APPENDIX H

Habitat Relationships of Juvenile Salmon Outmigration

APPENDIX H

TABLE OF CONTENTS

APPENDIX H

LIST OF APPENDIX FIGURES

## APPENDIX H

LIST OF APPENDIX TABLES

## INTRODUCTION

This appendix presents an analysis of the relationships between the outmigration timing of juvenile salmon and environmental variables for the Susitna River between the Chulitna River confluence and Devil Canyon. The purpose is to evaluate how environmental factors influence the outmigration of juvenile salmon. The proposed hydroelectric project will change the timing and magnitude of several environmental parameters. If the effect of these changes on the outmigration of juvenile salmon can be predicted, subsequent effects on the production of juvenile salmon by this reach of river can be better analyzed.

## METHODS

Parameters examined included mainstem discharge, water temperature, turbidity and photoperiod. Time of season, which integrates and sums other parameters such as photoperiod, water temperature and fish size, was also examined. The variation in size (mean length) of the juvenile salmon species was also examined as a factor influencing outmigration. The catch data for this appendix came from an outmigrant trap located at Susitna river mile 103.0, 4.5 miles above the Chulitna River confluence. The trap was operated from June 18 to October 12, 1982. Details of the methods used to operate the trap and the results are outlined in the Basic Data Report (ADF&G 1983a). Capture rates of juveniles of four species of salmon (chinook, coho, sockeye, and chum) were analyzed.

Juvenile pink salmon were not captured in large enough numbers to draw any conclusions about this species.

Discharge levels are the provisional data taken by the U.S. Geological Survey at the Gold Creek station. To obtain water temperatures representative of the area from which the juvenile salmon were migrating, most of the mainstem water temperature data were obtained from a continuous temperature recorder located at Curry (river mile 120.7), 17.7 miles above the outmigrant trap location (ADF&G 1983b). Since this recorder was not operated for the entire season, data were taken from recorders located at river miles 130.0 and 113.0 for the periods from June 24 to July 6 and from October 1 to 12, respectively. Data for June 18 to 24 were extracted from temperatures recorded by fish distribution crews at sites upstream of the trap. Turbidity readings were taken at the trap location (ADF&G, 1983a) only from August 14 to the end of the season. Day length information was obtained from the National Weather Service. Time of season was computed as the number of days from the first day (June 18) the outmigrant trap began fishing.

Mean length for each species (age 0+ only) was calculated by summing the daily catches of fish until a sample size of at least 25 fish was obtained, and then taking the mean length of these fish. In some cases, it took only one day to get a sample size of at least 25, and in other cases, it took several days. The number of fish caught in this period was divided by the number of hours that the trap was fished to obtain an overall catch/hour. The median date during the period was used as the time marker.

Outmigration timing was examined using catch/hour data taken on a daily basis for each of the four species of juvenile salmon. Age classes were not separated. The relationship of these data to the habitat variables was examined through the use of linear regression using one or multiple independent (habitat) variables and correlation analysis (Snedecor and Cochran 1967). Because the catch/hour data were quite variable from day to day, various data manipulations, including moving averages, exponential smoothing, time lags, and logarithmic transformations, were performed. We also used first-difference regressions, in which change (on a daily basis in our case) in a dependent variable is regressed against the daily change in an independent variable (Summers et al. 1981). This has the advantage that any existing cause/effect relationships can be detected without problems caused by differences in relative magnitude.

## RESULTS

### Habitat Variables

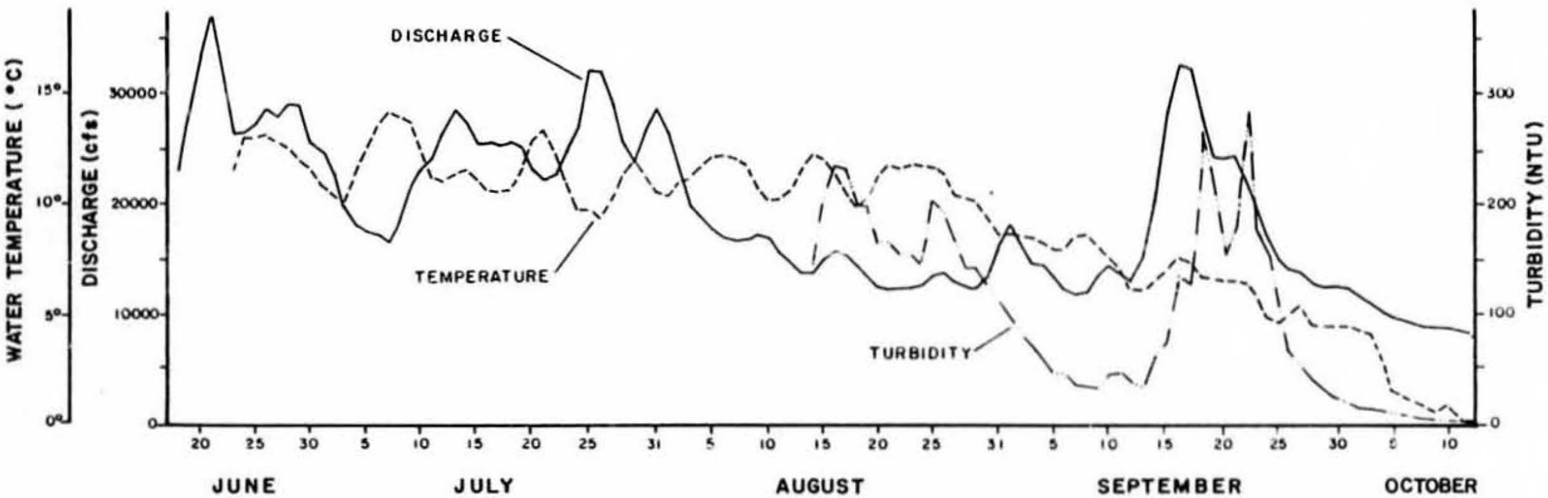
The mean and range for the physicochemical variables are summarized in Appendix Table H-1. The pattern of water temperature was exactly opposite that of the discharge pattern during the middle part of the season, but during the early and late part of the season, water temperature more closely paralleled discharge (Appendix Figure H-1). Turbidity fluctuations lagged discharge by two or three days. Day length (Appendix Table H-2) remained at 24 hours/day from the beginning of the

Appendix Table H-1. Range and mean for habitat variables and juvenile salmon catch/hour, outmigrant trap, June 18 - October 12, 1982.

| | min | max | mean | n |
|---|---|---|---|---|
| Discharge ($ft^3$/sec) | 7,950 | 37,000 | 19,225 | 104 |
| Water temperature (°C) | 0.5 | 14.1 | 9.2 | 104 |
| Turbidity (NTU)[a] | 8 | 284 | 103 | 51 |
| Daylength (hrs) | 11.8 | 24.0 | 18.4 | 104 |
| Catch/hour | | | | |
| chinook | 0.0 | 1.2 | 0.2 | 104 |
| coho | 0.0 | 19.5 | 0.7 | 104 |
| sockeye | 0.0 | 16.2 | 1.2 | 104 |
| chum[b] | 0.0 | 10.0 | 0.6 | 55 |

[a] Aug 14 - Oct 12 only

[b] Jun 18 - Aug 15 only




Appendix Figure H-1. Variation of Susitna River mainstem environmental variables above the Chulitna River confluence from June 18 to October 12, 1982. See text for exact source of data.

Appendix Table H-2. Civil twilight at Talkeetna, Alaska
(Source: National Weather Service)

| Date | Daylength (hours) | Date | Daylength (hours) | Date | Daylength (hours) |
|---|---|---|---|---|---|
| June 18 | 24.0 | August 01 | 19.8 | September 14 | 14.6 |
| June 19 | 24.0 | August 02 | 19.7 | September 15 | 14.5 |
| June 20 | 24.0 | August 03 | 19.5 | September 16 | 14.4 |
| June 21 | 24.0 | August 04 | 19.4 | September 17 | 14.3 |
| June 22 | 24.0 | August 05 | 19.3 | September 18 | 14.2 |
| June 23 | 24.0 | August 06 | 19.1 | September 19 | 14.1 |
| June 24 | 24.0 | August 07 | 19.0 | September 20 | 14.0 |
| June 25 | 24.0 | August 08 | 18.9 | September 21 | 13.9 |
| June 26 | 24.0 | August 09 | 18.7 | September 22 | 13.8 |
| June 27 | 24.0 | August 10 | 18.6 | September 23 | 13.7 |
| June 28 | 24.0 | August 11 | 18.5 | September 24 | 13.6 |
| June 29 | 24.0 | August 12 | 18.4 | September 25 | 13.5 |
| June 30 | 24.0 | August 13 | 18.2 | September 26 | 13.4 |
| July 01 | 24.0 | August 14 | 18.1 | September 27 | 13.3 |
| July 02 | 24.0 | August 15 | 18.0 | September 28 | 13.2 |
| July 03 | 24.0 | August 16 | 17.9 | September 29 | 13.1 |
| July 04 | 24.0 | August 17 | 17.7 | September 30 | 13.0 |
| July 05 | 24.0 | August 18 | 17.6 | October 01 | 12.9 |
| July 06 | 24.0 | August 19 | 17.5 | October 02 | 12.8 |
| July 07 | 24.0 | August 20 | 17.4 | October 03 | 12.7 |
| July 08 | 24.0 | August 21 | 17.3 | October 04 | 12.6 |
| July 09 | 24.0 | August 22 | 17.2 | October 05 | 12.5 |
| July 10 | 24.0 | August 23 | 17.0 | October 06 | 12.4 |
| July 11 | 24.0 | August 24 | 16.9 | October 07 | 12.3 |
| July 12 | 24.0 | August 25 | 16.8 | October 08 | 12.2 |
| July 13 | 24.0 | August 26 | 16.7 | October 09 | 12.1 |
| July 14 | 23.7 | August 27 | 16.6 | October 10 | 12.0 |
| July 15 | 23.0 | August 28 | 16.5 | October 11 | 11.9 |
| July 16 | 22.7 | August 29 | 16.3 | October 12 | 11.8 |
| July 17 | 22.4 | August 30 | 16.2 | | |
| July 18 | 22.2 | August 31 | 16.1 | | |
| July 19 | 22.0 | September 01 | 16.0 | | |
| July 20 | 21.8 | September 02 | 15.9 | | |
| July 21 | 21.6 | September 03 | 15.8 | | |
| July 22 | 21.4 | September 04 | 15.7 | | |
| July 23 | 21.2 | September 05 | 15.6 | | |
| July 24 | 21.0 | September 06 | 15.5 | | |
| July 25 | 20.9 | September 07 | 15.4 | | |
| July 26 | 20.7 | September 08 | 15.3 | | |
| July 27 | 20.6 | September 09 | 15.2 | | |
| July 28 | 20.4 | September 10 | 15.0 | | |
| July 29 | 20.3 | September 11 | 14.9 | | |
| July 30 | 20.1 | September 12 | 14.8 | | |
| July 31 | 20.0 | September 13 | 14.7 | | |

sampling season until mid-July, after which it steadily declined, usually by no more than 0.2 hours/day, to 11.8 hours/day on October 12.

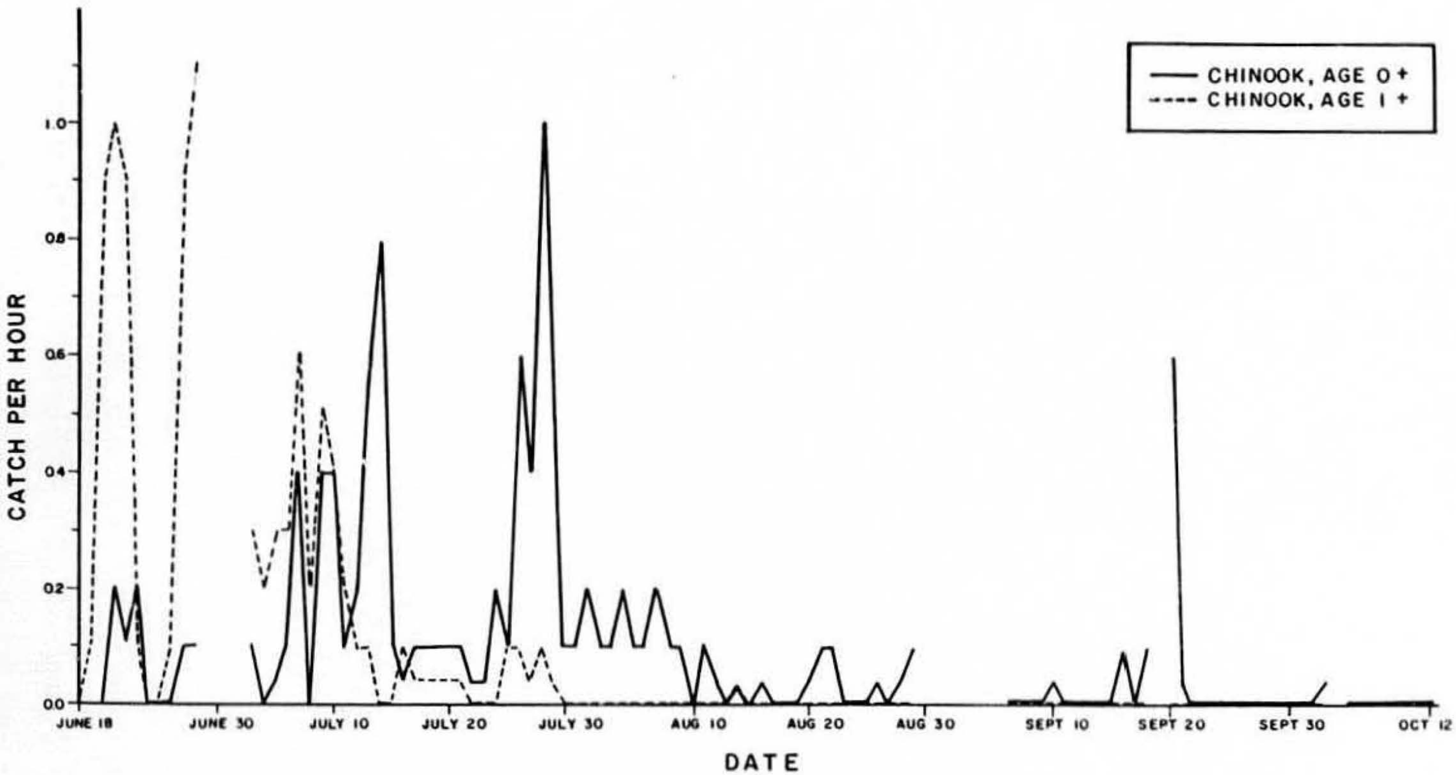
Except for a peak in mid-September, discharge generally declined over the course of the season. The correlation coefficient (r) between discharge and time of season was -0.65, $p < 0.01$. Temperature also generally decreased with time of season ($r = -0.83$, $p < 0.01$). The correlation between discharge and water temperature was highly significant ($p < 0.01$) but relatively low ($r = 0.42$). This correlation was not improved by lagging water temperature one day behind discharge.

Juvenile Salmon Catch - All Species

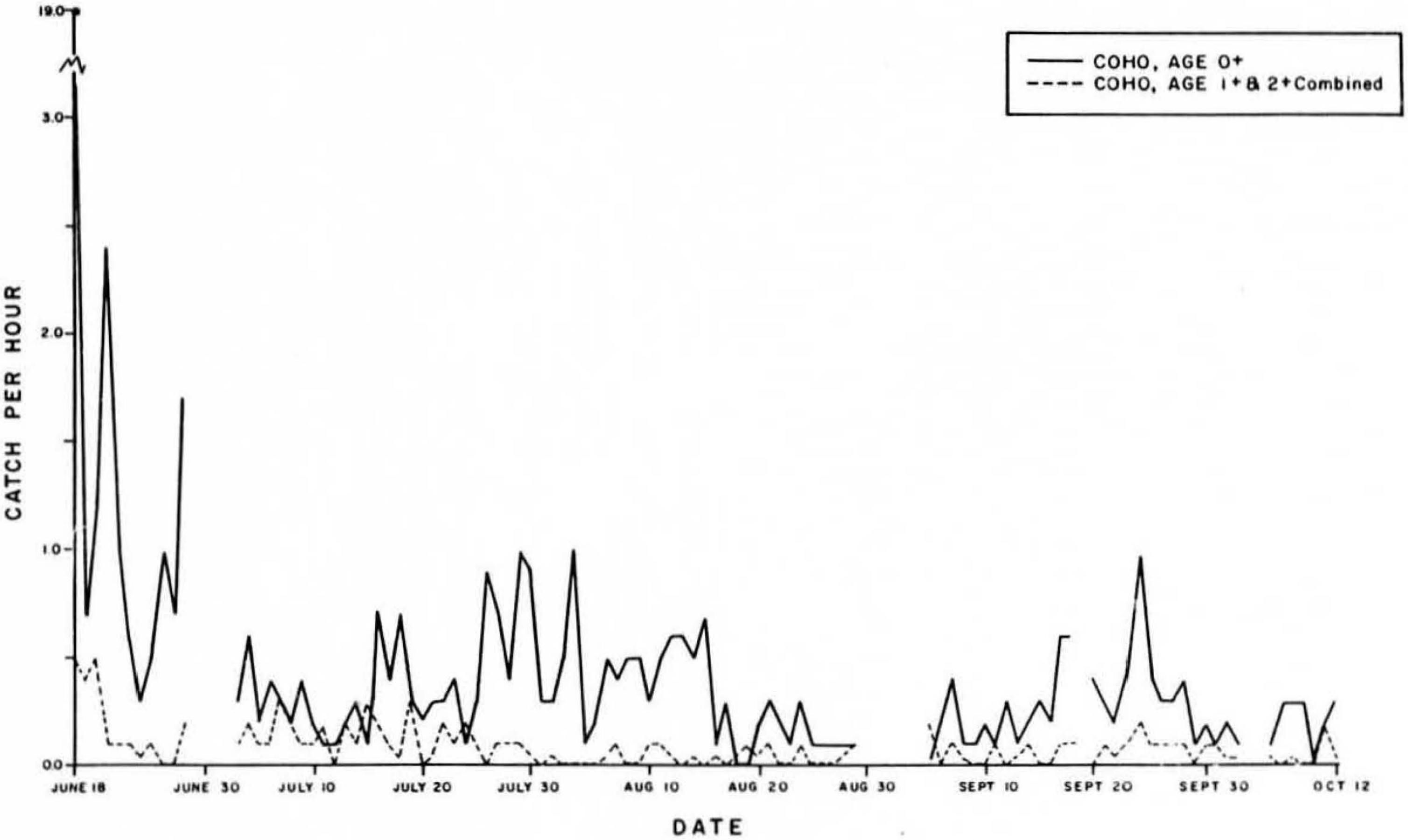
The catch/hour for the four species of juvenile salmon was initially relatively high and then declined over the course of the season (Appendix Figures H-2, H-3, and H-4). Appendix Table H-1 gives the range and mean catch/hour observed for each species.

Generally, a highly significant ($p < 0.01$) relationship was found between catch/hour for each individual species and the physical variables, but correlation coefficients were usually not very high.

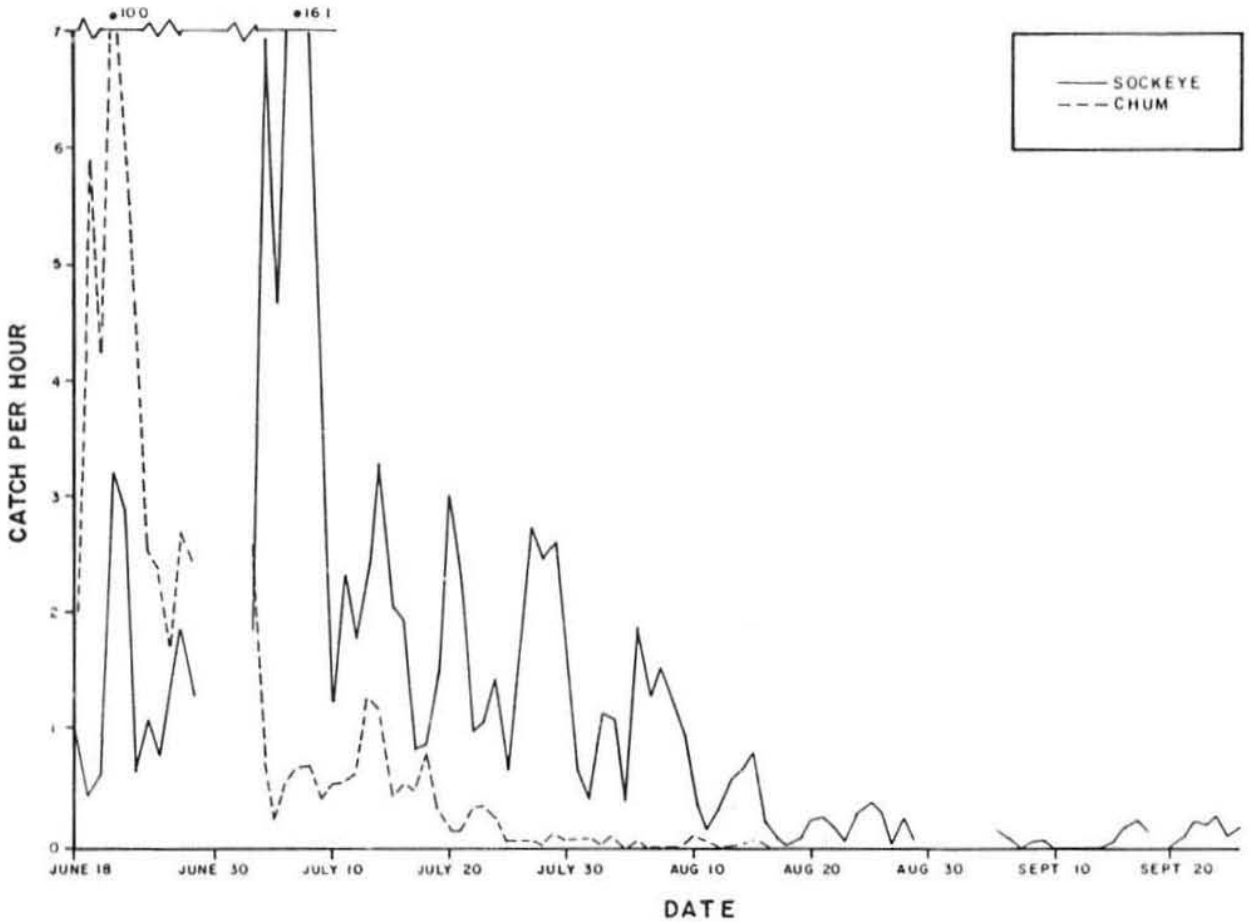
Correlations with turbidity were not calculated because turbidity data were available only after August 14. During this period, turbidity generally appeared to be closely related to discharge, so any correlation that existed between catch/hour and discharge would most likely also exist between catch/hour and turbidity.




Appendix Figure H-2. Catch per hour for Age 0+ and Age 1+ chinook salmon at the outmigrant trap, June 18 to October 12, 1982.




Appendix Figure H-3. Catch per hour for Age 0+ and Age 1+ and 2+ combined coho salmon at the outmigrant trap, June 18 to October 12, 1982.




Appendix Figure H-4. Catch per hour for juvenile sockeye and chum salmon at the outmigrant trap, June 18 to October 12, 1982.

The catch per hour for all species of salmon was summed to determine if there was a dominant factor influencing all species. This total was related to time of season ($r = -.69$, $p < 0.01$) and to daylength ($r = 0.67$, $p < 0.01$), but the correlations of total catch per hour with discharge and water temperature were low.

## Juvenile Chinook Salmon

The majority of age 1+ chinook salmon outmigrated in June and early July (Appendix Figure H-2). The peak outmigration for age 0+ chinook occurred in July after the peak for the age 1+ fish.

There was a moderate correlation of juvenile chinook salmon catch/hour with discharge ($r = 0.56$, $p < 0.01$). The correlation was not improved by lagging catch/hour one day behind discharge or using a logarithmic transformation of both variables. A first-difference regression between catch/hour and discharge gave a poor correlation. The correlation of catch/hour with time of season was slightly higher than the one with discharge. The best coefficient of determination ($r^2 = 0.64$, $p < 0.01$) was obtained by regressing the three day moving average of catch/hour versus time of season and temperature. This equation took the form: moving average of catch/hour = 0.93 - 0.01 (time of season) - 0.03 (temperature). Most of the variation in moving average which was accounted for was explained by time of season.

Outmigrating age 0+ chinooks showed two pulses in catch/hour - one at a mean length of 50 mm and one at a mean length of 60 mm (Appendix Figure

H-5). The 60 mm pulse occurred prior to the 50 mm pulse. Relatively large numbers of 50 mm fish outmigrating near the end of July depressed the plot of mean length at that time.

## Juvenile Coho Salmon

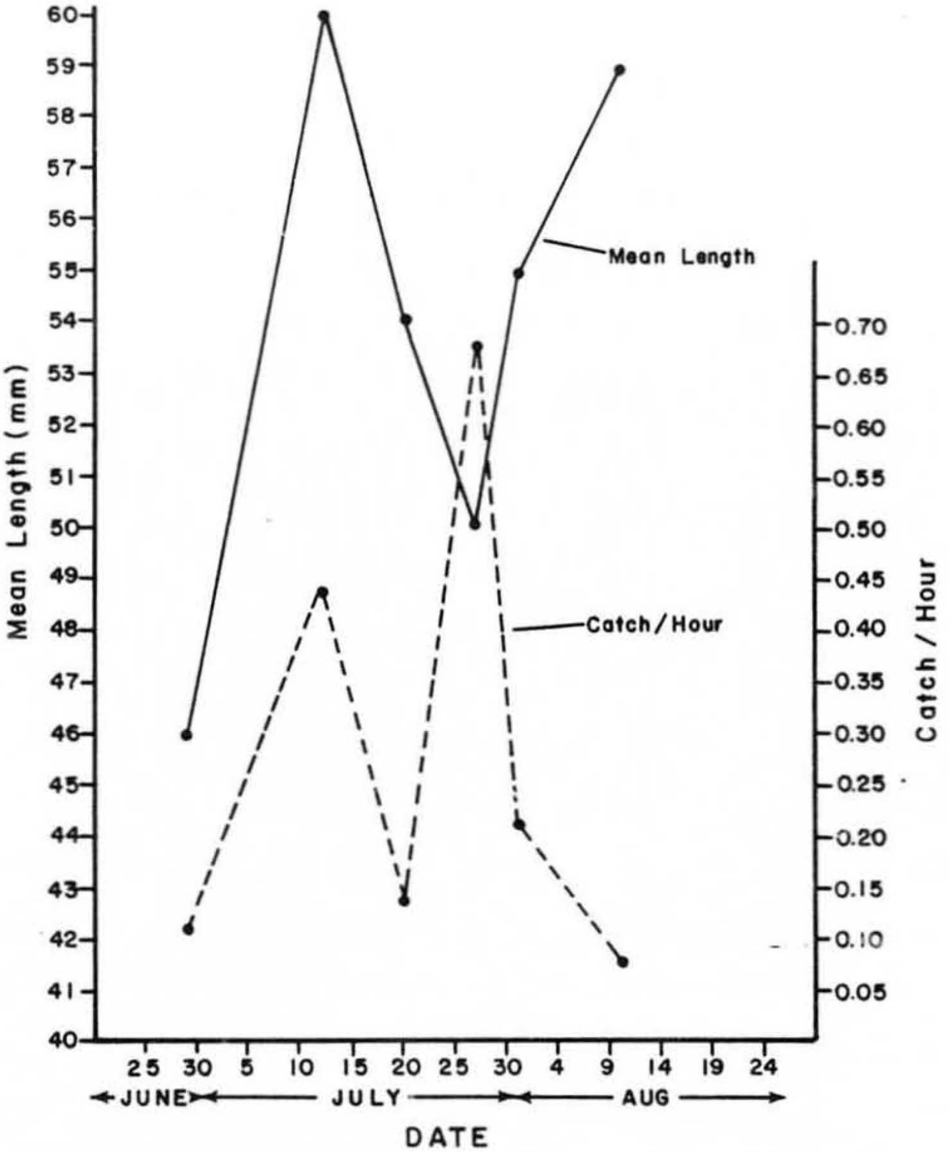
Coho salmon outmigrated in a more consistent manner throughout the season than the other species (Appendix Figure H-3). This was especially true with the age 1+ and age 2+ coho, which showed a marked contrast with the pattern of age 1+ chinook salmon.

The relationships of juvenile coho salmon catch/hour with discharge and time of season were highly significant ($p < 0.01$), but the correlations were modest. These correlations were not much improved by data lags or transformations. The first-difference regression between catch/hour and discharge yielded a poor relationship. The relationship of catch/hour with temperature was not significant.

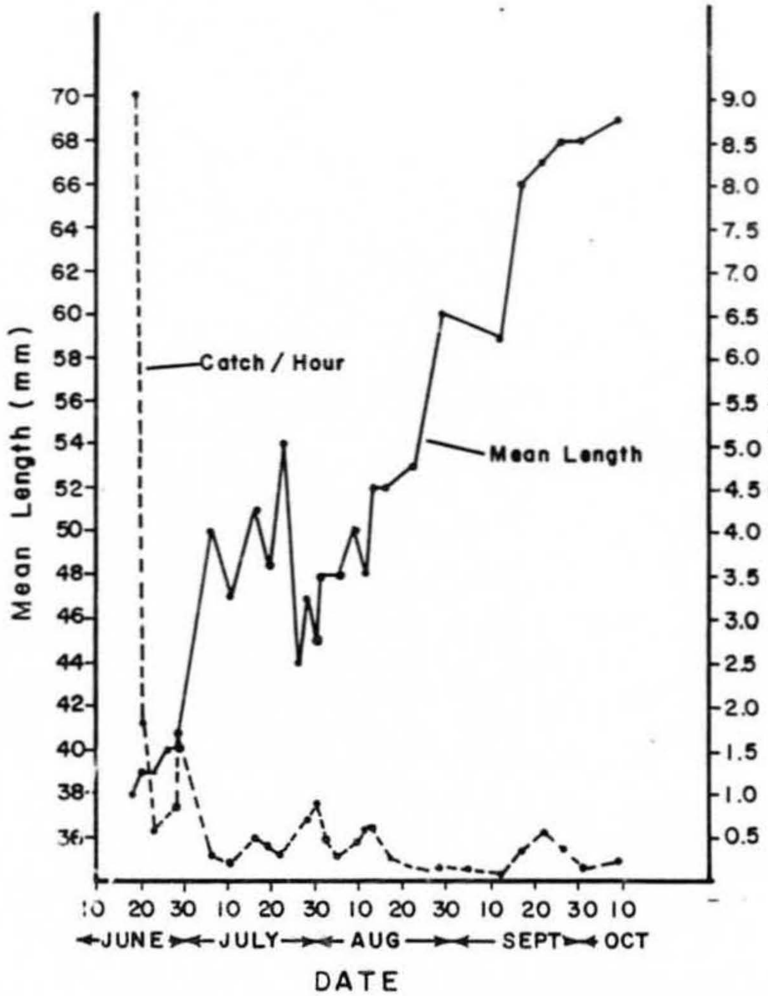
The highest catch/hour for age 0+ coho usually occurred at the smaller size classes (Appendix Figure H-6). Decreases in mean length generally were related to increases in catch/hour.

## Juvenile Sockeye Salmon

The correlation of juvenile sockeye salmon catch per hour with discharge was poor and was not improved by time lags, by using a moving average, or by performing a first-difference regression. There was a modest




Appendix Figure H-5. Relationship of mean length and catch per hour for age 0+ chinook salmon captured at the outmigrant trap.



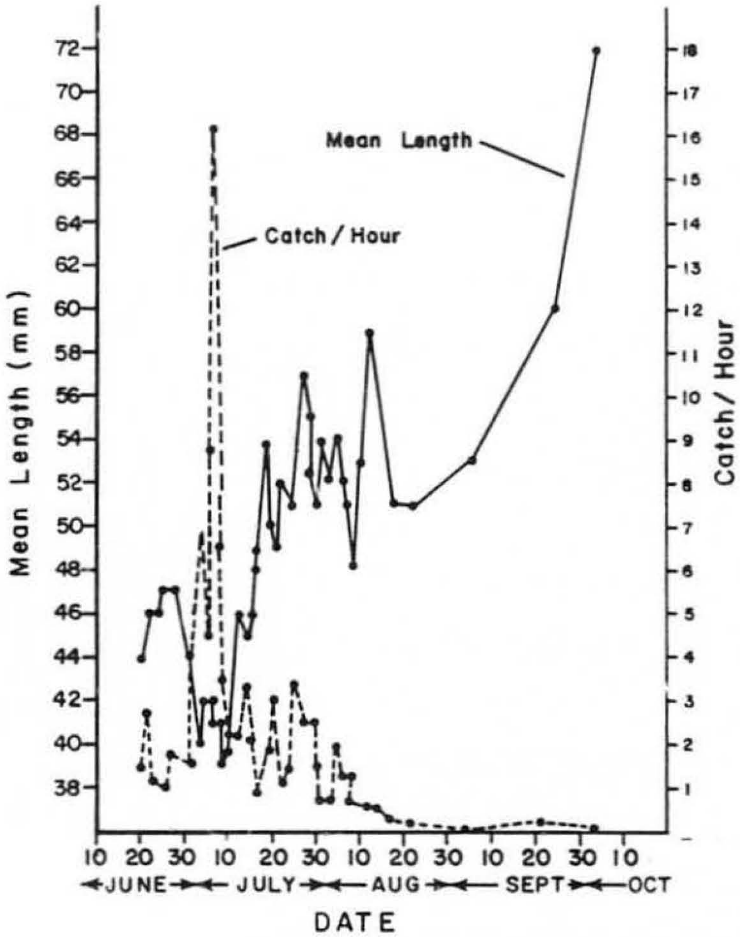

Appendix Figure H-6. Relationship of mean length and catch per hour for age 0+ coho salmon captured at the outmigrant trap.

correlation with time of season. A logarithmic transformation of the catch/hour gave fairly good correlations with time of season ($r = -0.82$, $p < 0.01$) and temperature ($r = 0.71$, $p < 0.01$).

The mean length/catch per hour relationship for age 0+ sockeye salmon was similar to that of age 0+ coho salmon (Appendix Figure H-7) and had a correlation coefficient of $r = -0.53$, $p < 0.01$. The highest catch/hour, occurring in early July, was related to a sharp decrease in the mean length.

## Juvenile Chum Salmon

The last juvenile chum salmon was captured on August 15, so only those sampling days from June 18 to August 15 (55 cases) were included in the analysis. The strongest factor relating to catch/hour was time of season ($r = -0.71$, $p < 0.01$). The relationship of catch/hour with discharge was modest and the relationship with temperature was poor. Logarithmic transformation of catch/hour provided no further insight. A first-difference regression of catch/hour with discharge gave inconclusive results. Using the three day moving average of catch/hour in a multiple regression against time of season and daily difference in discharge "explained" the most variation in catch/hour ($r^2 = 0.72$, $p < 0.01$). The equation for this regression is: moving average of chum catch/hour = 3.34 - 0.07 (time of season) + 1.30 (daily change in discharge/$10^4$). Most of the variation in the moving average was accounted for by time of season.

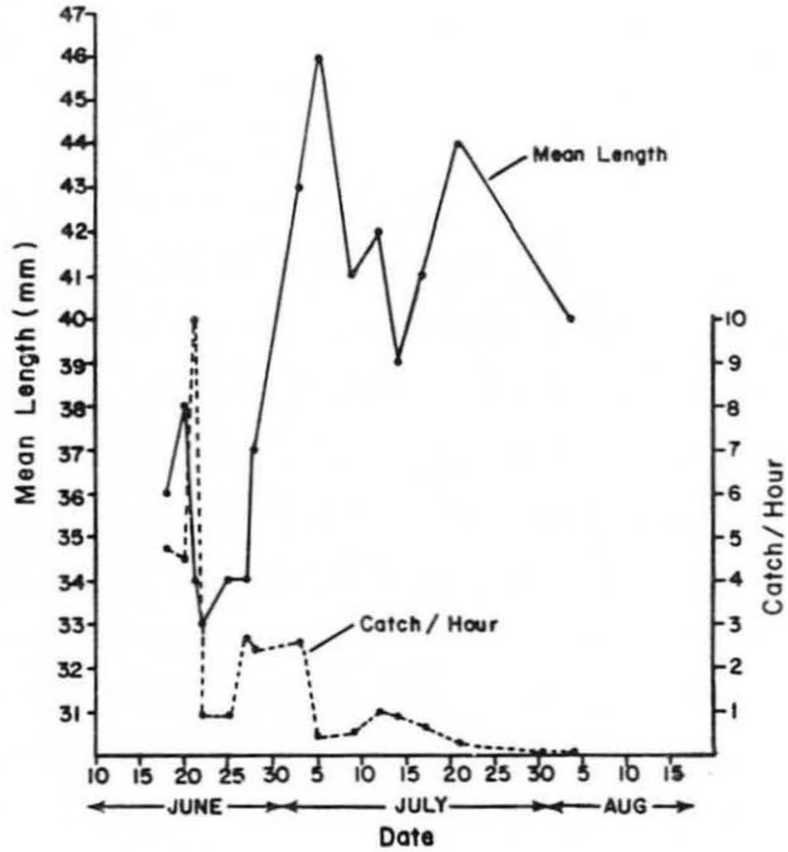



Appendix Figure H-7. Relationship of mean length and catch per hour for age 0+ sockeye salmon captured at the outmigrant trap.

The pattern of catch/hour and mean length was not as clear for chum salmon as it was for the other species (Appendix Figure H-8), but generally, the highest catch/hour occurred early in the season when the mean length was low. When the largest fish were outmigrating, the catch/hour was low.

## DISCUSSION

Catch/hour for all species generally declined with time (Appendix Figures H-2, H-3, H-4). Levels of the environmental variables (discharge, water temperature, and daylength) also generally decreased over the course of the season (Appendix Figure H-1, Appendix Table H-2). These two facts alone would probably lead to reasonable correlation coefficients between habitat variables and catch/hour. However, the real question is whether there is a cause-effect relationship between them or whether the correlation is simply coincidental. It may be that the fish are merely outmigrating in response to time of season. Evolution has coded juvenile salmon to outmigrate when conditions (discharge, water temperature, timing of plankton blooms in the estuary, and so on) are most likely to be favorable. Given this, the objective of this study has been to determine if the fish respond to short-term fluctuations (on the order of days) in environmental variables and if changes in those variables, such as might be caused by the proposed hydroelectric project, would affect the timing of outmigration.




Appendix Figure H-8. Relationship of mean length and catch per hour for age 0+ chum salmon captured at the outmigrant trap.

## Strength of Correlations

Although the relationships examined were usually highly significant, the correlation coefficients calculated were generally moderate to low. At best, 72 percent of the variation in catch/hour was "explained" by variation in habitat variables. The relationships would probably be much stronger had catch/hour data been available for the entire period of outmigration. Outmigration probably begins some time in late April or early May, so at least one and one-half months of data were not available. By the time the outmigrant trap began operation, the catch/hour for all species was already near the seasonal peak. Good data for outmigration occurring under the ice or during breakup (usually up until mid-May) will probably never be obtained because of sampling problems during that time of year.

Another factor leading to low correlations is that certain variables may have a strong influence on outmigration for a short period of time, but would not show a high correlation when calculated for the entire season. For example, the correlation of catch/hour and discharge was not very high for the whole season, but it can be seen from Appendix Figures H-1, H-2, and H-3 that the mid-September surge in discharge correlated very well with an increase in outmigration of chinook and coho salmon.

Correlations could probably be improved if more habitat data were available. Mainstem water temperatures were used in the calculations; slough and tributary water temperatures might be a better measure of the effect of temperature on outmigration. Also, other factors which may influence outmigration timing, such as rates of egg development, were not measured. Correlations for chinook and coho salmon might be improved by calculating the correlations for separate age classes, rather than for all age classes together.

Importance of the Habitat Variables

Before examining the relative importance of the different habitat variables, one should have a clear understanding of how these parameters interact with juvenile salmon. Discharge is important because an adequate flow is necessary for the fish to outmigrate. Also, an adequate stage of river at the heads and mouths of sloughs and other areas may be necessary for the juveniles to gain access to the mainstem. A faster current probably requires less energy to outmigrate than a slower current. Turbidity is an important factor in providing cover to outmigrating salmon in a large river such as the Susitna. In relatively short non-turbid rivers, juvenile chum salmon outmigrate mainly at night (Neave 1955). In the Susitna area, there is no true darkness during the time most of the juvenile salmon are outmigrating (Appendix Table H-2). Water temperature is a regulator of metabolism; juvenile salmon show a preference for certain ranges (Reiser and Bjornn 1979). Temperature can also serve as an impetus for outmigration (Sano 1966). Day length regulates the biological clocks of juvenile salmon. For example, an increasing day length (photoperiod) affects the pituitary system of juvenile chum salmon, causing an increasing tolerance for salt water (Baggerman 1960; Shelbourn 1966).

The highest correlations were generally obtained between catch/hour and time of season. This was particularly true with chum salmon. As mentioned previously, time of season is an integrator of several variables. The correlation with discharge was modest with all species except sockeye, whose catch/hour was poorly correlated with discharge. The correlation with temperature was never strong for any species, but temperature contributed to explaining catch/hour variation in some of the multiple regressions. Daylength and turbidity correlations were not calculated for each species, but daylength correlated well with the total catch of all salmon species.

Good correlations with some habitat variables were obtained for chum salmon catch/hour, which began high and then declined to zero in mid-August. Coho salmon correlations were the lowest. This species continued to outmigrate the entire time the trap was fishing whereas the others did not outmigrate in large numbers after the end of August.

### Comments on Methods

None of the first-difference regressions which were computed gave very good results. There are probably unpredictable time lags of one to three days which occur between the occurrence of an environmental event and the response of catch/hour at the outmigrant trap. If the time lags could be predicted, then a lag could be built into the calculation.

The daily catch/hour for all species is quite variable from day to day (Appendix Figures H-2, H-3 and H-4). The reasons for this variability are not evident at this time. The variability may be a result of juvenile salmon re-distributing themselves throughout the mainstem after migrating out of tributaries and sloughs. Small groups or individuals may hold for various lengths of time in the numerous small eddies, backwaters, and slack-water border areas. On any given day with this scenario, a more or less random number of individuals or groups of individuals migrates past the outmigrant trap. Regardless of the cause, the sharp fluctuations in numbers create problems in data analysis and probably require some sort of smoothing function. Stable results were obtained using a three day moving average. Some preliminary work using exponential smoothing also appeared to be promising. Further investigation with both of these techniques would probably be profitable, as would further calculations using different time lags. Mixed results were obtained using logarithmic transformations of one or two variables in a bivariate analysis.

### Future Work

The ultimate goal of this analysis, given the appropriate habitat data, is a prediction of the relative magnitude and timing of juvenile salmon outmigration. This goal was not met during the 1982 studies as the amount and types of data available did not allow for definitive relationships to be developed. In particular, more than one season of data is necessary. For example, a season in which discharge is low early in the season and then increases would be useful in determining whether this kind of discharge regime would override the effect of time of season on outmigration.

This report has provided some insight into the problem of habitat/ outmigration relationships and some direction for future work. During the 1983 studies, two outmigrant traps will be operated, beginning in mid-May. Also, more complete habitat data will be obtained. Furthermore, coded wire tagging, in conjunction with habitat measurements, will be conducted in several sloughs above the outmigrant traps. These studies will contribute a great deal to a more powerful analysis of juvenile salmon outmigration.

## LITERATURE CITED

Alaska Department of Fish and Game, 1983a. Resident and juvenile anadromous fish studies below Devil Canyon, 1982. Volume 3 of Phase II Basic Data Report. Susitna Hydro Aquatic Studies, Anchorage.

______. 1983b. Aquatic habitat and instream flow studies, 1982. Volume 4 of Phase II Basic Data Report. Susitna Hydro Aquatic Studies, Anchorage.

Baggerman, B. 1960. Salinity preference, thyroid activity and the seaward migration of four species of Pacific salmon (Oncorhynchus). J. Fish. Res. Bd. Can. 17(3):295-322.

Neave, F. 1955. Notes on the seaward migration of pink and chum salmon fry. J. Fish. Res. Bd. Can. 12(3):369-374.

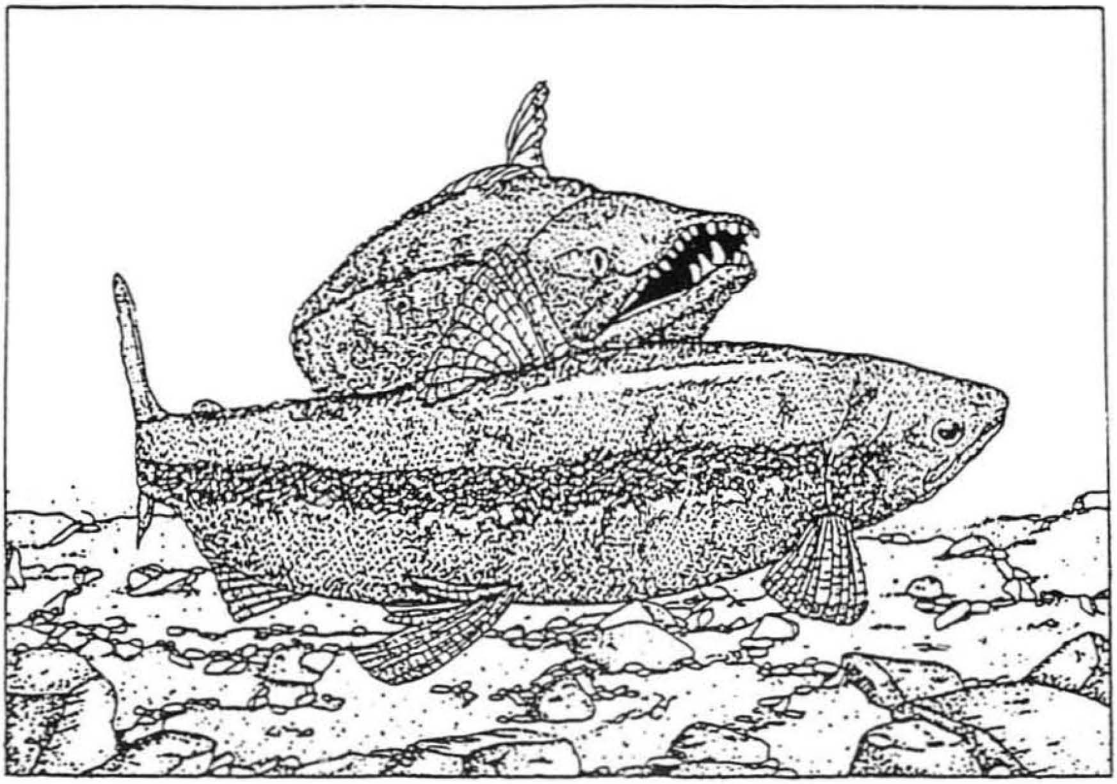
Reiser, D.W., and T.C. Bjornn. 1979. Influence of forest and rangeland management of anadromous fish habitat in the western United States and Canada. 1. Habitat requirements of anadromous salmonids. U.S. Dept. of Agricul., Forest Service. General Technical Report PNW - 96, Portland, Oregon. 54 pp.

Sano, S. 1966. Salmon of the North Pacific Ocean - Part III. A review of the life history of North Pacific salmon. 3. Chum salmon in the Far East. International North Pacific Fisheries Commission Bull. No. 18. Vancouver, B.C. pp. 41-57.

Shelbourn, J.E. 1966. Influence of temperature, salinity, and photoperiod on the aggregations of chum salmon fry (Oncorhynchus keta). J. Fish. Res. Bd. Can. 23(2):293-304.

Snedecor, G.W., and W.G. Cochran. 1967. Statistical methods. Iowa State University Press, Ames, Iowa. 593 pp.

Summers, G.W., W.S. Peters, and C.P. Armstrong. 1981. Basic statistics in business and economics. Wadsworth Publishing Co., Calif 594 pp.



# SUSITNA HYDRO AQUATIC STUDIES
## PHASE II REPORT

Synopsis of the 1982
Aquatic Studies and Analysis of
Fish and Habitat Relationships

— APPENDICES —

by

ALASKA DEPARTMENT OF FISH AND GAME
Susitna Hydro Aquatic Studies
2207 Spenard Road
Anchorage, Alaska 99503

1983