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

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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.

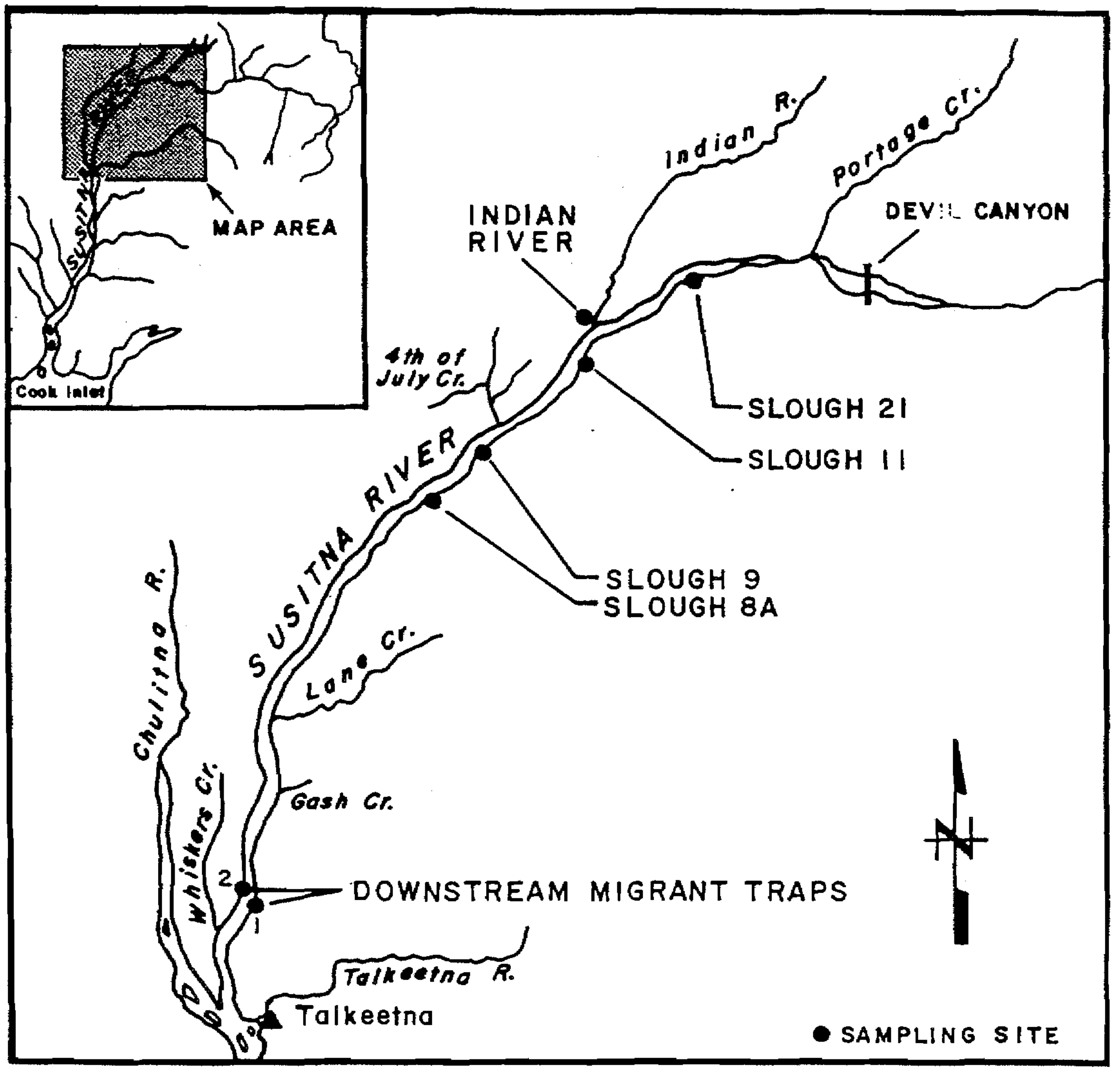

Figure 1. Map of the Susitna River from Talkeetna upstream to Devil Canyon showing the coded wire tag deployment and recovery sites.

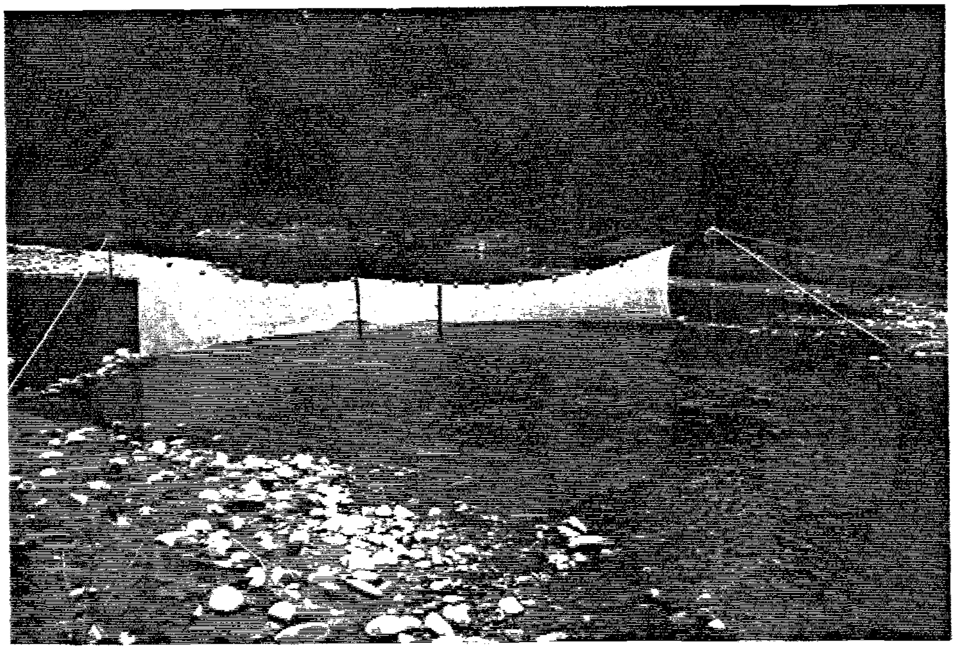

Plate 1. A weir set near the mouth of Slough 8A (RM 125.3) to collect outmigrating chum and sockeye salmon fry for coded wire tagging, 1983.

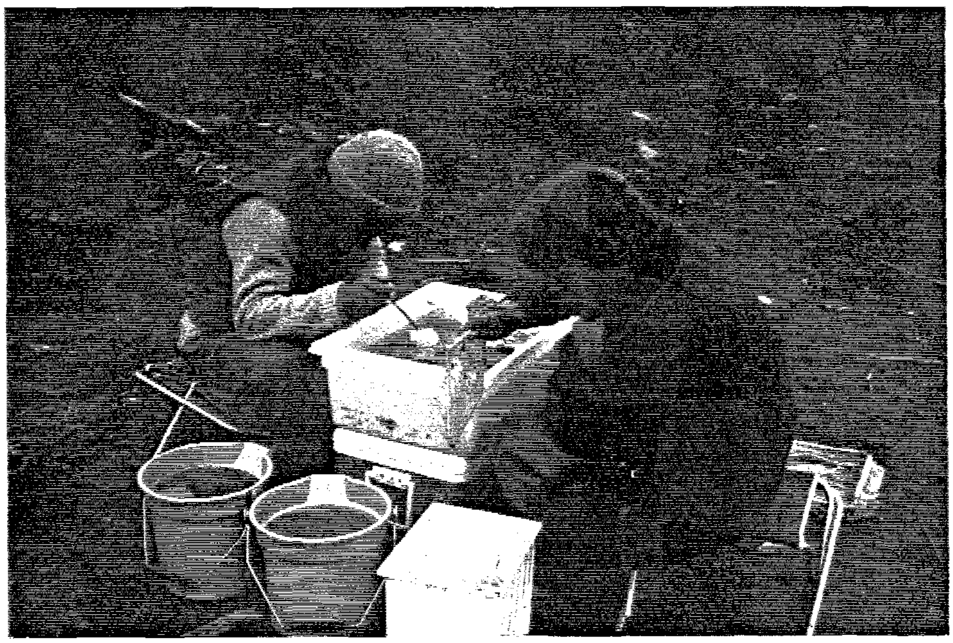

Plate 2. Separation of salmon fry by species and length prior to the implantation of coded wire tags, 1983.

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.

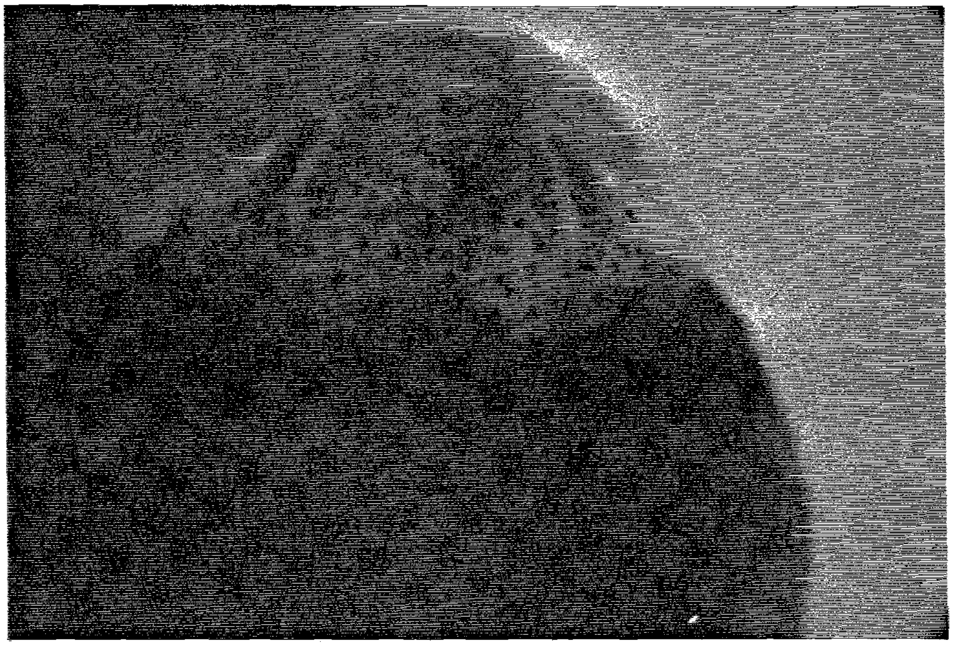

Plate 4. A dorsal view of a one-half length coded wire tag (arrow) in the snout of a sockeye salmon fry recovered in the downstream migrant traps, 1983.

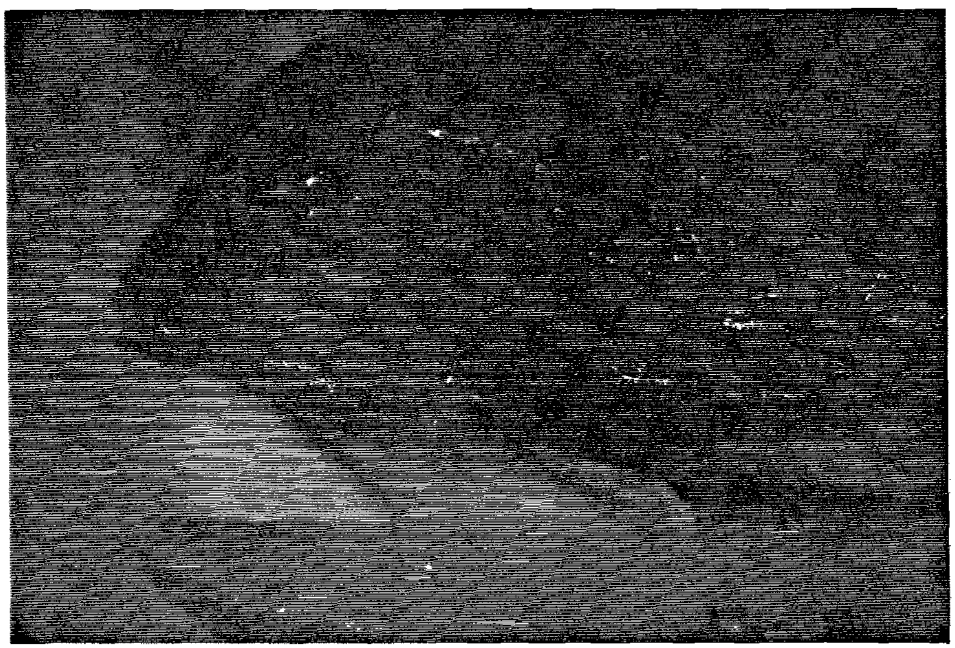

Plate 5. A side view of a one-half length coded wire tag (arrow) in the dissected snout of a sockeye salmon fry recovered in the downstream migrant traps, 1983.

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		Sockeye		Coho	
	Age 0+	Age 1+	Age 0+	Age 1+	Age 0+	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.

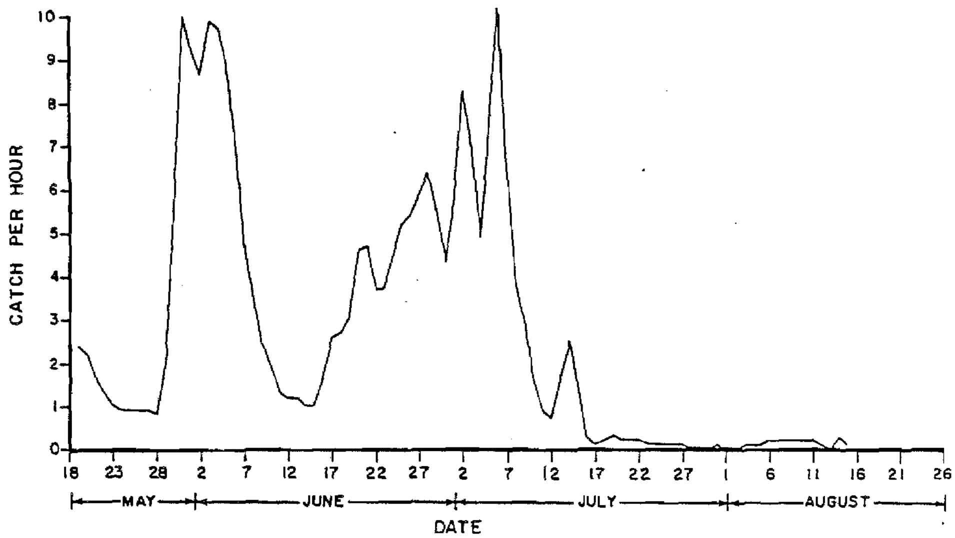

Figure 2. Chum salmon fry daily catch per hour recorded at the downstream migrant traps, May 18 through August 20, 1983, smoothed by $Z_{(t)}=\frac{1}{4}Y_{(t-1)}+\frac{1}{2}Y_{(t)}+\frac{1}{4}Y_{(t+1)}$.

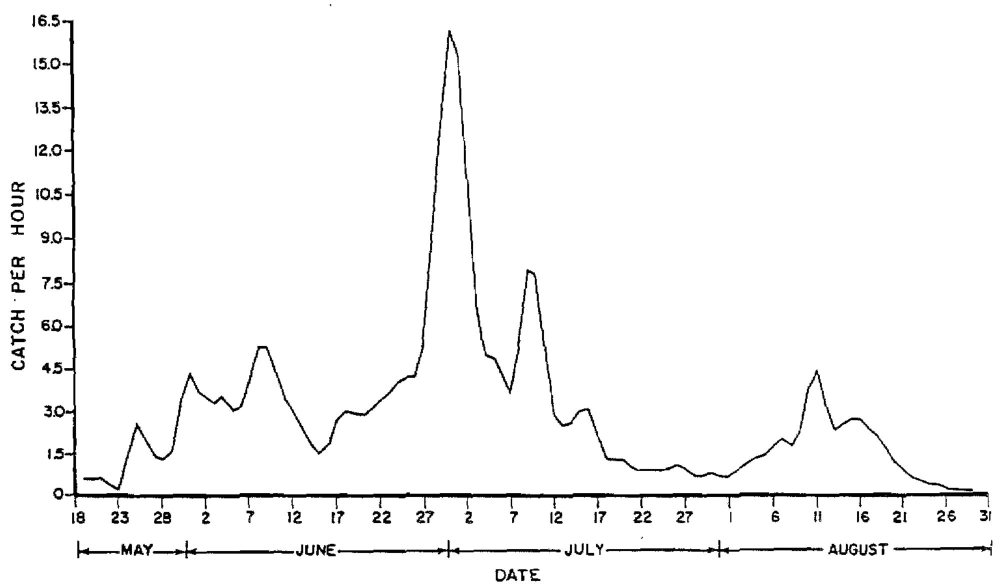

Figure 3. Sockeye salmon fry daily catch per hour recorded at the downstream migrant traps, May 18 through August 30, 1983, smoothed by $Z_{(t)}=\frac{1}{4}Y_{(t-1)}+\frac{1}{2}Y_{(t)}+\frac{1}{4}Y_{(t+1)}$.

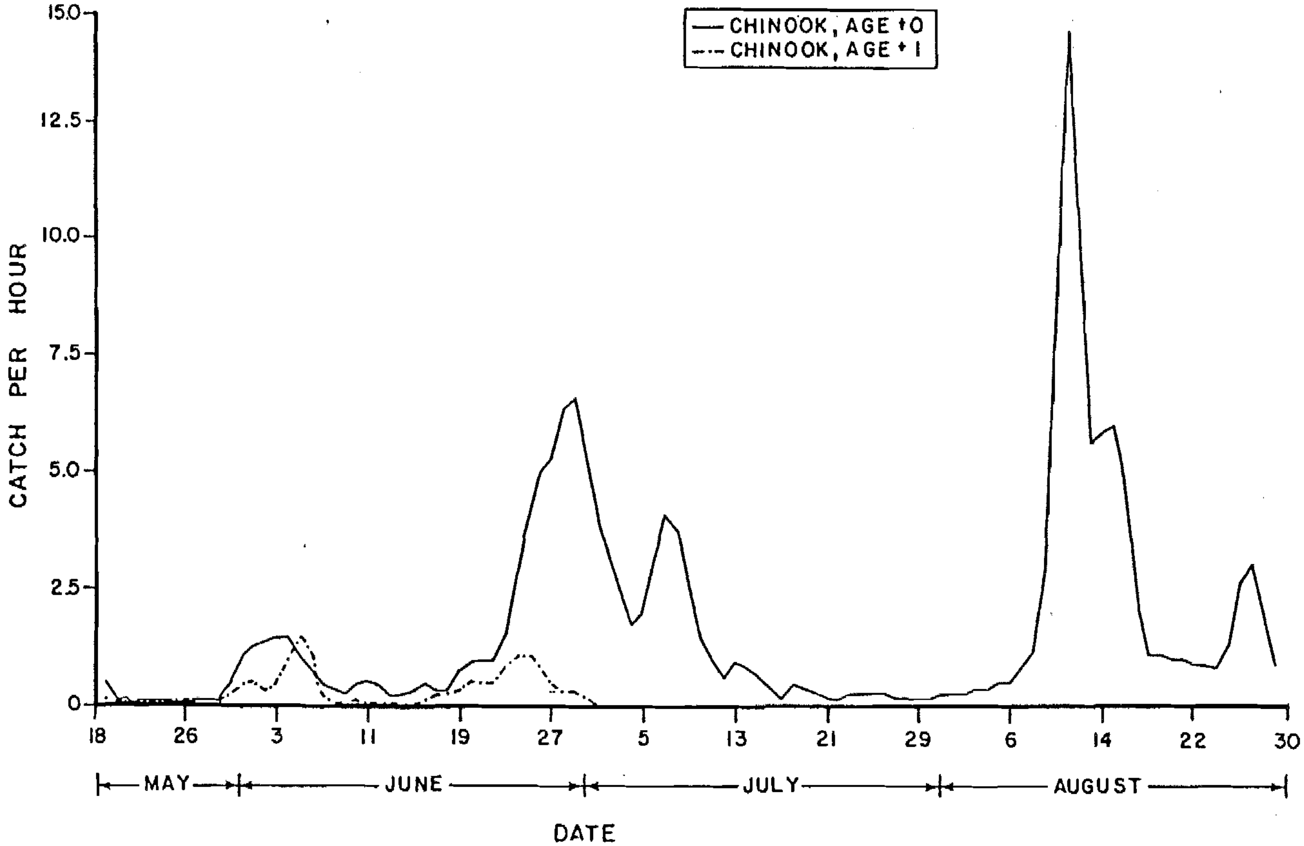

Figure 4. Chinook salmon age 0^+ and age 1^+ daily catch per hour recorded at the downstream migrant traps, May 18 through August 30, 1983, smoothed by $Z_{(t)}=\frac{1}{4}Y_{(t-1)}+\frac{1}{2}Y_{(t)}+\frac{1}{4}Y_{(t+1)}$.

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.

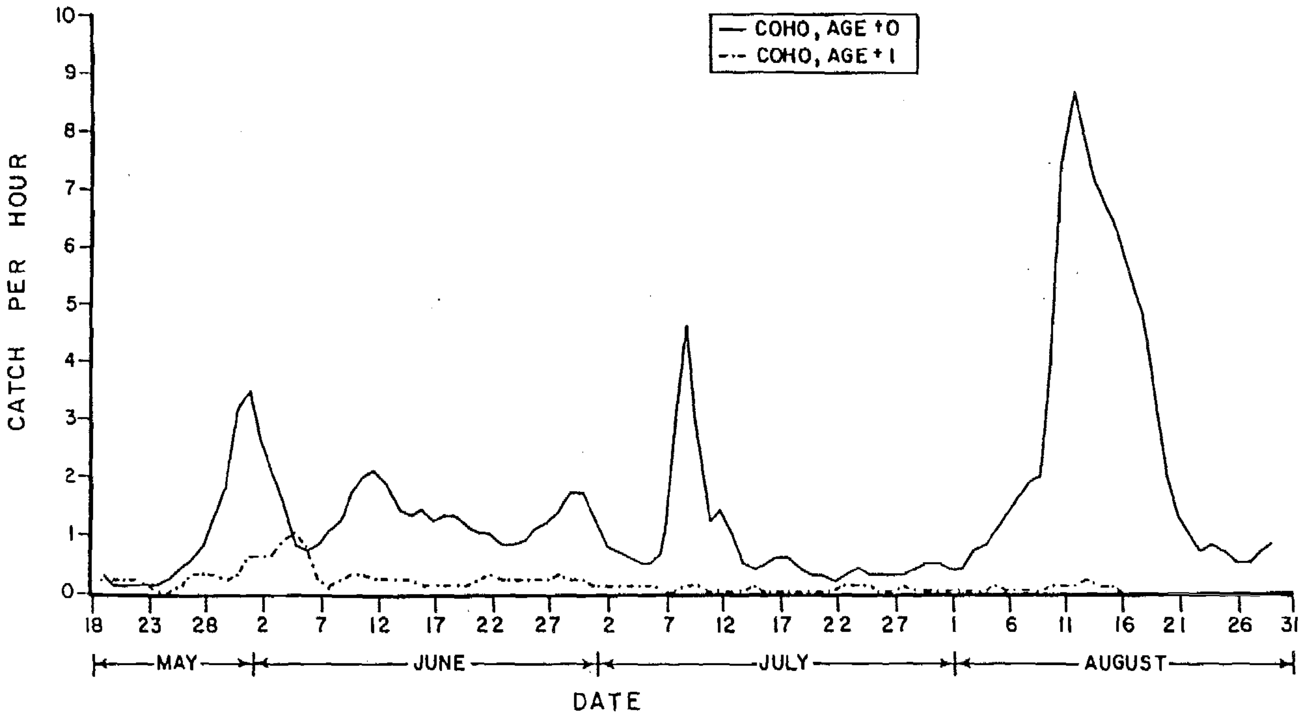

Figure 5. Coho salmon age 0^+ and age 1^+ or older daily catch per hour recorded at the downstream migrant traps, May 18 through August 30, 1983, smoothed by $Z_{(t)}=\frac{1}{4}Y_{(t-1)}+\frac{1}{2}Y_{(t)}+\frac{1}{4}Y_{(t+1)}$.

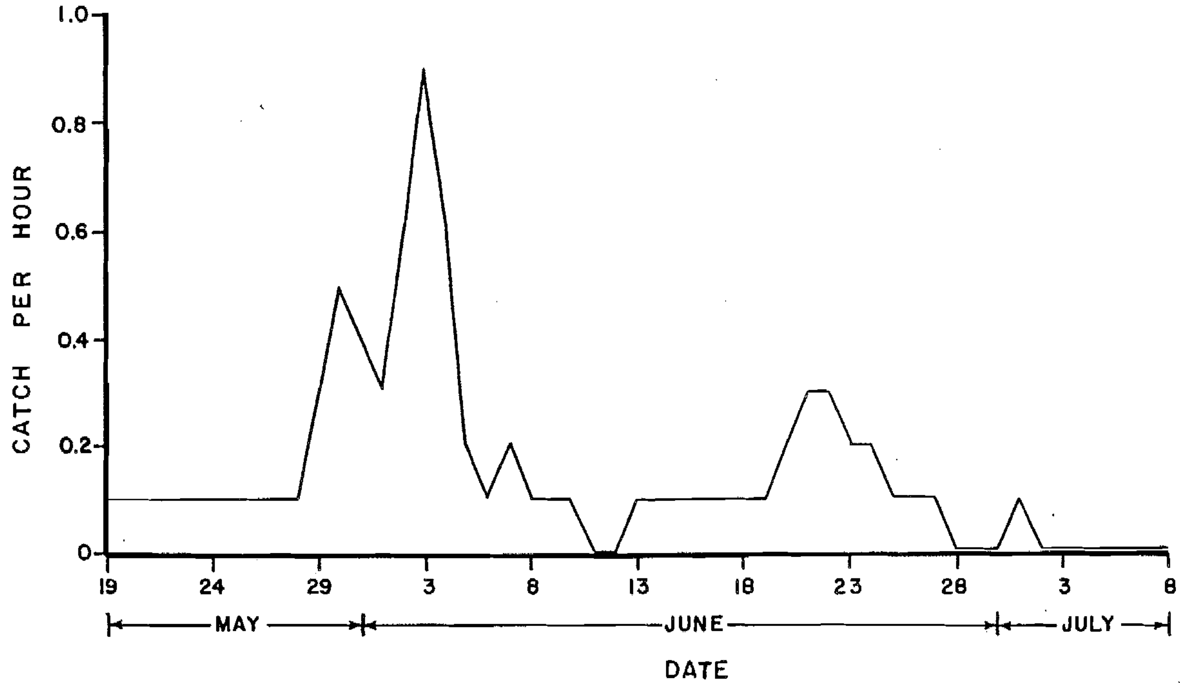

Figure 6. Pink salmon fry daily catch per hour recorded at the downstream migrant traps, May 18 through July 8, 1983, smoothed by $Z_{(t)}=\frac{1}{4}Y_{(t-1)}+\frac{1}{2}Y_{(t)}+\frac{1}{4}Y_{(t+1)}$.

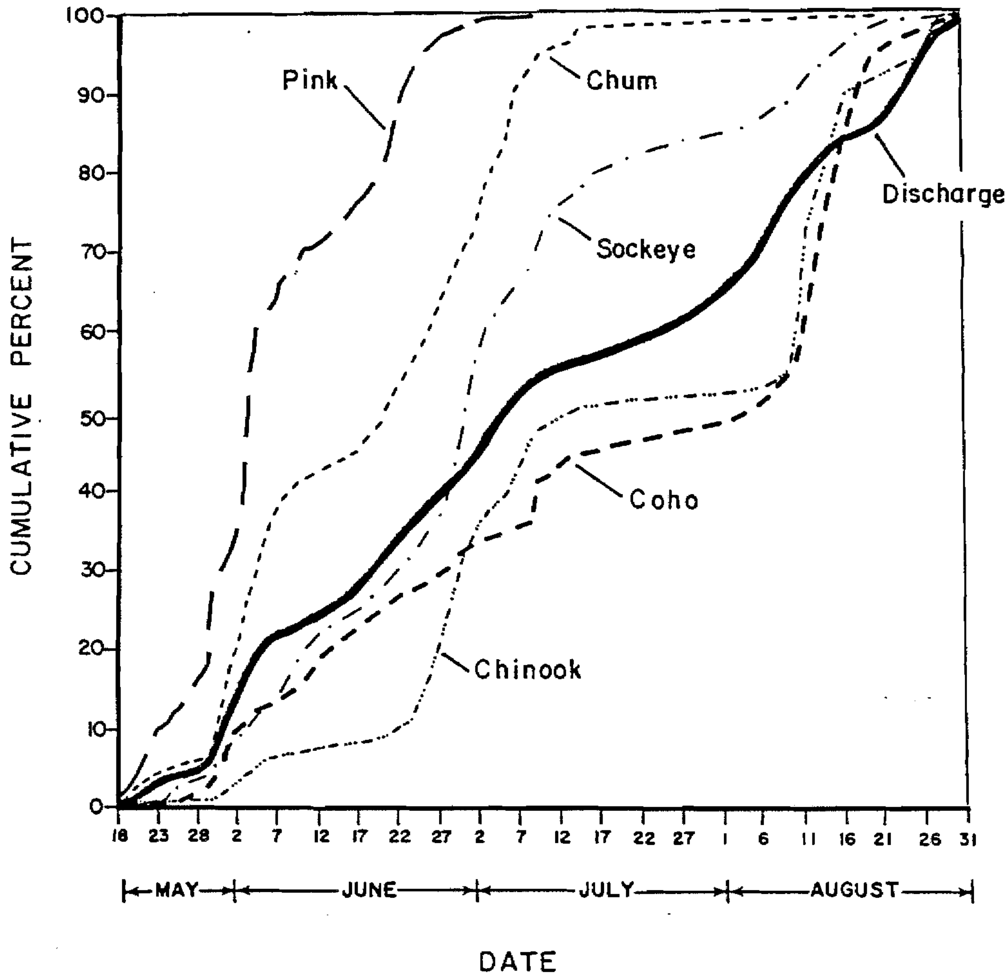

Figure 7. Cumulative catch for age 0+ chinook, coho, sockeye, chum and pink salmon recorded at the downstream migrant traps, May 18 through August 30, 1983, adjusted to 24 hour periods.

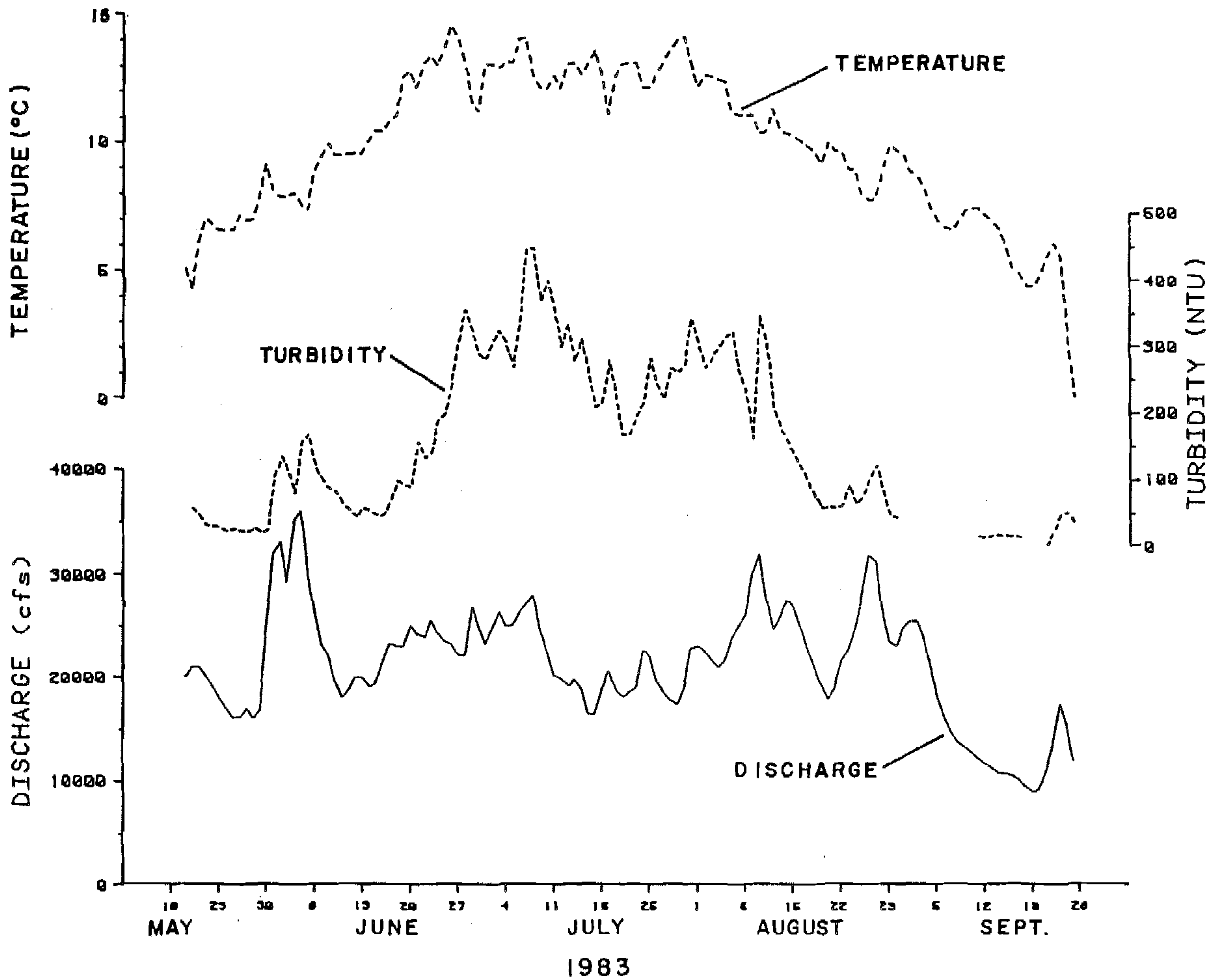

Figure 8. Mainstem discharge, water temperature, and turbidi [illegible]

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
$\text{Discharge}_{(t-1)}$/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.

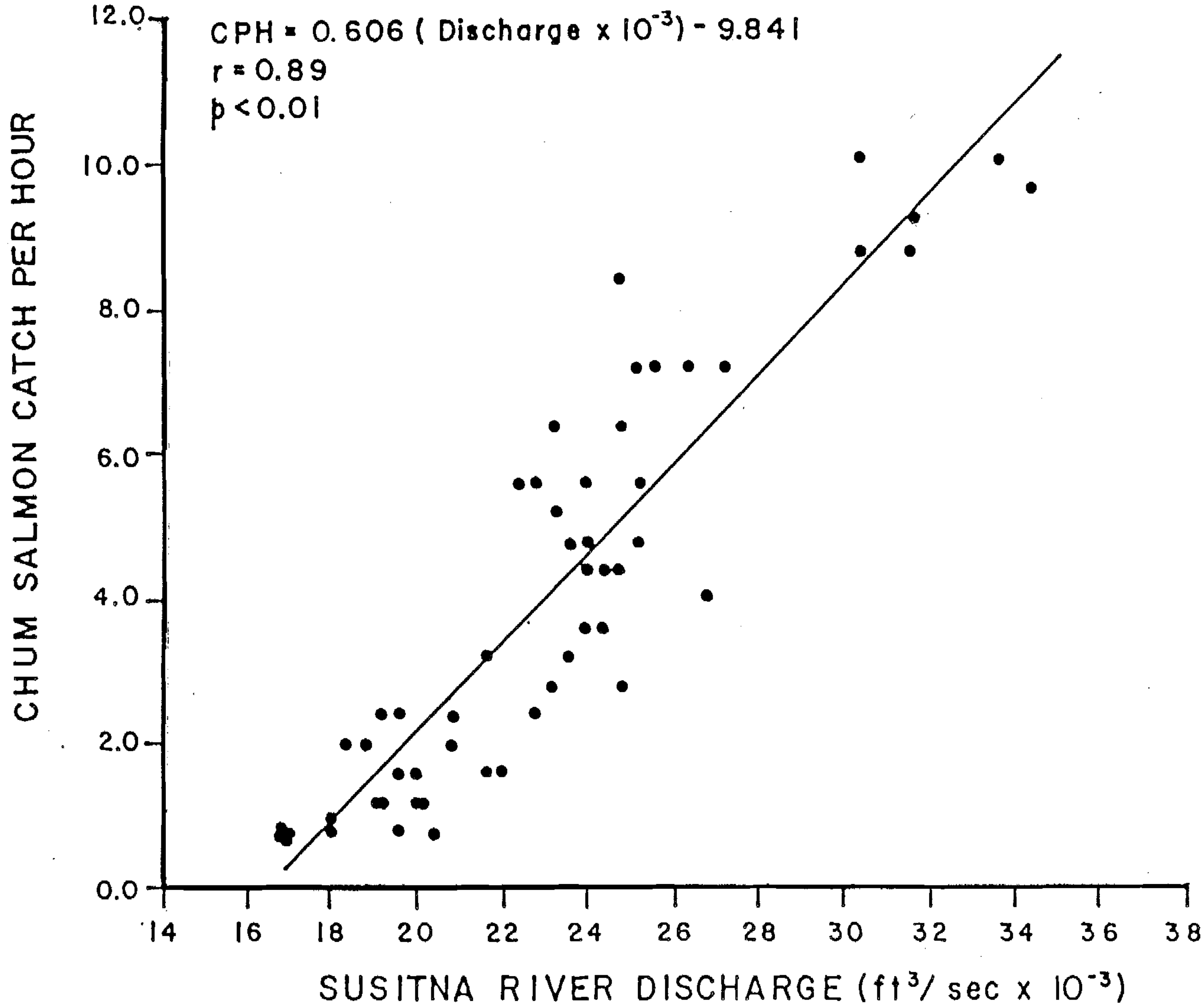

Figure 9. Relationship of mean daily discharge with mean daily chum salmon fry catch per hour at the downstream migrant traps, May 18 through July 15, 1983.

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:

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

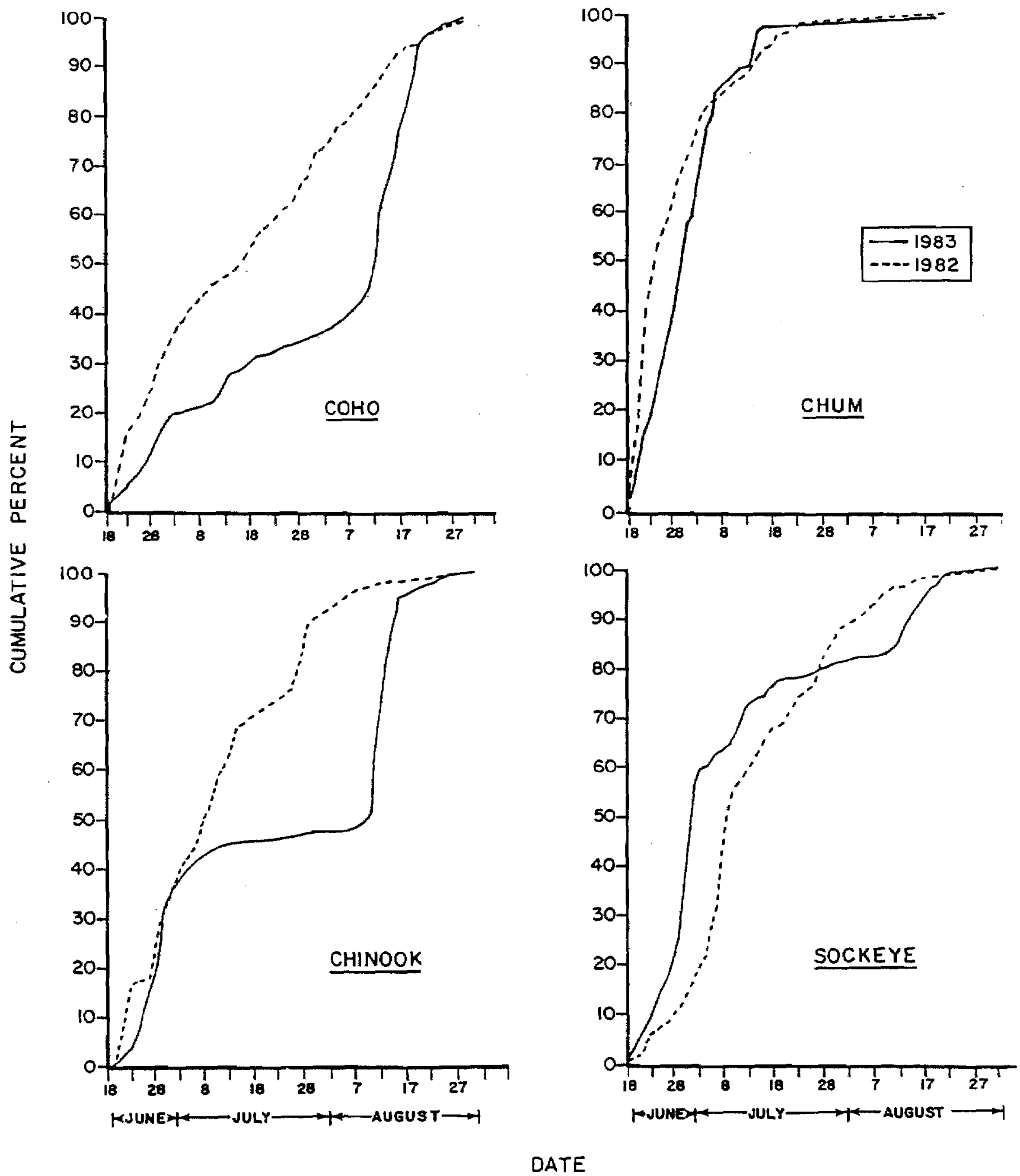

Figure 10. East bank outmigrant trap (Talkeetna Station, RM 103.0) cumulative catch recorded for juvenile coho, chinook, chum, sockeye salmon during 1982 and 1983, adjusted to 24 hour per for the calendar period from June 18 through August 30.

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.

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PART 1
The Outmigration of Juvenile Salmon from the Susitna River Above the Chulitna River Confluence

ALASKA DEPARTMENT OF FISH AND GAME
SUSITNA HYDRO AQUATIC STUDIES

REPORT NO. 2

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

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