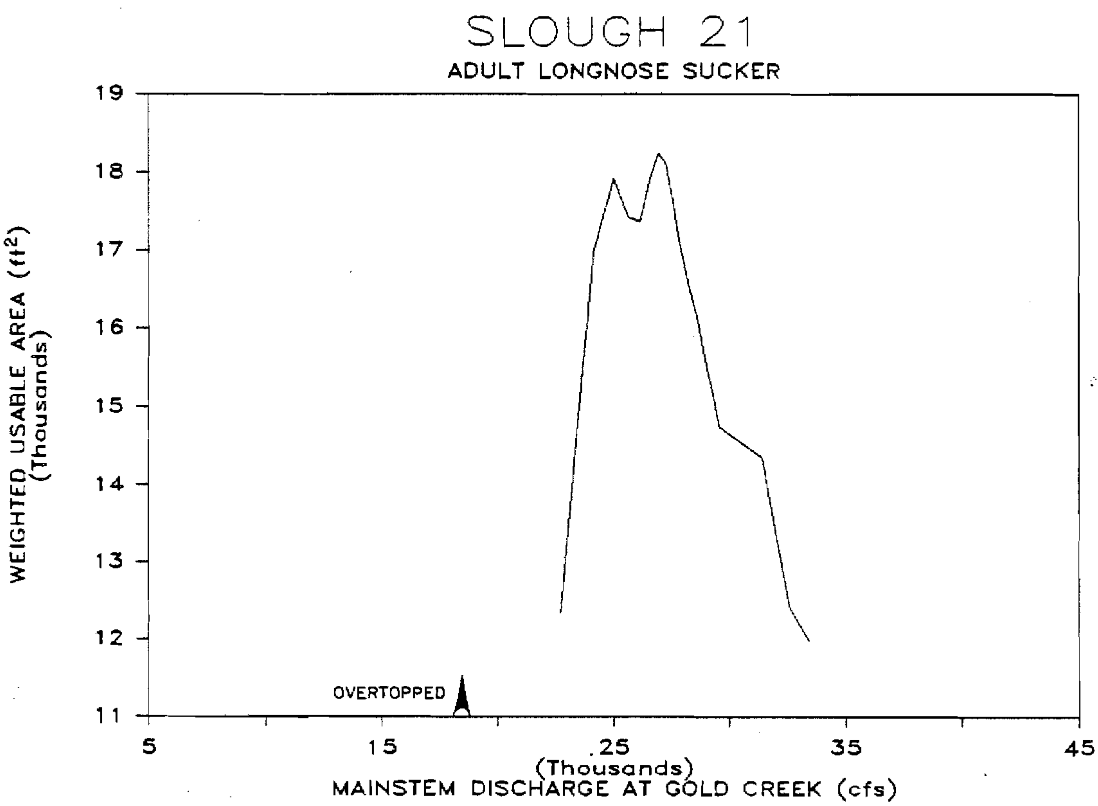
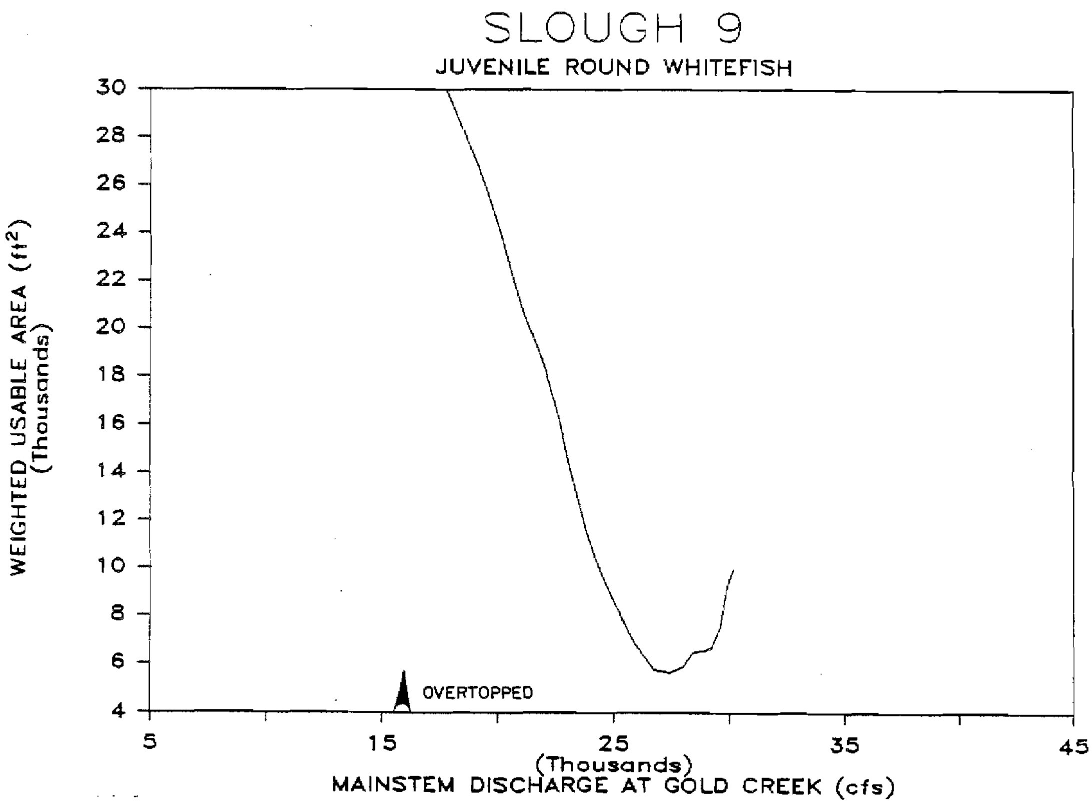


Figure 15. Weighted usable area for adult round whitefish and longnose suckers at the Slough 21 study site.



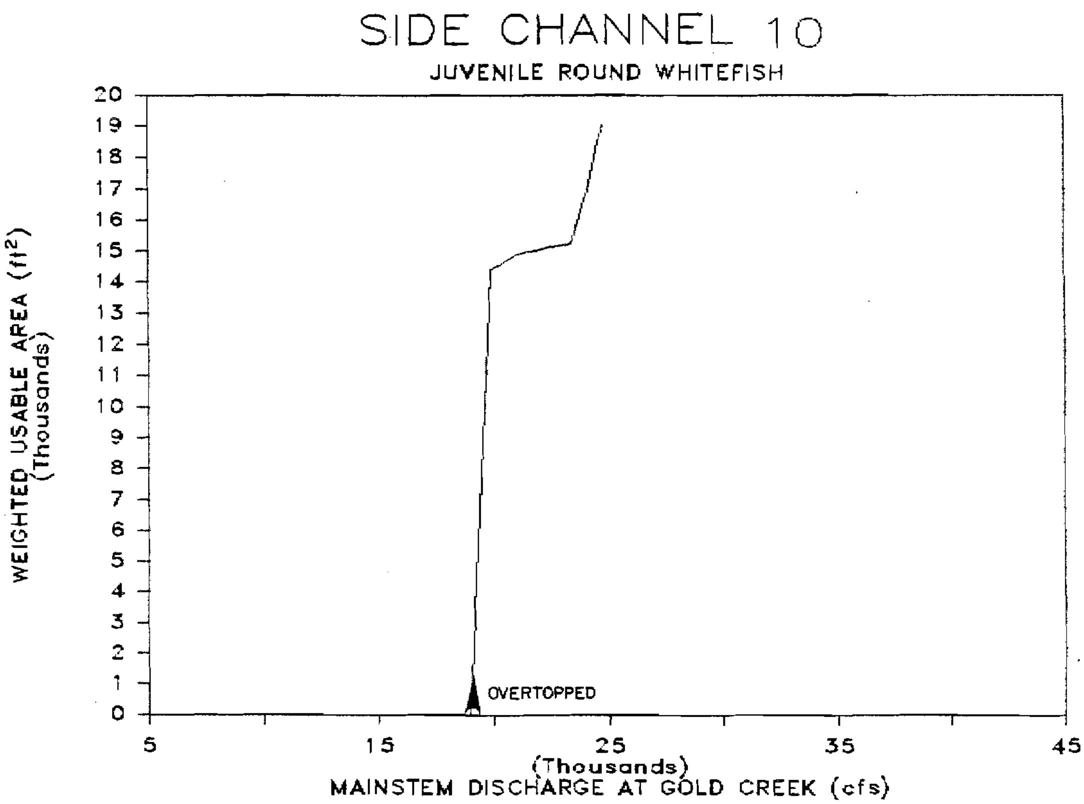
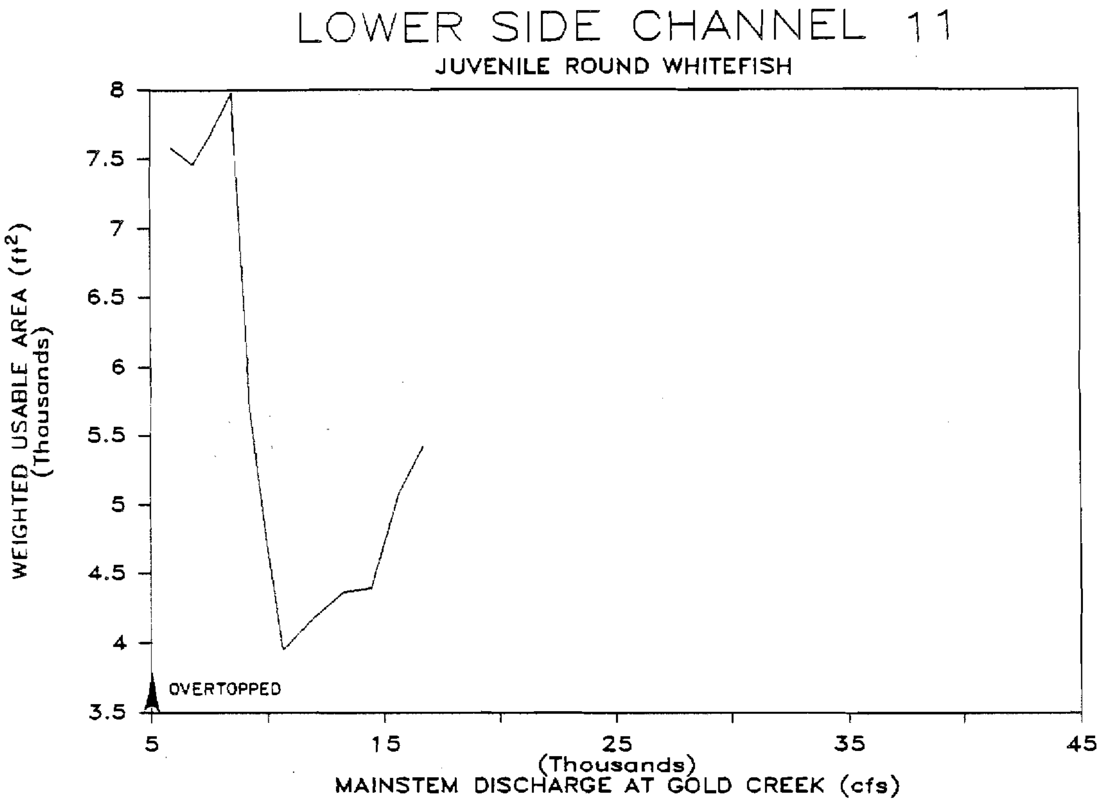


Figure 16. Weighted usable area for juvenile round whitefish at the Slough 9 and Side Channel 10 study sites.



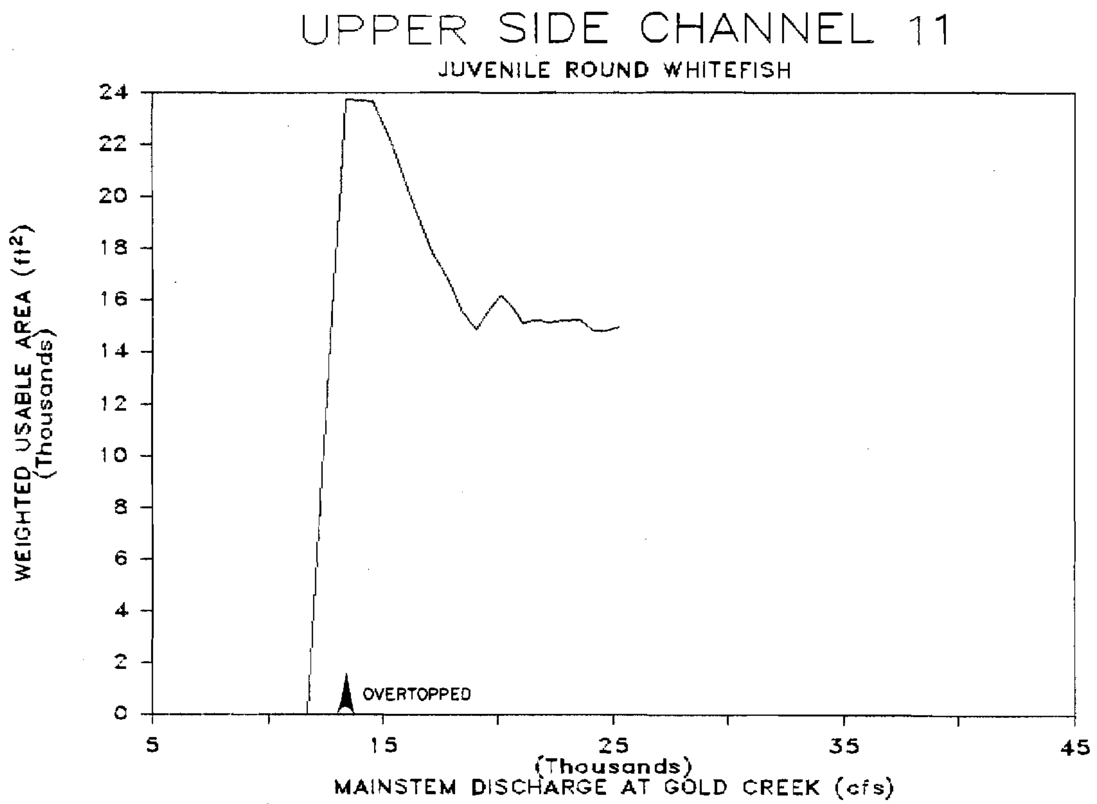
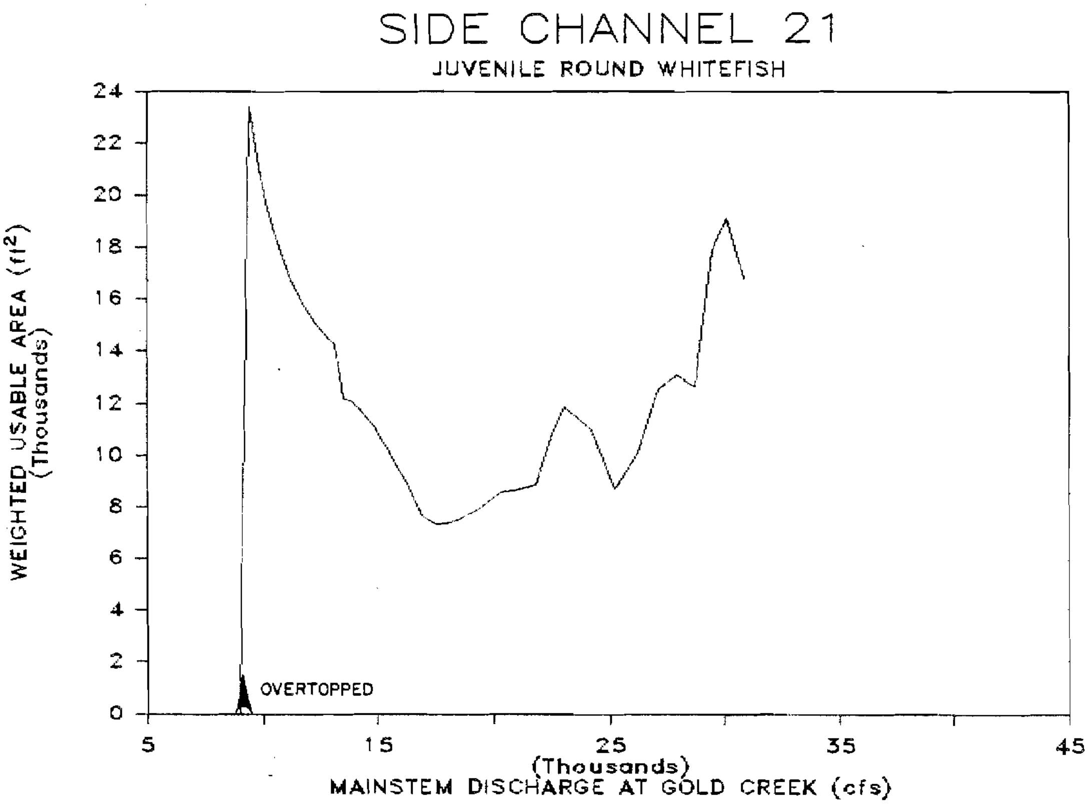


Figure 17. Weighted usable area for juvenile round whitefish at the Lower Side Channel 11 and Upper Side Channel 11 study sites.



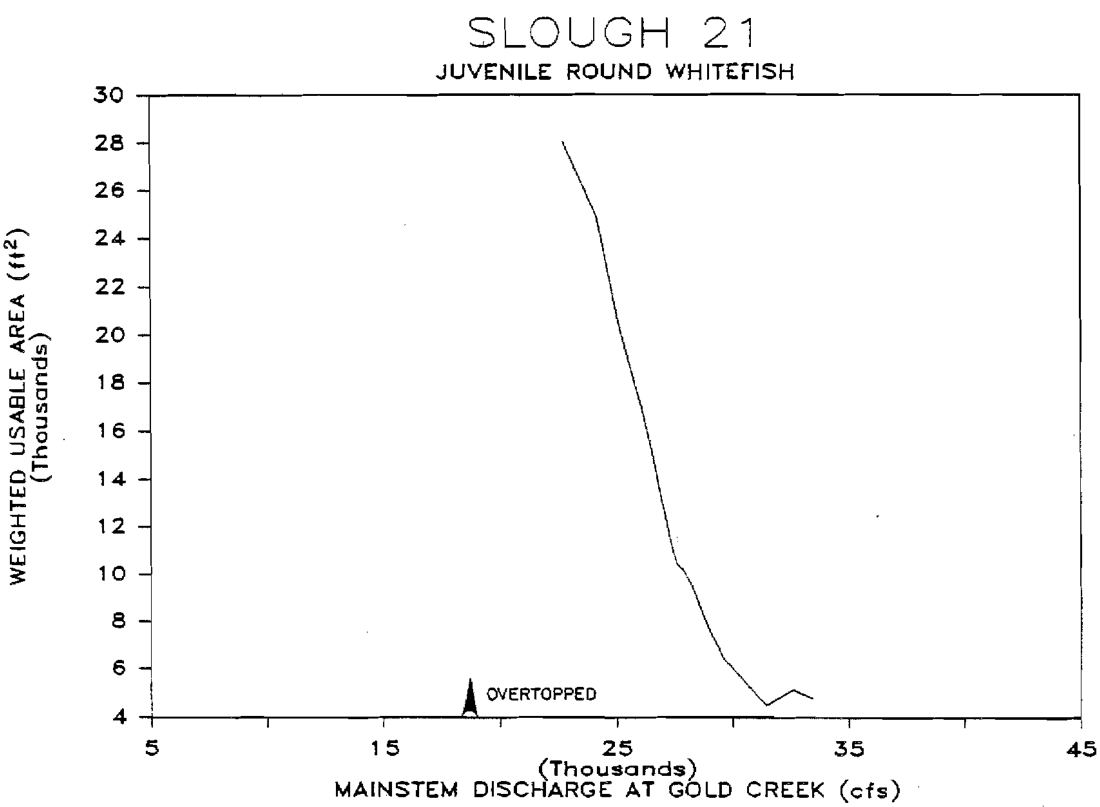


Figure 18. Weighted usable area for juvenile round whitefish at the Side Channel 21 and Slough 21 study sites.

Table 2. Correlations between composite weighting factors and catch transformed by natural log (X+1) for juvenile chinook salmon by selected sites and by all sites pooled.

	Chinook					
	Low turbidity (≤ 30 NTU)			High turbidity (> 30 NTU)		
Site	n	r	Sig [a]	n	r	Sig
Slough 9	48	0.35	0.008	63	0.48	< 0.001
Side Channel 10	(Insufficient data)			54	-0.08	0.28
All 7 sites pooled	99	0.40	< 0.001	192	0.25	< 0.001

[a] Significance level for rejection of hypothesis that there is no positive correlation between composite weighting factors and catch.

Table 3. Chi-square contingency tests of chum and sockeye salmon proportional presence by composite weighting factor intervals. Data from Sloughs 9, 21, and 8A pooled.

Chum

Composite weighting factor interval	No. of Cells Present	No. of Cells Absent	Total	Proportion Present
0.00-0.28	13	28	41	0.32
0.29-0.44	15	21	36	0.42
0.45-0.55	14	21	35	0.40
0.56-1.00	33	10	43	0.77

$X^2 = 20.05$ df = 3
$p < 0.001$

Sockeye

Composite weighting factor interval	No. of Cells Present	No. of Cells Absent	Total	Proportion Present
0.00-0.07	9	25	34	0.26
0.08-0.14	7	28	35	0.20
0.15-0.38	11	26	37	0.30

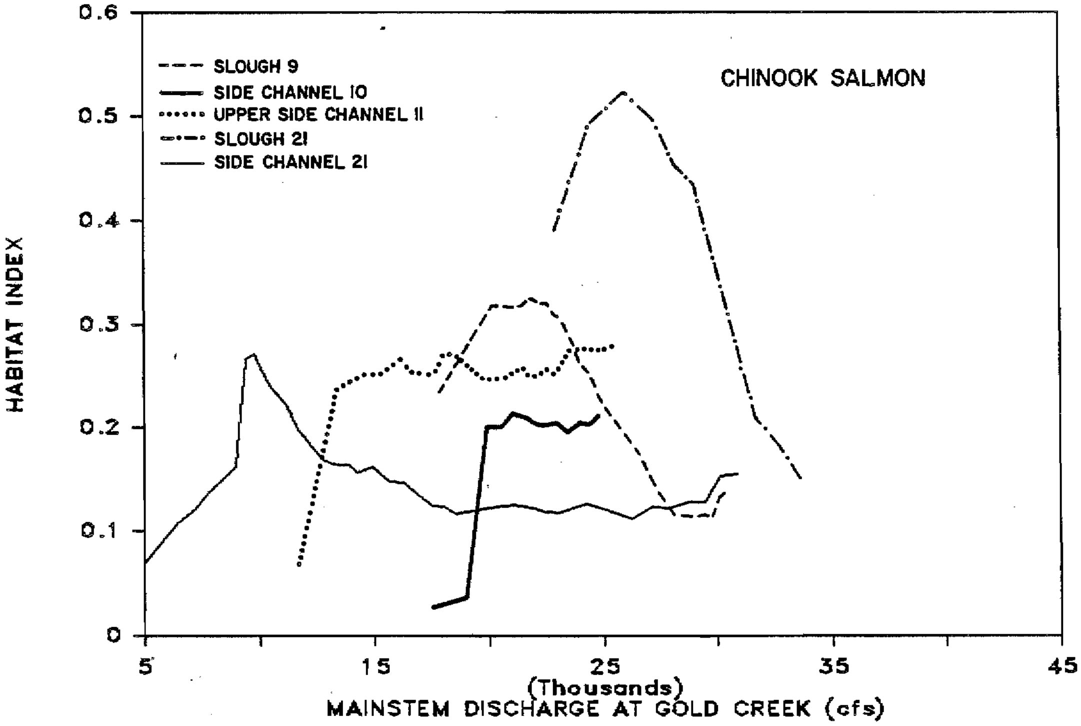
$X^2 = 0.92$ df = 2
$p < 0.37$

3.3.1 Juvenile salmon

The response of chinook salmon habitat indices to mainstem discharge varied by site (Figure 19). Habitat indices for juvenile chinook salmon in Sloughs 9 and 21 showed prominent peaks. Side Channel 10 and Upper Side Channel 11 chinook salmon habitat indices increased sharply after the heads were overtopped and then remained fairly constant because velocities did not become limiting at high discharge levels. Chum salmon habitat indices at Slough 9 and Slough 21 were very similar and showed distinct peaks. Sockeye salmon habitat indices at these two sloughs were very low and decreased slowly with discharge.

3.3.2 Resident species

The response of resident fish habitat indices to changes in discharge varied greatly by species. Juvenile round whitefish habitat indices changed in a similar way to chinook salmon habitat indices while Arctic grayling habitat indices steadily increased with discharge (Figure 20). Rainbow trout habitat indices at Slough 21 increased with mainstem discharge while adult longnose sucker habitat indices began to decrease at the higher mainstem discharge levels (Figure 21).



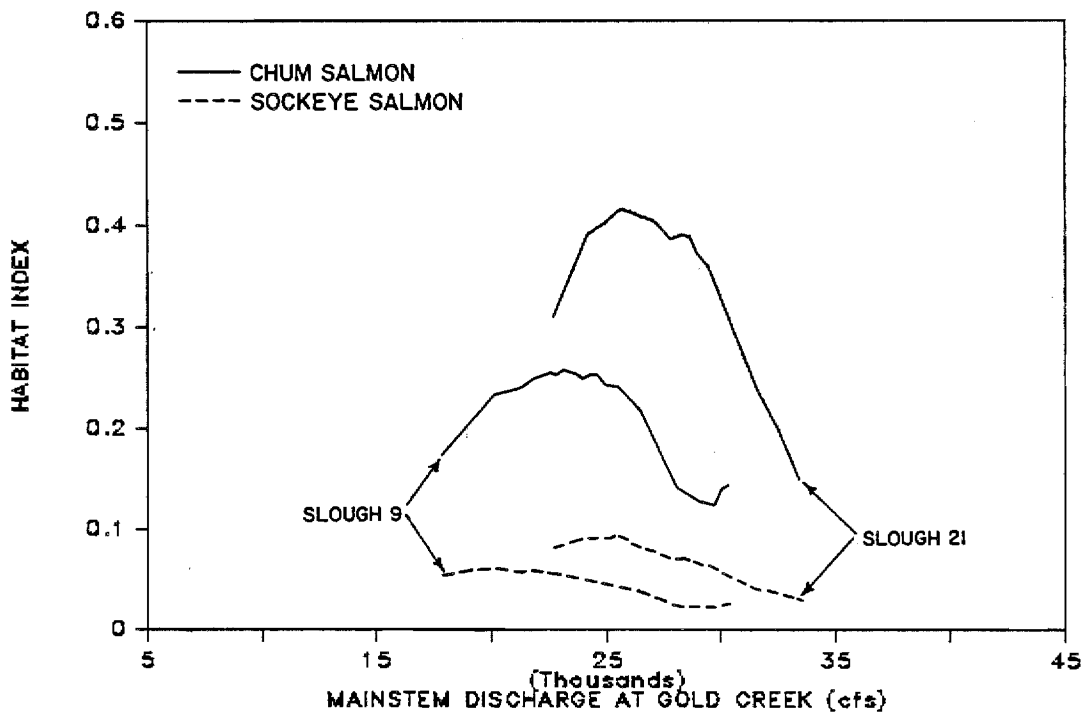


Figure 19. Habitat indices for juvenile salmon at IFG modelling sites.

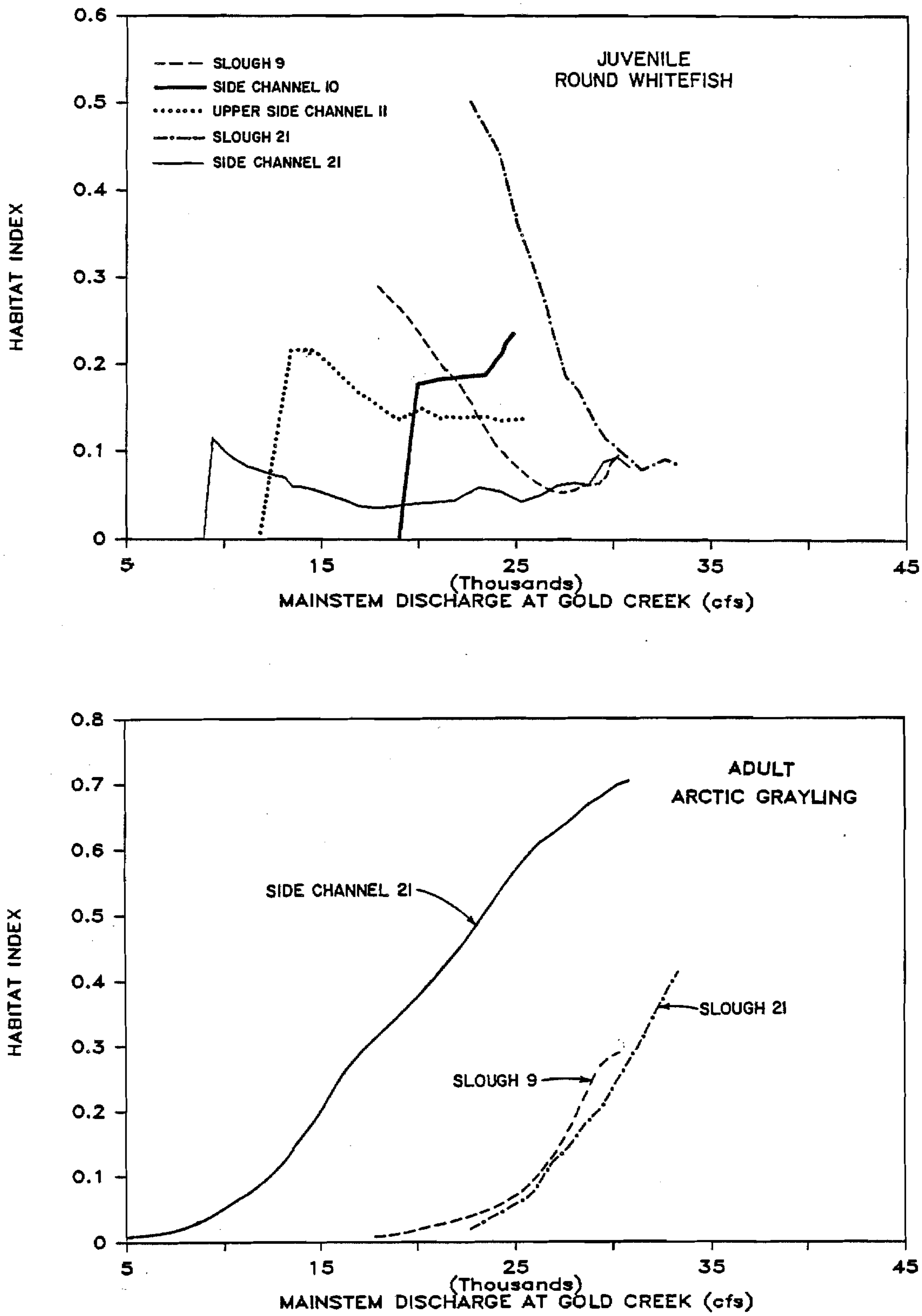


Figure 20. Habitat indices for juvenile round whitefish and adult Arctic grayling at IFG modelling sites.

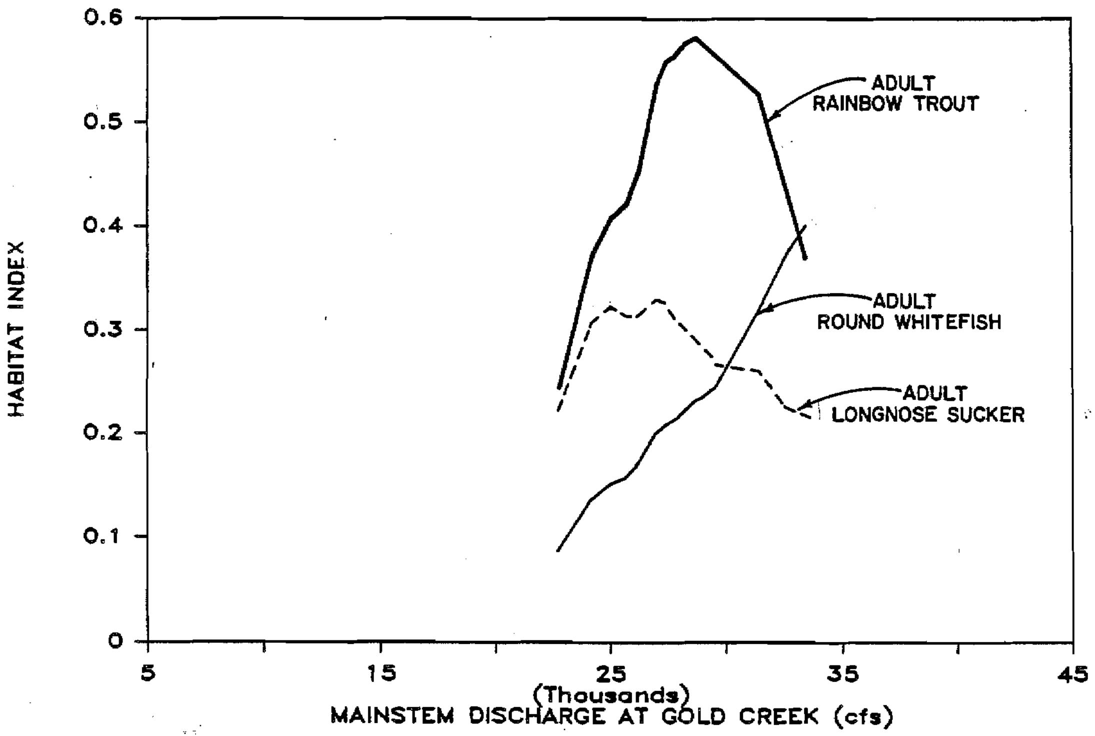


Figure 21. Habitat indices for adult rainbow trout, round whitefish, and longnose suckers at the Slough 21 modelling site.

4.0 DISCUSSION

4.1 Limitations of the Data

The assumptions of the incremental method of habitat analysis by calculating weighted usable areas have been outlined by Orth and Maughan (1982). As applied here, these assumptions are (1) cover, velocity, and depth are the most important variables affecting fish abundance when flow regime changes are considered; (2) the stream channel is not altered by changes in flow; (3) cover, velocity, and depth are independent in their influence on habitat selection by juvenile salmon; (4) the reach can be modelled by reference to a few study areas; and (5) there is a positive relationship between weighted usable area and habitat use.

The initial assumption is a difficult one to evaluate as changes in flow regime may have important effects on such factors as the food supply by affecting water quality. Turbidity is a factor which may have major direct and indirect effects on fish distribution but which was addressed only for chinook salmon indirectly by its use as cover. Analysis is also specific to the ice-free months and no analysis for effects of winter processes has been made. The importance of shoreline area cover to the suitability of offshore areas for rearing juvenile coho is similarly unknown.

Channel morphometry of the sites studies appeared to be stable during the period of study. At Slough 9, however, an IFG-4 modelling site, large amounts of silt were deposited during a flood event in September 1982 (Estes and Vincent-Lang 1984). Long term changes in channel morphometry are therefore possible.

Cover, velocity, and depth are probably not independent in their influence on habitat selection by young salmonids. Analysis of variance indicated that there is a significant interaction between depth and velocity for juvenile chinook and coho salmon catch (Part 3 of this report). Since depth was set to 1.0 over most of the range, this interaction became of little importance. Interactions between cover and velocity are also likely but should not have large effects on WUA projections.

The fourth assumption of the representativeness of the sites studied was probably not met because of several reasons. The study sites showed large variations in response to discharge which makes the concept of a representative site difficult to formulate. The two upland sloughs, in particular, showed large differences in response to changes in mainstem discharge (Part 4 of this report). The Susitna River reach under consideration is a vast mosaic of side channels, side sloughs, and upland sloughs which overtop at many different discharges. The thirteen sites modelled are representative of a large part of the habitat in this reach but do not include the mainstem or the mid-river side channels.

The correlations and proportional presence by composite weighting factor interval for the four species suggest that there is a positive relationship between the weighted usable area and habitat use at the cell level and, by inference, at the site level. Such factors as season and site are also important, however (see Part 2), and much of the variation in catches of fish is not explained by the composite weighting factors.

In summary, some of the assumptions of incremental analysis of habitat may be violated but the effects of these violations on the analysis are difficult to evaluate. The correlation and contingency table analysis, however, suggest that the simulations are related to actual fish use of the sites.

When interpreting the results of the habitat models presented in this paper, it is helpful to consider how close the discharge regime of the open water season of 1983 was to a typical year. Figure 22 shows that June, July, and September discharges were a little lower than the 30 year mean and that the August discharge was higher.

4.2 Comparison of IFG Models with RJHAB

4.2.1 Model characteristics

A comparison of the characteristics of the IFG models and RJHAB as used in this study is summarized in Table 4. The IFG models are based on an underlying theory of hydraulics which enables a simulation of physical conditions that were not actually measured. RJHAB can not simulate physical conditions because cell measurements were not taken in exactly the same physical location each time, and therefore can not be used to project velocities or depths at a study site. It does, however, model habitat which is based on physical measurements and this habitat can be interpolated between actual measurements.

The enormous capacity of the IFG models to predict detailed information on depths and velocities is perhaps overkill when the question to be answered is the availability of rearing habitat. Juvenile salmon and resident fish do not necessarily respond to increments of velocity and depth on the order of 0.1 ft/sec or 0.1 ft. Fish will select an area that has a general range of velocities or depths. Further, factors other than the variables simulated by the IFG models, such as food availability, probably override small differences in depth or velocity in influencing fish density. Restricted access into Slough 8A, for example, caused by beaver dams and lack of overtopping flows limited juvenile chinook use of the site. The IFG models are probably more useful in modelling salmon spawning habitat, where the variables which the IFG model is good at simulating (depth, velocity, substrate) are also of primary importance to the fish. The IFG models in 1983 were mainly used to model salmon spawning habitat; hence, the quality of cover data obtained was lower than would have been desirable from the standpoint of rearing habitat. RJHAB was specifically designed to consider the effect of discharge on cover.

Another benefit of RJHAB is that the field data collection effort required is considerably less than of the IFG models. This enabled us to sample a larger range of habitat types in the reach. Also, RJHAB can be used in more complex sites or sites such as upland sloughs which are primarily backwater areas.

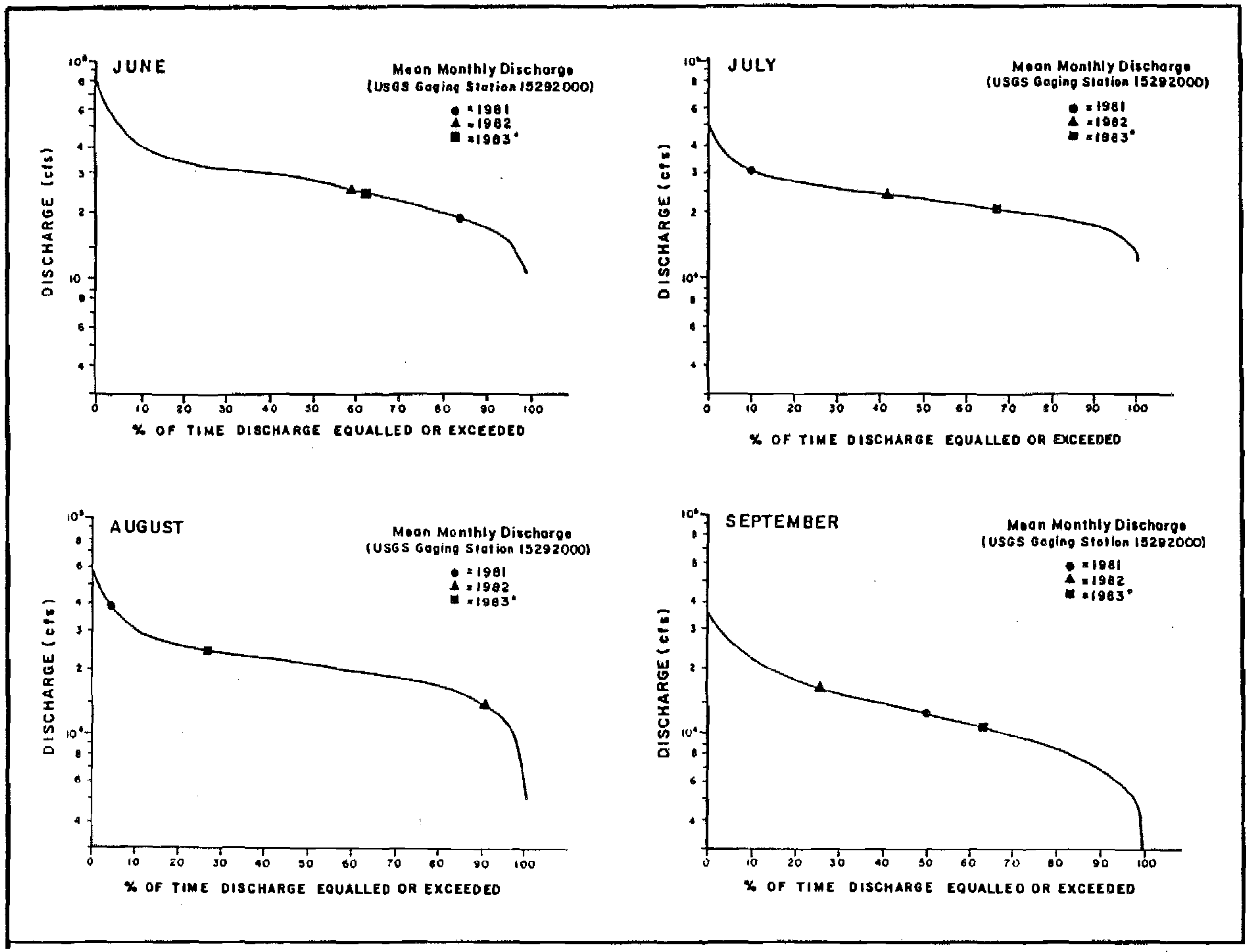


Figure 22. Time duration curves and mean monthly discharges for June, July, and August, and September based on the 30 year record of Susitna River discharge at Gold Creek. Sources: time duration curves - Bredthauer and Drage (1982); mean monthly discharges - USGS (1982), Lamke et al. (1983), and USGS provisional data.

Table 4. Comparison of model characteristics of IFG models and RJHAB.

Parameter	IFG Model	RJHAB
Transects	4 to 11	8 to 9
Measurements	point specific	300 sq ft cells
Data collection	intensive	less intensive
No. of calibration measurements	1 to 4	4 to 6
Extrapolated range	40-250% of calibration range	5,000 to 45,000 cfs
Total surface area	yes	yes
Physical simulation	yes	no
Resolution	fine	coarse
Computer	mainframe	micro
Cost	more	less
Upland sloughs	no	yes
WUA	standardized to 1,000 ft reach	depends on size of site but could be standardized to a 1,000 ft. reach

4.2.2 Model output

The output from the IFG models and RJHAB can be directly compared in at least two different ways: 1) compare percent change in weighted usable area over similar increments of mainstem discharge, and 2) compare the habitat index plots. The actual values of WUA are not comparable without modification because the IFG WUA's are standardized to a linear reach of 1,000 ft while RJHAB was calculated based on the size of the site.

Generally, the shape of the habitat index curves for chinook salmon juveniles are similar for side sloughs and side channels modelled by the IFG models and RJHAB (Figure 23). The RJHAB curves have been smoothed and extrapolated to the discharge range 5,000 to 45,000 cfs. The habitat index for chinook juveniles is the highest at a discharge level which is slightly (within a few thousand cfs) higher than that required to overtop the head of the site. This is because chinooks prefer moderate flows and moderately turbid water. As the discharge levels increase further, the velocity at the sites becomes too great and the habitat index decreases.

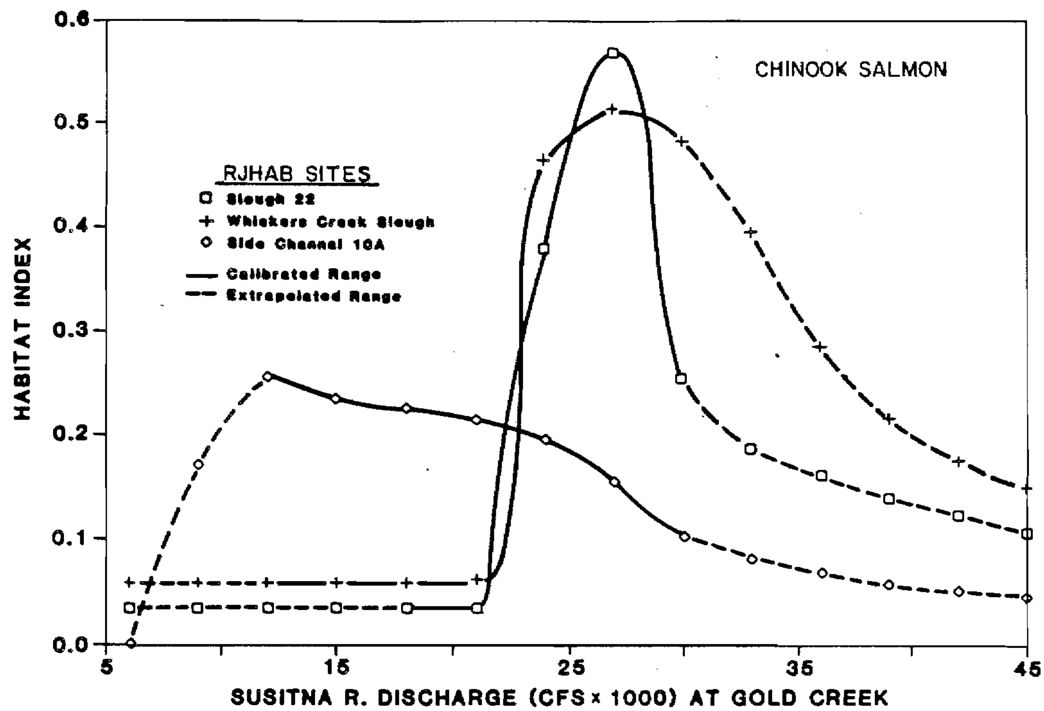
The habitat indices calculated for coho salmon from RJHAB are generally low. The same would be true from the IFG models, had we calculated them. The highest habitat indices are from the two upland slough sites, Slough 5 and Slough 6A. This is in agreement with the observed distribution of coho salmon; the density of this species in turbid waters is low (see Part 2 of this report).

Chum habitat indices were similar to those for chinook in that a discharge slightly over the overtopping point produced the maximum habitat index.

Sockeye habitat indices were generally low. The highest indices were for upland sloughs, which are the most lake-like of all the macrohabitat types. Generally, this reach of river is not prime sockeye rearing habitat (see also discussion in Part 1 and Part 2 of this report). There are not very many upland sloughs available. Neither the IFG model or RJHAB successfully predicted the heavy use of side sloughs by sockeye juveniles. This use is more a result of side sloughs being the dominant sockeye spawning grounds in this reach of river than it is a result of the quality of the rearing habitat available in side sloughs.

Sockeye habitat indices increased in side sloughs with increasing discharge as surface area increased. After the heads of the sites were overtopped by mainstem water, the habitat index started to decline sooner than did the habitat indices for chinooks and chums. This reflects the preference of sockeye juveniles for lower velocity water than the other two species.

Habitat indices for all species in upland sloughs increase steadily as mainstem discharge increases. This is mainly a function of increased surface area attributable to the backwater effect of mainstem stage at the mouth of these sites. Similar results were obtained by the 1982



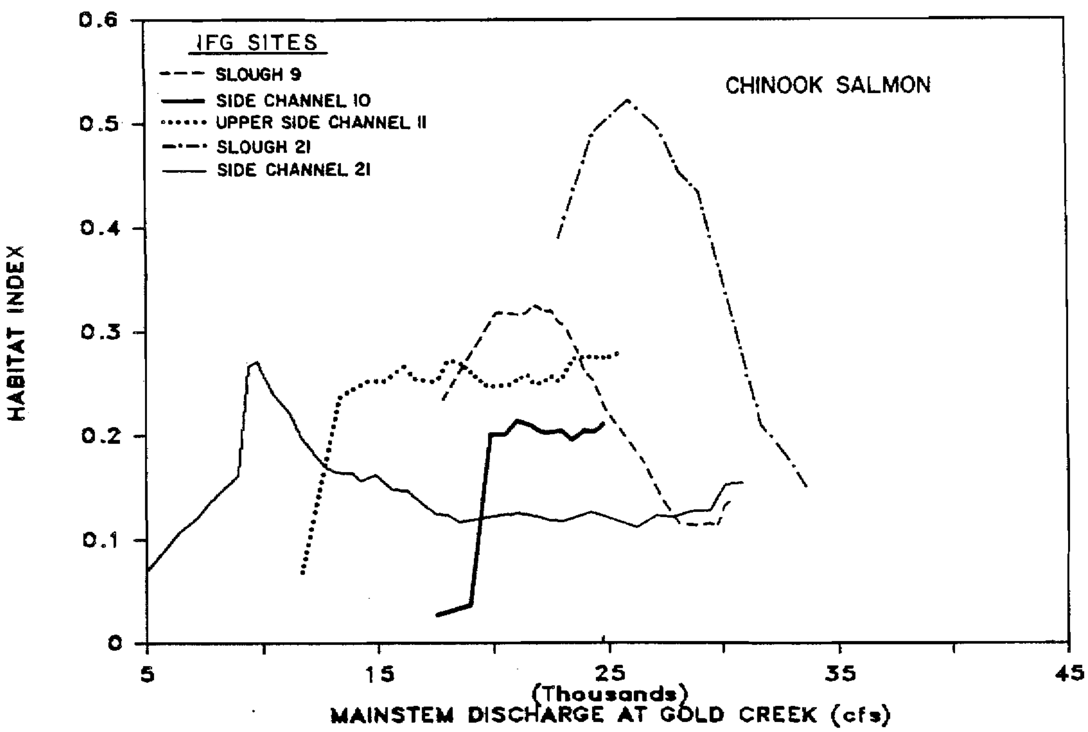


Figure 23. Comparison of RJHAB and IFG habitat indices for juvenile chinook salmon.

study that specifically examined the effect of the backwater phenomenon on rearing habitat (ADF&G 1983c). At very low mainstem discharges, cover may also be lost around the shoreline of sites such as Slough 6A where undercut banks and overhanging riparian vegetation are present.

4.3 Summary of Seasonal Habitat Projections for Rearing Salmon and Resident Fish

An examination of the figures in which chinook weighted usable area is plotted versus mainstem discharge and versus time of season shows that some sites provide the most weighted usable area when discharge is low (e.g., Lower Side Channel 11), some when discharge is at an intermediate level (e.g., Slough 9), and some when discharge is high. The controlling factor is the discharge at which the head of the site is overtopped. The maximum weighted usable area for chinook at most sites occurred at a discharge slightly greater than the overtopping discharge. Therefore, chinook weighted usable area in this reach of river would theoretically be the highest at the discharge level which just overtops the maximum number of sites (the size of each site must also be considered).

There is undoubtedly a correlation between a decline in weighted usable area at the rearing sites and re-distribution of juvenile salmon. If a rearing area is essentially saturated by fish and then weighted usable area decreases, some fish are forced to leave. We have observed this at sites such as Slough 22 where chinook juveniles were abundant when the head was overtopped and less abundant when the water cleared after mainstem water no longer entered the slough. Also, we have demonstrated a positive correlation between composite weighting factors and juvenile salmon density.

The fish that are forced out of a certain site must either seek a new rearing site or, under more extreme conditions, migrate out of that reach of river. In the latter situation, there should be an increase in the capture rate at the downstream migrant traps. It is difficult to discern such a relationship with the 1983 data. The outmigration rate of chinook juveniles was relatively low when the weighted usable area at Slough 9 was high and the outmigration rate was high when WUA at Slough 9 was lowest (disregarding the month of September, when discharge was low). However, this relationship was reversed at other sites. Ideally, only the best rearing sites should be considered in this approach. This relationship may also be obscured by major outmigrations from the tributaries which have little to do with changes in mainstem conditions.

There is also the larger question of whether in fact rearing habitat is limiting to salmon. If the number of fry emerging from the gravel is not enough to saturate the available rearing habitat, then there would be more flexibility with regard to varying discharges. In our experience on the Susitna River, both saturation and under-utilization of rearing habitat occurs. A partial explanation is that there is no substantial amount of spawning above the upper end of this reach. Therefore, when waves of juvenile chinook and coho migrate out of Portage Creek, they probably saturate a certain portion of the available rearing habitat in the Susitna River downstream of the Portage

Creek confluence until they have had sufficient time to re-distribute further downstream. During other periods of time, when few fish are migrating out of Portage Creek, these same rearing areas may not be saturated, especially if an intervening period of poor habitat (discharge too low or too high) has caused the previous occupants to leave the area. We have observed this at such sites as Slough 22 and Slough 21 on occasions when habitat conditions appeared to be relatively good (and weighted usable area was high); yet, fish density was low relative to other times of apparently equal habitat quality.

It seems almost certain that rearing habitat is limiting for sockeye juveniles in this reach of river. The deeper, low velocity, relatively clear water that they prefer does not occur in the reach in large quantities (Klinger and Trihey 1984). A high proportion of the young-of-the-year fish leave this reach (based on downstream migrant trap catch rates, see Part 2). The Age 0+ fish must either rear in the lower river or die, because only a miniscule number of adult sockeyes migrating upstream past the Talkeetna Station outmigrated to the ocean as Age 0+ fish. The majority of adults are 4_2's (Barrett et al. 1984).

It has been conclusively shown (Part 1) that chum salmon rear in this reach of river because they show substantial growth between emergence and outmigration. The correlation of chum catch per hour at the outmigrant traps and discharge was high ($r^2 = 0.79$, see Part 2), suggesting that high water events displace or trigger outmigration by chums rather than contribute to suitable habitat. If rearing habitat became restricted because of low discharge, the fish would probably leave this reach later rather than sooner because of the lack of a high water pulse that might trigger outmigration.

Although few data on winter distribution are available, there are strong indications of substantial changes in macrohabitat use during the winter. Discharge levels are much reduced and the mainstem water becomes clear. Many chinook and coho juveniles move out of tributaries to overwinter in the mainstem. There appears to be a trend in the fall that has been noticed for three consecutive years in which chinook and coho move into the deeper slough areas. There may be a thermal attraction produced by upwelling water in the sloughs.

Resident fish use of both microhabitat and macrohabitat is closely linked to turbidity and apparently to food supply. Juvenile round whitefish are found in the small side channels which have a low flow, so distribution is tied to discharges at which the heads of these side channels are slightly overtopped.

The use of side sloughs by most species of adult resident fish is probably limited by the very small amount of flow through these sites. As heads are overtopped and flows increase, the sites rapidly become more favorable for adult resident fish. These fish also use portions of the mainstem for rearing. The rearing habitat may be limiting but this is not likely due to lack of suitable open water season cover, depths, or velocities. It is more likely to be attributable to other factors such as overwintering mortality or food supply, as densities of residents are low almost everywhere in mainstem-influenced sites with the exception of selected tributary or slough mouths where fish may gather to feed on salmon eggs, outmigrating juvenile salmon, or invertebrates.

In conclusion, the results presented in this part and the data and analysis from parts one through six of this report suggest the following trends:

(1) Of the salmon juveniles rearing in the Susitna River, chinook and chum appear to make the best use of habitats associated with the mainstem and also have the most abundant adult returns (even year pink salmon excluded) in this reach of the river. Juvenile coho salmon apparently rear primarily in tributaries, but will take advantage of the upland slough habitat that is available.

(2) Sockeye salmon appear to be most heavily limited by rearing habitat with highly successful incubation, but limited rearing, occurring in this reach of river. Either rearing survival is low or rearing takes place in the lower river. Successful rearing does occur within limited portions of some of the upland and clear water sloughs but is probably minor when compared to the total population of emergent fry. Apparently, sockeye rearing does not occur in tributaries to any great extent.

(3) Of the habitats affected by mainstem discharge, microhabitat within side channels/side sloughs is most affected, primarily by dewatering, lowered turbidity, and lower water velocity after the head is no longer overtopped by mainstem flows. This habitat is heavily used by chinook juveniles, who appear to be limited by cover when the sites are not turbid (generally associated with the heads not being overtopped). Maximum habitat value for chinook salmon is obtained at a discharge level slightly greater than the overtopping discharge level.

(4) Wintering habitat for all rearing species is heavily dependent on mainstem habitats as indicated by spring and fall migratory movements. The models presented have not been designed to evaluate habitat conditions during the winter.

(5) Resident species using mainstem habitat areas are most predictively associated with levels of turbidity and appear limited by food supply. They often associate with the mouths of clear water tributaries or with spawning salmon. The response of primary productivity of the system may be more indicative of the response of resident species than the values generated by habitat simulation based on hydraulic models.

The results and discussion presented in this report do not conclude the analytical effort required to use this information in a decision making process. It remains to integrate these results with the studies conducted on adult anadromous spawning and to further extrapolate our study sites to the entire reach of river which they were chosen to represent using the surface area information provided by Klinger and Trihey (1984). Further, these results must be weighted with respect to the importance of the harvestable adults of each species. Finally, these results must be portrayed in such a manner as to depict the effects of alternative flow regimes on different species so that the flow requirements of different management goals can be ascertained. Future reports prepared by other investigators will use this report to ultimately provide the above information.

5.0 CONTRIBUTORS

IFG hydraulic model data collection was done by the Aquatic Habitat Group of the Su Hydro Aquatic Studies. Kim Sylvester of the AH group and Diane Hilliard of E. Woody Trihey and Associates calibrated the hydraulic models. Diane Hilliard input cover data, the suitability criteria, and ran the PHABSIM habitat models which generated weighted usable areas. Bob Marshall made some helpful suggestions.

Drafting was done by Sally Donovan and Carol Riedner. The typing was done by Skeers Word Processing Services.

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