APPENDIX F

Influence of Habitat Parameters on Distribution and Relative Abundance of Juvenile Salmon and Resident Species.

APPENDIX F

TABLE OF CONTENTS

APPENDIX F

LIST OF APPENDIX FIGURES

APPENDIX F

LIST OF APPENDIX TABLES

LIST OF APENDIX TABLES (Continued) Page

INTRODUCTION

The physical and chemical parameters of the Susitna River such as discharge, surface area, water velocity and depth, temperature, and water quality have wide ranging spatial and temporal variations. Spatial variations range from micro-habitat (on the order of a few feet), to macro-habitat (such as tributary mouths or sloughs), to entire river segments. Temporal variations occur on a scale ranging from daily, to annual, to multi-year cycles. Fish and other organisms respond to these spatial and temporal variations and this response is reflected in the distribution and relative abundance of each species. The proposed hydroelectric project could create physical-chemical conditions which are outside the limits of natural variation with regard to timing, magnitude, or both. This appendix presents an analysis of the cause-effect relationships observed between natural variations in physical and chemical conditions and the distribution and abundance of fish during the 1982 open water season. An understanding of these relationships will be useful in predicting the effect of the proposed project on fish populations.

The emphasis of this appendix is on the relationship between mainstem discharge and juvenile salmon distribution and abundance, although other species and variables are also discussed. Measuring the changes in available juvenile salmon habitat in response to changing Susitna River discharge presents substantial difficulties. Although much research has been conducted elsewhere using hydraulic models to predict the availability of habitats over incrementally varying discharges

(Bovee 1982), these studies have not been directed towards large and diverse glacial systems such as the Susitna River.

Observations made during the 1981 studies indicated the problems associated with evaluating juvenile salmon habitat of the Susitna River on a detailed basis and led to a hypothesis regarding the factors affecting juvenile salmon distribution and abundance at an intermediate level of resolution. The hypothesis is that juvenile salmon distribution and abundance at the important summer rearing areas (sloughs and tributary mouths) are controlled by the hydraulic conditions at these areas which are in turn controlled by variations in mainstem discharge. The 1982 field study plan focused on those factors which were obviously influenced by mainstem discharge.

Central to this approach was the thesis that several sites would have to be examined to adequately address the natural variability among habitat types used by the majority of each species. This decision prevented the quantification of micro-habitat conditions within each of the study sites. To monitor the changes in physical habitat with changing mainstem discharge without an intensive data collection effort, we developed a system to classify the habitat conditions present at a study site into nine possible habitat zones. The surface areas of the zones were measured under the variable flow conditions of the mainstem Susitna during the open water season. Physical and chemical habitat variables of each zone and the distribution and relative abundance of fish among the zones were also measured. Changes in micro-habitat within the zones as a function of discharge were not evaluated during the 1982 study.

An estimate of how juvenile salmon habitat changes with variations in mainstem discharge was developed by combining the catch variations between zones with the changes in the surface area of the zones. The resulting habitat index is plotted as a function of discharge. This work provides a logical step in the quantitative analysis of the available habitats over an incremental range of mainstem Susitna River discharges.

METHODS

Data for this appendix were drawn from the 1982 open-water studies at the 17 Designated Fish Habitat (DFH) sites described in Volume 3 (Section 2.1.3) and Volume 4 (Section 2.1.3.1 of Part I and Section 2.2 and 2.3.2 of Part II) of the Basic Data Report (ADF&G 1983a, ADF&G 1983b). The sites included several different major habitat types located from Goose Creek (RM 73.1) to Portage Creek (RM 148.8). Two reaches were defined - the upper reach included twelve sites above the Chulitna River confluence (RM 98.5) and the lower reach included five sites below this point. These 17 sites were sampled once every two weeks during June, July, August, and September. Each recognizable habitat type at a site was categorized as one of nine possible habitat zones. These habitat zones are defined in Volume 4, Part II, Section 2.2 of ADF&G (1983b) - a summary table is included at the end of this appendix. Criteria used in delineating habitat zones included water source, water velocity, and mainstem backwater influence. Sampling at each site was standardized by zone as much as possible to minimize sampling biases.

Three steps are followed in this appendix. First, the effect of sampling site, sampling period, and habitat zone within a site on the catch per unit effort of each species of fish and on each habitat variable is examined. Inherent in this step are tests to determine if any differences among sites, periods, or zones are statistically significant. Next, the relationships between catch per unit effort for a particular species and the habitat variables are examined. Finally, the effects of variations in mainstem discharge on habitat are investigated. This is done by deriving a quality index for each habitat zone and then multiplying the quality index by the surface area of that zone which was present at a particular level of discharge to obtain a habitat index. Mainstem discharge is treated in this separate analysis because of the likelihood that it is and would be the dominating environmental factor in controlling other habitat variables and fish distribution and abundance in both natural and post-project conditions.

Assumptions

A word model of the factors affecting juvenile salmon catch within a zone can be constructed as follows:

Catch = f (abundance, sampling effort, gear efficiency, and fish catchability) where:

Abundance = f (local habitat suitability, time of season, success of previous fall's spawning, percent incubation survival, proximity to spawning grounds)

where:

Local habitat suitability = f (temperature, water chemistry, water velocity, depth, substrate, turbidity, cover, food)

Some of these parameters can be quantitatively evaluated, while others can only be subjectively evaluated. For others, we have no data.

During data collection and subsequent analysis, we have attempted to eliminate the variables sampling effort, gear efficiency, and fish catchability so that catch reflects abundance. The location of the site integrates such factors as proximity to spawning grounds, success of previous fall spawning, and incubation survival. Local habitat suitability is integrated by hydraulic zone. Therefore, we can simplify the model to:

Catch = f (abundance) = f (time of season, site, and habitat zone within sampling site).

Each species of fish, at each site during any particular sampling period, was assumed to have a choice of habitat types available at a site and presumably would be found in greatest abundance in that habitat type which was most suitable to them.

Spatial and Temporal Variation in Habitat Variables and in Relative Abundance of Fish.

The three variables that cause variation in catch data are sampling site, habitat zone within sampling site, and sampling period. Analysis by sampling site and habitat zone address spatial variation, and sampling period addresses seasonal variation (during the open water season). Sampling site takes into account macro-habitat variations including differences between reaches and differences between major habitat types such as tributary mouths versus upland sloughs. Habitat zone addresses a more narrowly defined habitat and considers the effect of habitat variables such as water temperature and velocity within a site. The resolution of habitat zone falls somewhere in between macro-habitat and micro-habitat (such as would be obtained by point-specific measurements). The emphasis of this report is on differences of habitat variables and fish abundance among zones within a site. Seasonal variation is examined briefly. Differences among sites are analyzed in Appendix G of this report.

The catch and habitat data were sorted and pooled in various ways (as outlined in the results section). One way in which the habitat zones were pooled was by aggregate zone types. Three different criteria were used to aggregate habitat zones - (1) by the presence or absence of a mainstem backwater zone, (2) by water source, and (3) by water velocity. Details describing these aggregate zones were presented in Section 2.2, Part II, Volume 4 of the Basic Data Report (ADF&G 1983b). A summary follows:

	Criterion	Aggregate Zone	Description
1.	presence of mainstem backwater area	H-I	tributary or slough above mainstem backwater area
		H-II	mainstem backwater area
		H-III	mixing zone below mainstem backwater area
2.	water source	W-I	tributary water
		W-II	mainstem water
		W-III	mixed water
3.	water velocity	V-I	fast water
		V-II	slack water

The assumption with each of the categories is that, if the aggregating criterion is important, the habitat quality of all the individual habitat zones in each aggregate zone (e.g., H-I zone) is equal or, stated in another way, differences in habitat quality within an aggregate zone are insignificant when compared with differences among aggregate zones.

The effect of zone on variations in habitat variables and in catch data was examined by t tests and by chi-square tests (Snedecor and Cochran, 1967). The t test was used to compare the pooled means (all sites, all sampling periods) of selected habitat variables by aggregate hydraulic zone.

The t test was also used to test for significant differences between aggregate hydraulic zones for catch/effort data for juvenile chinook salmon, juvenile coho salmon, rainbow trout, and burbot. Catch/minnow trap data were used for chinook and coho and catch/trotline data were used for rainbow and burbot because these sampling techniques were effective for these species and because we were able to consistently use minnow traps and trotlines in the different zones sampled. The minnow trap data have the further advantage of five to ten replicates per zone.

It was not possible to consistently use sampling techniques such as beach seining and backpack electrofishing, which were effective at capturing other species, in all of the zones sampled. Therefore, a chi-square test was used to determine if there were associations of juvenile chum salmon, juvenile sockeye salmon, round whitefish, Arctic grayling, longnose sucker, and slimy sculpin with the three different aggregate zones. Presence/absence data were compiled only from beach seining or backpack electrofishing effort. Only those zones which had such effort were included in the analysis. Sampling effort over the entire open water season was pooled to increase sample size.

Correlation of Fish Abundance and Habitat Variables

Methods for examining the relationship of fish abundance with habitat zone were presented in the previous section. In this section, methods used to examine relationships between fish abundance and individual habitat variables, such as water temperature, are given. Caution should be used in interpreting such an analysis because there are several habitat variables that have an interactive effect on fish. For example, a low level of dissolved oxygen can be more detrimental at a high temperature than at a low temperature. The objective of this section was to detect any single variables that might have a strong effect on the distribution and abundance of a particular species.

A correlation matrix was calculated for four species of fish (juvenile chinook salmon, juvenile coho salmon, rainbow trout, and burbot) and three habitat variables. The habitat variables water temperature, turbidity, and velocity were chosen because they are among the most important of those variables measured in affecting fish distribution.

The matrix was compiled for these seven variables by individual habitat zone. Two zones (zones 5 and 8) were deleted from the analysis because of low sample size. All sites and all sampling periods were pooled for each zone prior to calculating the correlations.

Relationship of a Habitat Index and Mainstem Discharge

The value of a habitat type to a population of fish is a function both of the quality of the habitat and the amount available. In this section, we derive a quality index for each habitat zone and multiply the index by the surface area of that habitat zone available within the study boundaries at incremental levels of mainstem discharge.

The raw catch data from the 17 fish habitat sites used to determine quality indices are contained in Appendices G and H of Volume 4 of the

Basic Data Report (ADF&G 1983b). The surface area data for the sites are for the study boundaries as defined in Appendix E of the present report.

First, the nine separate habitat zones were aggregated into the three types of hydraulic zones. The H-I aggregate hydraulic zone consisted of all habitat zones which occurred above the influence of mainstem backwater areas. The H-II aggregate hydraulic zone included all habitat zones which were backed up by a hydraulic barrier created by mainstem stage at the mouth of tributaries, sloughs, or side channels. The H-III aggregate hydraulic zone was the mainstem mixing area, just below the H-II zone. The hydraulic zone category, rather than the water source or water velocity categories, was used to aggregate the individual habitat zones because of its utility in relating habitat change to mainstem discharge.

A catch ratio (CR) was calculated for each hydraulic zone at each site during each sampling period. This was done for each species. The ratio took the form:

$$CR_i = \frac{(CPUE)_i}{\sum_{\substack{j \geqslant 1 \\ j \neq i}}^{n} (CPUE)_j \;/n-1}$$

where: CPUE = catch per unit effort
n = total number of zones sampled
i = zone number of the zone in question
j = zone numbers of all other zones

This is simply the ratio of the CPUE of the zone in question to the mean of the CPUEs of all other zones. The ratio was calculated in this manner in accordance with the original assumption - each species will concentrate in the zone that has the most desirable conditions. This ratio was used because it is independent of the absolute numbers of fish at the site; if a particular zone is preferred, it could have the same ratio whether there were 50 fish or 500 fish present at a site. A further advantage of the ratio is that it is independent of the number of zones sampled, which ranged from two to four. All cases where less than ten fish of any one species were captured at a site during a particular sampling period were dropped from the data set because of the small sample size. This was done to eliminate those instances where a few fish might chance to be in an uncommon zone.

The zone in question was compared to the mean of all other zones rather than to the mean of all zones at the site for two reasons. First, with this method, the possible values of CR will range from zero to infinity. Had the mean of all zones at the site been used as the denominator, then CR would range from zero to some unknown and non-constant number, thus complicating further mathematical manipulation. Secondly, had the site mean been used, CR would be affected by the number of zones sampled for those cases where all the fish at a site were caught in one zone, a situation which was not uncommon. It was desirable to keep CR independent of the number of zones sampled.

Only minnow trap data were used to compile the CPUE for juvenile chinook and coho salmon. The CPUE was defined as catch/trap in a three hour set. Minnow traps were most effective in collecting these two species and were the most reproducible unit of gear between zones. The CPUE for juvenile sockeye and chum salmon were compiled from beach seining and backpack electrofishing data, which were the two methods most effective in capturing these species. Because of the difficulty in replicating effort among zones with these types of gear, a code was established using catch data:

Number Captured	Code
0	0
1-10	1
11-25	2
more than 25	3

The catch ratio (CR) for sockeye and chum salmon was calculated based on these codes. To be included in the analysis, at least two zones at any one site and sampling period had to have been sampled by the gear previously mentioned.

The catch ratio can vary from zero, if no fish were captured in the zone in question, to infinity, if all the fish at the site were captured in this zone. In order to transform this range into the range zero to one, which was desirable from the perspective of a habitat quality index, we derived the following equation:

$$ZQI_i = 1 - \frac{1}{CR_i + 1} = \frac{CR_i}{CR_i + 1}$$

where: ZQI_i = zone quality index for zone i

CR_i = catch ratio for zone i

This asymptotic equation transforms catch ratios to a value ranging from zero to one. The ZQI approaches zero for small values of CR and one for large values of CR. A value of zero means that none of the fish captured at the site were caught in the zone in question and a value of one means that all the fish were caught in this zone. A value of 0.5 means that the catch rate in this zone was equal to the average catch rate of all other zones. Further, if the catch/trap in zone X is twice as great as the catch/trap in zone Y, then the ZQI for zone X is twice as high as that for zone Y. This zone quality index is considered to be independent of mainstem discharge and sampling site surface area.

This zone quality index is unlike the quality index commonly used in habitat suitability index (HSI) models in that it is a relative measure only - one zone relative to other zones. For example, if no fish of a certain species were captured at a site, an HSI of zero would be indicated; in this case, a ZQI would not be calculated because there is no sample to compare one zone against another. The only way to obtain a ZQI of zero are the cases where the species was captured at the site, but none were captured in the zone in question. The zone quality index, like the habitat suitability index, is compiled from catch data rather than from habitat data. However, the ZQI is based on relative abundance of fish among zones, while the HSI is based on frequency distribution of fish compiled from data collected at the micro-habitat level.

ZQI's were calculated for each species, each site, each aggregate hydraulic zone, and each period which met the criteria listed previously. For the present analysis, seasonal ZQI's for each zone at each site were calculated by taking the mean of all sampling periods for that zone at that site. This was performed after examination of the ratios among periods showed that there were no obvious trends over the course of the season. The exception is chum salmon, which were more prevalent in tributaries early in the season than they were later on. The assumption is that the value for a species of each of the zones relative to the other zones was approximately constant over the period June through September. These calculations were done for each species for each of the three aggregate hydraulic zones.

Having obtained a zone quality index (the mean ZQI of all sampling periods) for each zone for each species, the next procedure was to multiply these ZQI's by the total surface area of that zone which was present at a particular level of mainstem discharge. The surface area data used were those which were calculated for discharge increments of 2,500 cfs (upper reach) and 5,000 cfs (lower reach). The surface area values for the aggregate zone H-II were presented in Sections 3.1.3.1 and 4.1.3.1 of Volume 4, Part I, of the Basic Data Report (ADF&G 1983b). Values for the total wetted surface area are included in Appendix E of the present report. Values for the surface area of zone H-I was similarly obtained from the digitized maps. The tributary sites (Portage Creek, Indian River,and Fourth of July Creek) were excluded from the analysis at this point because none of them had a mainstem backwater (aggregate zone H-II) area.

The product of zone quality index times surface area provides a habitat index (HI) for that zone. A site habitat index was calculated according to the following equation:

$$HI = \sum_{i=1}^{n} (ZQI_i \times SA_i)$$

where:

ZQI_i = zone quality index for zone i

SA_i = surface area of zone i

n = number of zones

For the present analysis, this equation took the form:

$$HI = (ZQI_{H-I} \times SA_{H-I}) + (ZQI_{H-II} \times SA_{H-II})$$

where:

H-I = aggregate hydraulic zone H-I

H-II = aggregate hydraulic zone H-II

The site habitat index here is the sum of the zone H-I habitat index and the zone H-II habitat index. The surface area of the aggregate H-III zone was not included because it is assumed to be a constant - this type of habitat was always available to fish, regardless of the level of mainstem discharge observed during 1982, and was therefore not a factor. Zone and site habitat indices are a product of habitat quality and habitat quantity and can be plotted as a function of mainstem discharge.

RESULTS AND DISCUSSION

Spatial and Temporal Variation in Habitat Variables and in Relative Abundance of Fish

Habitat variables

Appendix Table F-1 shows the mean values for the habitat variables that were measured in each of the nine habitat zones. The mainstem backwater zones (zones 2, 6, 7, and 8) were generally warmer than the other zones. There did not appear to be any differences in dissolved oxygen levels among zones that would matter to fish except that the level in zone 9 (morphological pools) was somewhat low. The median pH of tributary water (zones 1 and 2) was lower than that of all other zones, except zone 9. As expected for this time of the year, the turbidity of tributary zones was relatively low compared to the slough and mainstem zones. Zone 9 had a low turbidity because this zone generally occurred within tributaries.

Data from these individual habitat zones were pooled into the aggregate zones (Appendix Table F-2). Slack water areas (zones H-II and V-II) were warmer than areas having a faster water velocity. This is illustrated for aggregate hydraulic zones by sampling period in Appendix Figure F-1. Temperature differences were greater during the first part of the season than they were after cooling began in early September. Slack water zones also had a lower mean dissolved oxygen level than

RESULTS AND DISCUSSION

Spatial and Temporal Variation in Habitat Variables and in Relative Abundance of Fish

Habitat variables

Appendix Table F-1 shows the mean values for the habitat variables that were measured in each of the nine habitat zones. The mainstem backwater zones (zones 2, 6, 7, and 8) were generally warmer than the other zones. There did not appear to be any differences in dissolved oxygen levels among zones that would matter to fish except that the level in zone 9 (morphological pools) was somewhat low. The median pH of tributary water (zones 1 and 2) was lower than that of all other zones, except zone 9. As expected for this time of the year, the turbidity of tributary zones was relatively low compared to the slough and mainstem zones. Zone 9 had a low turbidity because this zone generally occurred within tributaries.

Data from these individual habitat zones were pooled into the aggregate zones (Appendix Table F-2). Slack water areas (zones H-II and V-II) were warmer than areas having a faster water velocity. This is illustrated for aggregate hydraulic zones by sampling period in Appendix Figure F-1. Temperature differences were greater during the first part of the season than they were after cooling began in early September. Slack water zones also had a lower mean dissolved oxygen level than

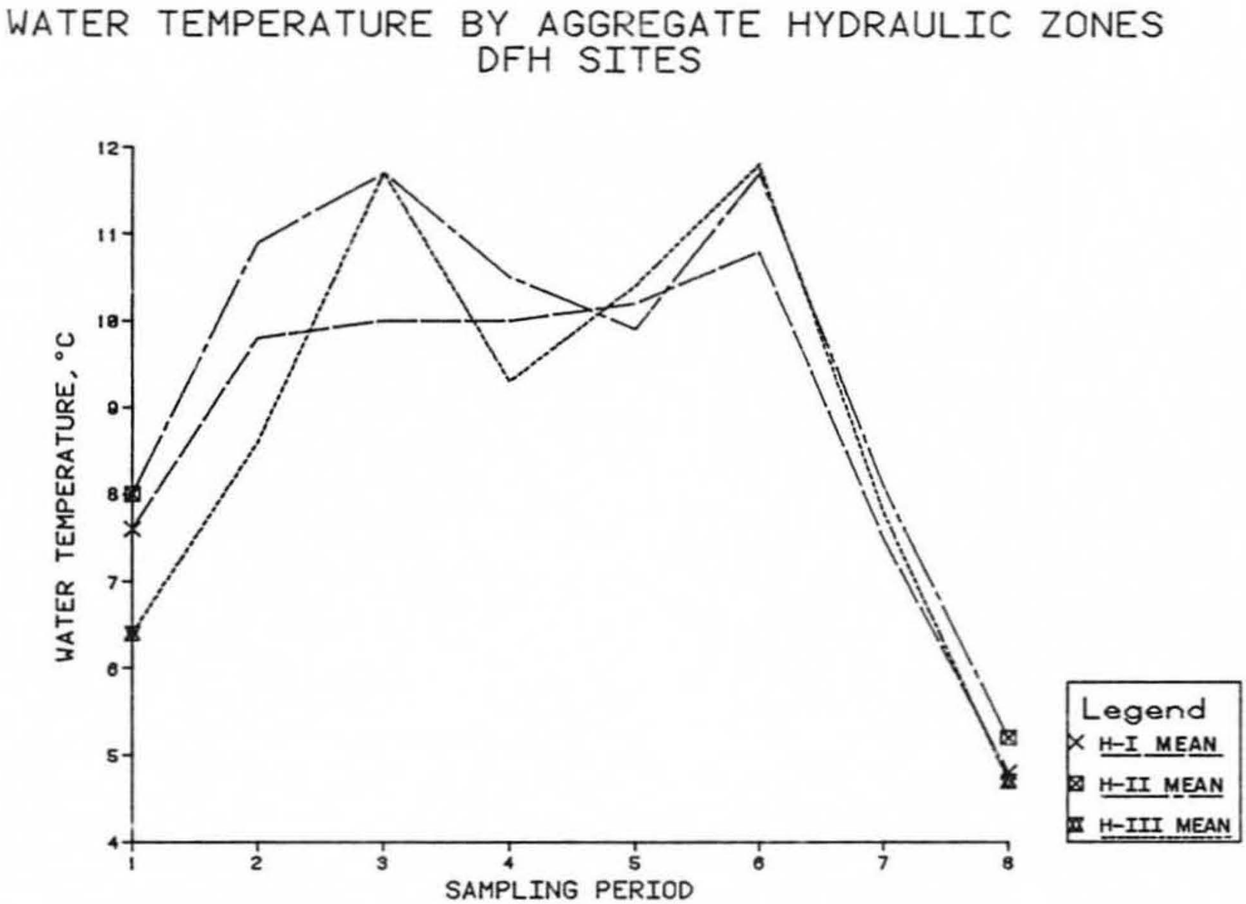
Appendix Table F-1 Matrix table of mean habitat conditions by zone. All sites, all periods, June through September, 1982. Standard error in parentheses.

Zone	Mean Water Temp(°C)	Mean DO (mg/l)	Median pH	Mean Conductivity (umhos/cm)	Mean Turbidity (NTU)	Mean Water Velocity (ft/sec)
1	8.8(0.3)	10.9(0.2)	6.9	81(7)	5(1)	1.4(0.1)
2	9.5(0.4)	10.3(0.2)	6.8	105(8)	6(1)	0.1(0.0)
3	8.7(0.3)	11.0(0.2)	7.1	98(4)	45(4)	1.2(0.1)
4	9.0(0.4)	11.2(0.4)	7.3	101(6)	36(8)	1.1(0.2)
5	6.6*	12.3*	7.0*	75*	17*	1.4*
6	9.2(0.5)	10.7(0.3)	7.0	114(8)	52(12)	0.3(0.1)
7	10.5(0.6)	10.9(0.4)	7.0	62(7)	36(9)	0.5(0.1)
8	15.5*	9.1*	7.4*	82*	85*	--*
9	8.7(0.6)	8.9(0.5)	6.6	78(9)	12(4)	0.1(0.1)

* = sample size ≤ 3

Appendix Table F-2 Matrix table of mean habitat conditions by aggregate zone. All sites, all periods, June through September, 1982. Standard error in parentheses.

Aggregate Zone	Mean Water Temp(°C)	Mean DO (mg/l)	Median pH	Mean Conductivity (umhos/cm)	Mean Turbidity (NTU)	Mean Water Velocity (ft/sec)
H-I	8.8(0.3)	10.7(0.1)	6.8	83(5)	10(2)	1.2(0.1)
H-II	9.7(0.3)	10.4(0.2)	6.8	98(6)	18(3)	0.2(0.0)
H-III	8.7(0.3)	11.0(0.2)	7.1	98(4)	45(4)	1.2(0.1)
W-I	9.1(0.3)	10.7(0.1)	6.9	91(5)	5(1)	0.9(0.1)
W-II	9.3(0.3)	10.9(0.2)	7.2	106(5)	44(7)	0.7(0.1)
W-III	9.0(0.3)	11.0(0.2)	7.0	92(4)	43(4)	1.1(0.1)
V-I	8.8(0.2)	11.0(0.1)	7.0	90(4)	26(3)	1.3(0.1)
V-II	9.5(0.3)	10.2(0.2)	6.8	95(5)	17(3)	0.2(0.0)



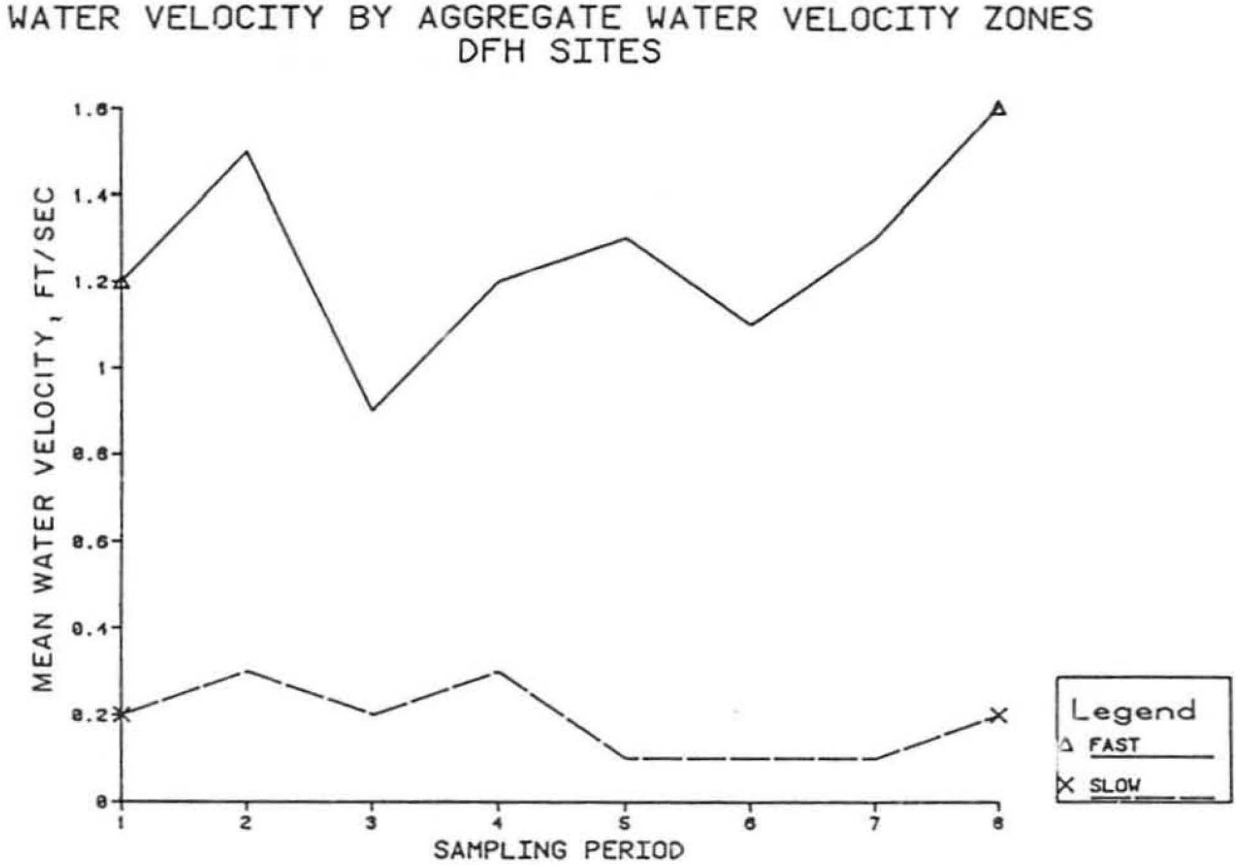
Appendix Figure F-1. Mean water temperature of aggregate hydraulic zones by sampling period, June through September, 1982.

other zones. Mainstem water (zone W-II) had a higher mean conductivity, mean turbidity, and median pH than tributary water (zone W-I). The mainstem backwater zone (H-II) and the low velocity zone (V-II), as would be expected by definition, had lower mean water velocities than the other zones (Appendix Figure F-2).

Data from all 17 sites and all 8 sampling periods for each of the three aggregate hydraulic zone types were pooled and the three variables water temperature, water velocity, and turbidity were tested for statistical differences using a t test. These three variables were chosen because they are the most important of the measured variables in influencing fish distribution. All differences between mean values, with one exception, were statistically significant as shown in the following table:

Pair	Water Temperature	Water Velocity	Turbidity
H-I/H-II	$p < 0.05$	$p < 0.01$	$p < 0.05$
H-I/H-III	NS	no difference	$p < 0.01$
H-II/H-III	$p < 0.05$	$p < 0.01$	$p < 0.01$

Mean water temperatures of the H-I zone and the H-III zone were quite close; mean water velocities of these two zones were equal. Statistically significant differences among the nine individual habitat zones could exist while differences among aggregate zones may not be statistically significant. This can occur because habitat zones which were hydraulically similar, but perhaps different in other habitat variables, were grouped to obtain aggregate hydraulic zones. This indicates whether the aggregating criterion is important.



Appendix Figure F-2. Mean water velocity of aggregate velocity zones by sampling period, June through September, 1982.

The above analysis establishes the uniqueness of the hydraulic zones with regard to a composite of these three habitat variables. Therefore, it is valid to test variations in catch against habitat variations among these zones. Because the aggregate hydraulic zone category can be used to illustrate the effects of changing mainstem flows, further analysis of habitat availability uses this category rather than the aggregate water source or water velocity categories.

Relative abundance of fish

Relative abundance, expressed as the mean of catch per unit effort data for four species of fish for all sites and sampling periods pooled is presented by habitat zone in Appendix Tables F-3 to F-6.

The highest catch rates for chinook salmon juveniles occurred in habitat zones 1 and 2 (tributary) and 7 (mainstem backwater zone below tributary mouth). Juvenile coho salmon catch rates were highest in the tributary habitat zones.

Rainbow trout were more broadly distributed among the habitat zones than the other species analyzed, but showed a preference for clear water tributary zones (zones 1 and 2) over turbid slough or mainstem zones. Burbot were captured most frequently in the turbid mainstem mixing zone (zone 3), followed by turbid slough zones.

These same data were grouped by aggregate zone, using the three separate criteria - hydraulic condition, water source, water velocity. Using a

Appendix Table F-3. Range and mean of chinook salmon juvenile CPUE (catch per minnow trap) by zone at DFH sites on the Susitna River below Devil Canyon, all periods, June through September, 1982.

Zone	Min CPUE	Max CPUE	Mean CPUE	No. of sites
1	0.0	6.9	0.4	15
2	0.0	5.8	0.2	13
3	0.0	1.0	0.1	17
4	0.0	0.2	0.0	7
5	0.0	0.0	0.0	2
6	0.0	0.7	0.1	5
7	0.0	13.0	0.9	6
8	0.0	0.0	0.0	1
9	0.0	0.4	0.0	5

Aggregate Zone	Mean CPUE	No. of Sites
Hydraulic		
H-I	0.3	15
H-II	0.4	14
H-III	0.1	17
Water Source		
W-I	0.3	17
W-II	0.1	8
W-III	0.2	17
Water Velocity		
V-I	0.2	17
V-II	0.3	15

Appendix Table F-4. Range and mean of coho salmon juvenile CPUE (catch per minnow trap) by zone at DFH sites on the Susitna River below Devil Canyon, all periods, June through September, 1982.

Zone	Min CPUE	Max CPUE	Mean CPUE	No. of Sites
1	0.0	25.6	1.2	15
2	0.0	18.1	0.9	13
3	0.0	1.4	0.0	17
4	0.0	0.3	0.0	7
5	0.0	1.8	0.9	2
6	0.0	0.7	0.1	5
7	0.0	1.7	0.3	6
8	0.0	0.0	0.0	1
9	0.0	1.9	0.1	5

Aggregate Zone	Mean CPUE	No. of Sites
Hydraulic		
H-I	1.2	15
H-II	0.8	14
H-III	0.0	17
Water Source		
W-I	1.0	17
W-II	0.0	8
W-III	0.1	17
Water Velocity		
V-I	0.6	17
V-II	0.8	15

Appendix Table F-5. Range and mean of rainbow trout CPUE (catch per trotline) by zone at DFH sites on the Susitna River below Devil Canyon, all periods, June through September, 1982.

Zone	Min CPUE	Max CPUE	Mean CPUE	No. of Sites
1	0.0	2.0	0.2	15
2	0.0	4.0	0.3	13
3	0.0	5.0	0.2	17
4	0.0	1.0	0.1	7
5	0.0	0.0	0.0	2
6	0.0	0.0	0.0	5
7	0.0	2.0	0.2	5
8	0.0	0.0	0.0	1
9	0.0	1.0	0.1	4

Aggregate Zone	Mean CPUE	No. of Sites
Hydraulic		
H-I	0.2	15
H-II	0.3	14
H-III	0.2	17
Water Source		
W-I	0.3	17
W-II	0.1	8
W-III	0.2	17
Water Velocity		
V-I	0.2	17
V-II	0.3	14

Appendix Table F-6. Range and mean of burbot CPUE (catch per trotline) by zone at DFH sites on the Susitna River below Devil Canyon, all periods, June through September, 1982.

Zone	Min CPUE	Max CPUE	Mean CPUE	No. of Sites
1	0.0	2.0	0.0	15
2	0.0	5.0	0.3	13
3	0.0	4.0	0.7	17
4	0.0	2.0	0.6	7
5	0.0	0.0	0.0	2
6	0.0	2.0	0.6	5
7	0.0	2.0	0.5	5
8	0.0	0.0	0.0	1
9	0.0	2.0	0.3	4

Aggregate Zone	Mean CPUE	No. of Sites
Hydraulic		
H-I	0.1	15
H-II	0.2	14
H-III	0.7	17
Water Source		
W-I	0.1	17
W-II	0.6	8
W-III	0.6	17
Water Velocity		
V-I	0.5	17
V-II	0.2	14

t test, the mean catch rate of all sites for each pair of aggregate hydraulic zones was tested for significant differences for each of the four species.

The mean catch rate for juvenile chinook salmon was approximately equally balanced between zone H-I and zone H-II; the mean rate for zone H-III was significantly ($p < 0.05$) lower than zone H-II (Appendix Table F-3). Chinook juveniles showed a slight preference for tributary water (W-I) over slough or mainstem water. There was not as strong a preference demonstrated for water velocity aggregates (V-I versus V-II).

Juvenile coho salmon preferred the area above the mainstem backwater zone over the backwater zone itself (Appendix Table F-4). The mean catch rate in the mainstem mixing zone (H-III) was significantly ($p < 0.05$) lower than zone H-I. Coho juveniles strongly preferred tributary water (W-I) over slough or mainstem water (W-II or W-III).

Rainbow trout did not show any strong separation by the aggregate zone categories, but they appeared to least prefer mainstem water (zone W-II) (Appendix Table F-5). Burbot clearly demonstrated a preference for the mainstem mixing zone (H-III), mainstem water (W-II), and higher velocity water (V-I) (Appendix Table F-6). The mean catch rate in zone H-III was significantly ($p < 0.01$) higher than that of zones H-I or H-II.

Results of the chi-square tests performed with the other species are shown in Appendix Tables F-7 to F-10. The distribution of juvenile

Appendix Table F-7. Chi-square tests of association between juvenile salmon presence/absence and aggregate zones at DFH sites, all periods, June through September, 1982.

Aggregate Zone Category	Juvenile Sockeye Salmon		Juvenile Chum Salmon	
	Chi-square	Probability	Chi-square	Probability
Hydraulic zone df=2	18.9	$p < 0.01$	6.3	$p < 0.05$
Water source df=2	9.4	$p < 0.01$	4.5	NS
Velocity df=1	16.3	$p < 0.01$	3.5	NS

Appendix Table F-8. Ratios of observed to expected presence of juvenile sockeye and chum salmon in aggregate zones with significant differences in use.

Aggregate Zone Category	Juvenile Sockeye Salmon	Juvenile Chum Salmon
Hydraulic Zone		
I - Not Mainstem Backwater	0.80	0.96
II - Mainstem Backwater	1.58	1.34
III - Mainstem Mixing Zone	0.52	0.35
Water Source		
I - Tributary	1.11	--
II - Mainstem	1.66	--
III - Mixing	0.65	--
Velocity		
I - Fast	0.65	--
II - Slack	1.51	--

Appendix Table F-9. Chi-square tests of association between resident fish presence/absence and aggregate zones at DFH sites, all periods, June to September, 1982.

Aggregate Zone Category	Round Whitefish		Arctic Grayling		Longnose Sucker		Slimy Sculpin	
	χ^2	Prob.	χ^2	Prob.	χ^2	Prob.	χ^2	Prob.
Hydraulic	22.4	$p < 0.01$	25.2	$p < 0.01$	3.8	NS	0.7	NS
Water Source	25.5	$p < 0.01$	19.8	$p < 0.01$	14.6	$p < 0.01$	0.0	NS
Velocity	1.3	NS	11.6	$p < 0.01$	2.9	NS	0.6	NS

Appendix Table F-10. Ratios of observed to expected presence of resident fish by species in aggregate zones. Only those ratios from significant chi-square tests are presented.

Aggregate Zone Category	Round Whitefish	Arctic Grayling	Longnose Sucker
Hydraulic			
I - Not Mainstem Backwater	0.46	0.68	--
II - Mainstem Backwater	0.82	0.19	--
III - Mainstem Mixing Zone	1.74	2.24	--
Water Source			
I - Tributary	0.43	0.29	0.70
II - Mainstem	1.48	0.89	2.86
III - Mixing	1.58	1.95	0.80
Velocity			
I - Fast	--	1.51	--
II - Slack	--	0.25	--

sockeye salmon was significantly associated with aggregate zone type for all three zone groupings (Appendix Table F-7). Juvenile chum salmon showed a significant association with the aggregate hydraulic (H) zones, but no association with aggregate water source (W) zones or aggregate velocity (V) zones. Ratios of observed to expected presence for those associations that were found to be significant (Appendix Table F-8) indicate that both species preferred the mainstem backwater zone (zone H-II) over adjacent zones. Sockeye salmon juveniles showed a preference for slow water, originating from the mainstem.

The preference shown by juvenile sockeye salmon for the mainstem backwater zone, rather than the higher velocity areas above and below this zone, is probably related to the common use of lakes for rearing by this species. Chum salmon juveniles, which also were more likely to occur in the mainstem backwater zone than in other zones, did not show as strong an association as did sockeye. The tendency of sockeye salmon juveniles to be present in mainstem rather than tributary water was not always shared by chum salmon juveniles which were also captured in tributaries as they outmigrated from tributary spawning grounds.

Slimy sculpin showed no significant associations with any of the aggregate zones (Appendix Table F-9). In other words, the likelihood of capture for this species was equal in all of the zones. The distribution of Arctic grayling was significantly associated with particular zones within all three of the zone groupings. Water source was of importance to round whitefish and longnose sucker; hydraulic zone mattered to round whitefish. Ratios of observed to expected presence

(Appendix F-10) shows a preference of round whitefish and Arctic grayling at these sites for mixing water, rather than for pure tributary or mainstem water. Longnose sucker clearly preferred mainstem water. Arctic grayling also showed a preference for fast water over slack water.

Round whitefish and Arctic grayling were frequently captured in the mainstem just below the confluence of tributary mouths and were less commonly captured in sloughs or in tributaries just above the mouth. This distributional pattern is reflected in the observed association with a mixed water source with a relatively high velocity.

Correlation of Fish Abundance and Habitat Variables

Juvenile chinook salmon abundance showed a good correlation with water temperature, but not with turbidity or water velocity (Appendix Table F-11). The abundance of juvenile coho salmon did not show any relationship with temperature but was negatively related to turbidity. The capture rate for burbot was strongly correlated with turbidity. Rainbow trout capture rates did not exhibit significant correlations with any of the three habitat variables.

Turbidity was a strong factor influencing fish distributions in this study. Rearing coho salmon apparently avoided turbid water while burbot were captured almost exclusively in turbid areas. These preferences were probably related to differences in feeding behavior of the two species. Juvenile chinook salmon apparently were attracted to warm

Appendix Table F-11. Correlation matrix for four species of fish and three habitat variables by individual habitat zone (7 cases for each variable).

		TMP	TRB	VEL	CHN	COH	RBT	BRB
Temperature	(TMP)	1.00						
Turbidity	(TRB)	0.15	1.00					
Velocity	(VEL)	-0.35	0.11	1.00				
Juvenile Chinook	(CHN)	0.82*	-0.04	0.04	1.00			
Juvenile Coho	(COH)	0.07	-0.76*	0.14	0.33	1.00		
Rainbow Trout	(RBT)	0.27	-0.56	0.10	0.39	0.61	1.00	
Burbot	(BRB)	0.13	0.90*	-0.03	-0.19	-0.86*	-0.36	1.00

* = correlation significant at 95% level

water areas; none of the other three species showed such a tendency, although the sign was positive for all four species. Zone water velocity was not a factor for any of these species.

Relationship of a Habitat Index and Mainstem Discharge

Zone quality indices

Zone quality indices (ZQI) calculated for the aggregate hydraulic zones for four species of juvenile salmon for each of the two reaches are given in Appendix Table F-12. The value shown is the mean of the seasonal ZQI's of all the sampling sites in the reach where the data from at least one sampling period met the criteria explained in the methods section.

Chinook salmon apparently do not have strong preferences between the backwater areas (zone H-II) and the free-flowing areas above the backwater zone (zone H-I), as the mean ZQI's are fairly evenly balanced. There is a slight preference shown for zone H-I. Chinook also show more association with the mixing zone (zone H-III) below the backwater area than other juvenile salmon species. These results suggest that chinook juveniles are associated with broader ranges of habitat parameters than the other species. Similar results were obtained when examining chinook distribution among the major habitat types (tributary mouths, upland sloughs, and so on) in Appendix G.

Appendix Table F-12. Range and mean zone quality indices (ZQI) for aggregate hydraulic zones by reach by species, June through September, 1982. The means are the mean of the seasonal ZQI's for all the sites in the reach. The sample size (n) equals the number of sites included in calculating the mean.

ZQI-Lower reach

Species	Zone H-I Min	Max	Mean	n	Zone H-II Min	Max	Mean	n	Zone H-III Min	Max	Mean	n
Chinook	0.49	0.71	0.59	4	0.46	0.66	0.53	4	0.32	0.32	0.32	1
Coho	0.71	0.88	0.82	3	0.18	0.45	0.32	3	0.00	0.05	0.02	3
Sockeye	0.00	0.00	0.00	1	1.00	1.00	1.00	1	-	-	-	-
Chum	0.28	0.67	0.54	3	0.33	0.72	0.57	3	0.00	0.00	0.00	1

ZQI-Upper reach

Species	Zone H-I Min	Max	Mean	n	Zone H-II Min	Max	Mean	n	Zone H-III Min	Max	Mean	n
Chinook	0.52	0.52	0.52	1	0.48	0.48	0.48	1	0.00	0.00	0.00	1
Coho	0.94	1.00	0.97	3	0.04	1.00	0.40	3	0.00	0.03	0.01	4
Sockeye	0.00	1.00	0.59	6	0.33	1.00	0.70	5	0.00	0.50	0.20	6
Chum	0.00	0.33	0.29	4	0.67	1.00	0.88	5	0.00	0.00	0.00	3

Coho salmon showed the strongest association of all the species for the area above the backwater zone (zone H-I). If the nine separate habitat zones had been aggregated using water source as a criterion rather than mainstem backup, a strong preference by coho for tributary water would have been evident. This kind of aggregation would separate the turbid H-I area of sloughs with a mainstem water source (zone 4) from the clear water H-I area of tributaries (zone 1). Very few juvenile coho salmon were caught in zone H-III. There was one site in the upper reach (Slough 6A) which never had a zone H-I present during the samplings. All the coho salmon caught at the site were in zone H-II; none were caught in zone H-III. This is the reason for the maximum ZQI of 1.00 in zone H-II for coho in the upper reach.

All of the sockeye salmon present at the one site in the lower reach which met the previously defined criteria were caught in zone H-II. In the upper reach, a preference for zone H-II is apparent. However, there was at least one site where all the sockeye present were in zone H-I, leading to the maximum value of 1.00 for that zone. Field observations indicated that the sockeye present in zone H-I were often associated with the small calm water morphological pools present in these areas. This was the case in sites such as Slough 8A and Slough 19. If point-specific data were available for sockeye juveniles, they would probably show a very strong preference by sockeyes for low-velocity water.

Chum salmon in the lower reach were approximately equally divided between zone H-I and zone H-II, with a slight preference shown for the latter. A strong preference for zone H-II was shown in the upper reach. Chum salmon were rarely caught in zone H-III. Although chum salmon juveniles showed a preference for the mainstem backwater zone (zone H-II), there were several cases where they were present in zone H-I. Juvenile chum salmon were captured in tributaries (zone I) during outmigration from tributary spawning grounds (as at Goose Creek). Also, they were frequently present in sloughs above the backwater zones (zone 4), having emerged from nearby redds (Slough 11) or having entered the slough head during outmigration.

Zone and site habitat indices

We have included in this report plots of the zone and site habitat indices as a function of mainstem discharge at three or four sites for each of the four salmon species. The sites selected in each case were among the top four or five in total catch for the season for the species and had zone quality indices which were typical for that species among the several sites in the reach. Together, the graphs include all the major habitat types, represent both reaches, and illustrate all the main points which result from this kind of analysis.

The shape of the zone habitat index curves for the mainstem backwater zone (zone H-II) resembles the shape of the mainstem backwater surface area curves (see Appendix E of this report) because the zone habitat index is a multiple of surface area. There are slight differences because the surface area curves (Appendix E) were plotted from the raw data, while the zone habitat indices used surface area values extracted from these curves at evenly spaced increments of mainstem discharge. The shape of the site habitat index curves do not usually resemble the shape of the total wetted surface area curves (shown in Appendix E) because zones H-I and H-II are given different weighting factors (the ZQI) and because there are small differences resulting from interpolation of the raw surface area versus discharge curves at incremental discharge levels.

Many of the zone habitat index curves have a steeper slope at lower discharges than at higher discharges. This results from the greater effect of a given change in discharge on zone surface area at lower discharges than at higher discharges.

Juvenile chinook salmon

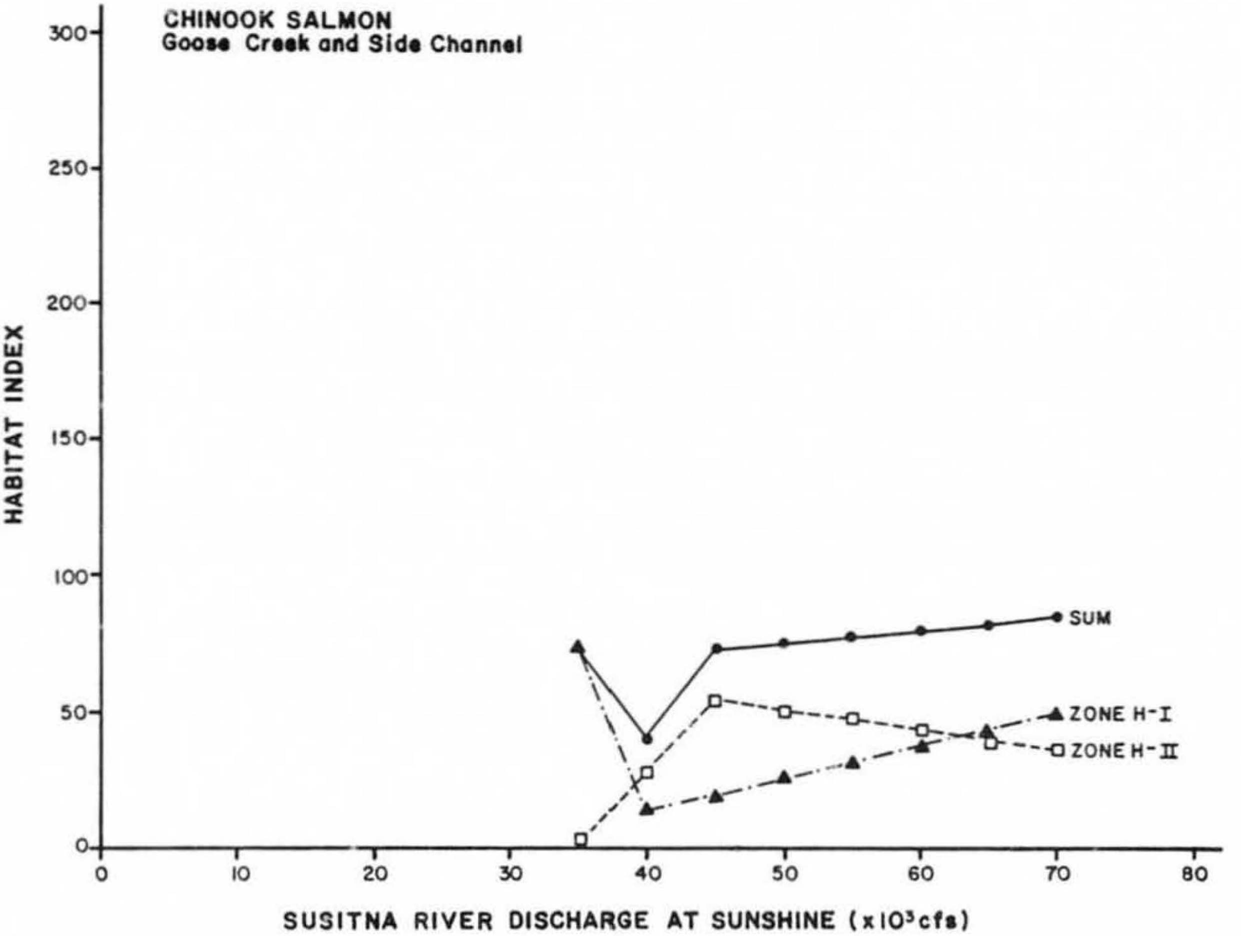
Zone and site habitat indices for juvenile chinook salmon were calculated for three sites in the lower reach and one site in the upper reach (Appendix Table F-13). The zone quality index for juvenile chinook salmon at three of the four sites selected was close to 0.5 for both zones. Rabideux Creek and Slough had a higher ZQI in the H-I area.

The site habitat index at the Goose Creek and Side Channel site (Appendix Figure F-3) shows a steady decrease with a decrease in discharge until discharge drops to about 40,000 - 45,000 cfs. At this point, the head of the slough closed, the H-II area began to decrease, and the tributary section of the H-I area moved out into the slough channel. For a more detailed explanation of the hydraulics of these

Appendix Table F-13. Habitat indices for juvenile chinook salmon for aggregate hydraulic zones at four sites, June through September, 1982.

Susitna Discharge at Sunshine (cfs)	Goose Creek and Side Channel Zone H-I (ZQI=0.54)	Goose Creek and Side Channel Zone H-II (ZQI=0.46)	Goose Creek and Side Channel Site Habitat Index (ΣHI)	Rabideux Creek and Slough Zone H-I (ZQI=0.71)	Rabideux Creek and Slough Zone H-II (ZQI=0.48)	Rabideux Creek and Slough Site Habitat Index (ΣHI)	Birch Creek and Slough Zone H-I (ZQI=0.49)	Birch Creek and Slough Zone H-II (ZQI=0.51)	Birch Creek and Slough Site Habitat Index (ΣHI)
35,000	73	0	73	355	238	593	144	43	187
40,000	13	27	40	142	396	538	105	75	180
45,000	19	54	73	121	422	543	104	77	181
50,000	25	50	75	99	448	547	103	78	181
55,000	31	47	79	78	474	552	74	115	189
60,000	37	43	80	57	499	556	15	186	201
65,000	43	39	82	36	523	559	15	193	208
70,000	49	36	85	14	552	566	15	196	211

Susitna Discharge at Gold Creek (cfs)	Whiskers Creek and Slough Zone H-I (ZQI=0.52)	Whiskers Creek and Slough Zone H-II (ZQI=0.48)	Whiskers Creek and Slough Site Habitat Index (ΣHI)
12,500	73	14	87
15,000	74	18	92
17,500	71	25	96
20,000	69	32	101
22,500	66	39	105
25,000	69	40	109
27,500	70	40	110

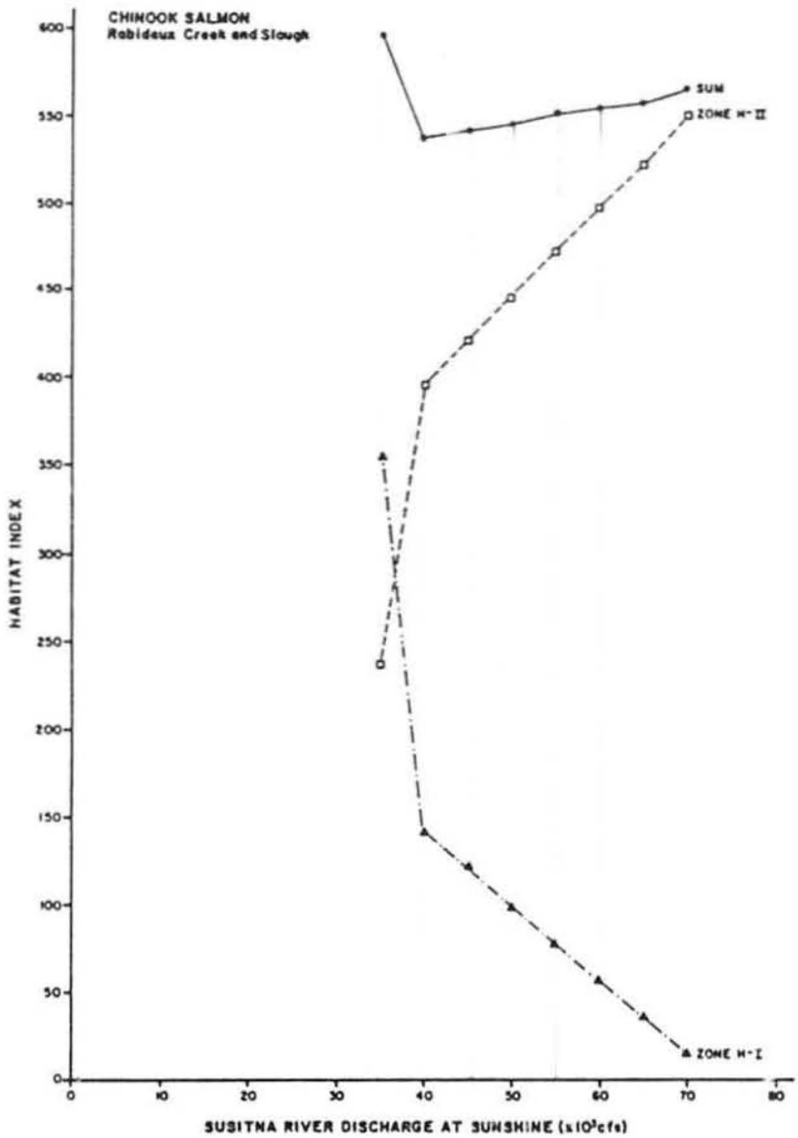


Appendix Figure F-3. Zone and site habitat indices for juvenile chinook salmon at Goose Creek and Side Channel study site as a function of mainstem discharge, June through September, 1982.

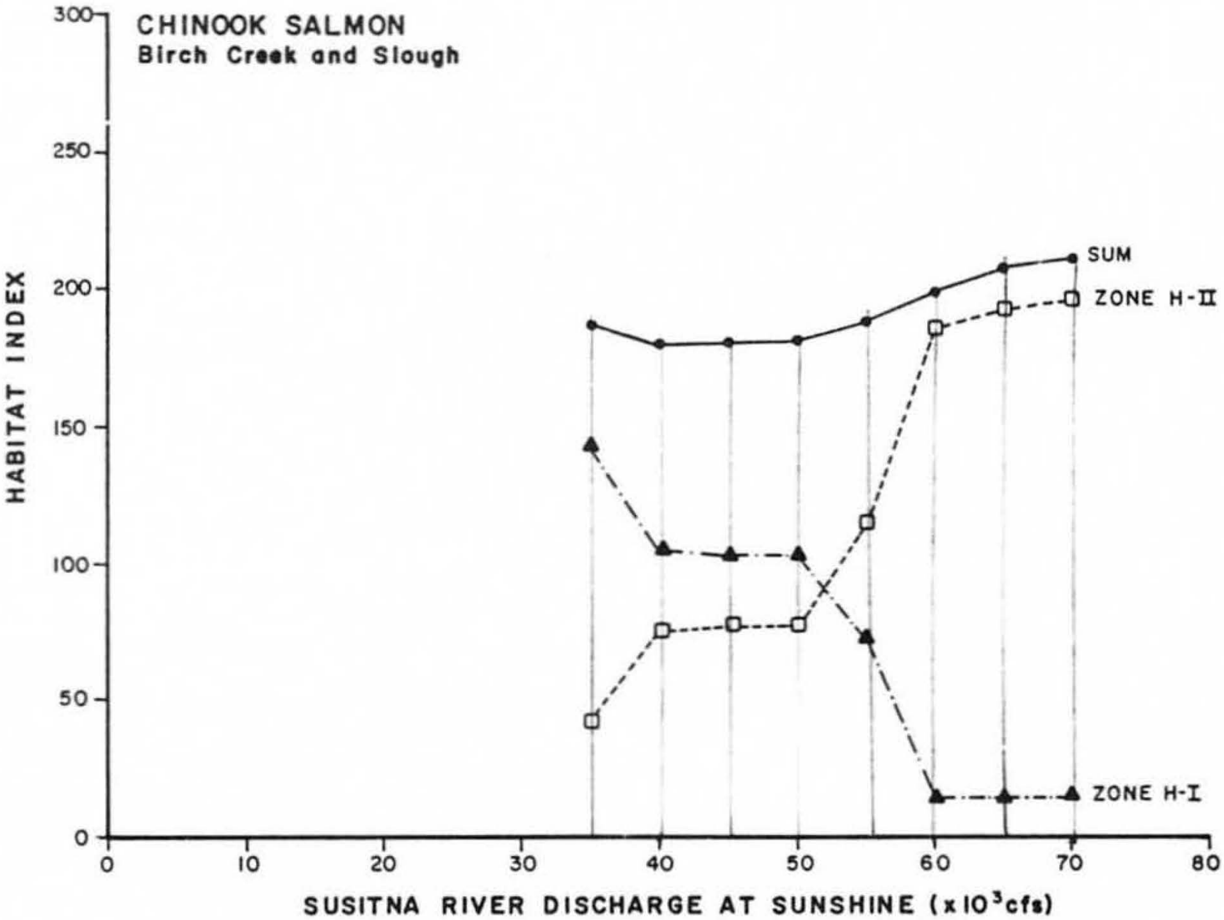
sites, refer to Appendix E of this report and Volume 4, Part I, Section 3.1.3.1 of the Basic Data Report (ADF&G 1983b).

Large changes in surface area occurred in both zones at the Rabideux Creek and Slough site with changes in mainstem discharge, but the site habitat index remained relatively constant (Appendix Figure F-4). As mainstem discharge decreased from the maximum observed, the mainstem backwater zone (H-II) receded and was replaced by the tributary (H-I) zone. Because the tributary area was better habitat than the backwater area for rearing chinooks, the site habitat index is highest at the lowest discharge observed. At about 40,000 cfs, a large pond-like pool (included in zone H-II) which had been backed up by mainstem stage at greater flows was no longer affected by mainstem stage and became zone H-I. However, the pond-like area remained (although at a lower level) as a zone 9 (morphological pool) within the aggregate zone H-I and probably did not undergo a great deal of change with regard to the quality of habitat.

The pattern shown at the Birch Creek and Slough site (Appendix Figure F-5) was typical for juvenile chinook salmon at several of the sampling sites. With an increase in mainstem discharge, the habitat index for zone H-I decreases, and then levels off; the habitat index for zone H-II does exactly the opposite. The site habitat index (sum of the habitat index for the two zones) gradually increases with an increase in mainstem discharge because of increasing total wetted surface area. Because the seasonal zone quality indices for the two zones at Birch Creek and Slough for chinook salmon were fairly similar (Appendix Table



Appendix Figure F-4. Zone and site habitat indices for juvenile chinook salmon at the Rabideux Creek and Slough study site as a function of mainstem discharge, June through September, 1982.



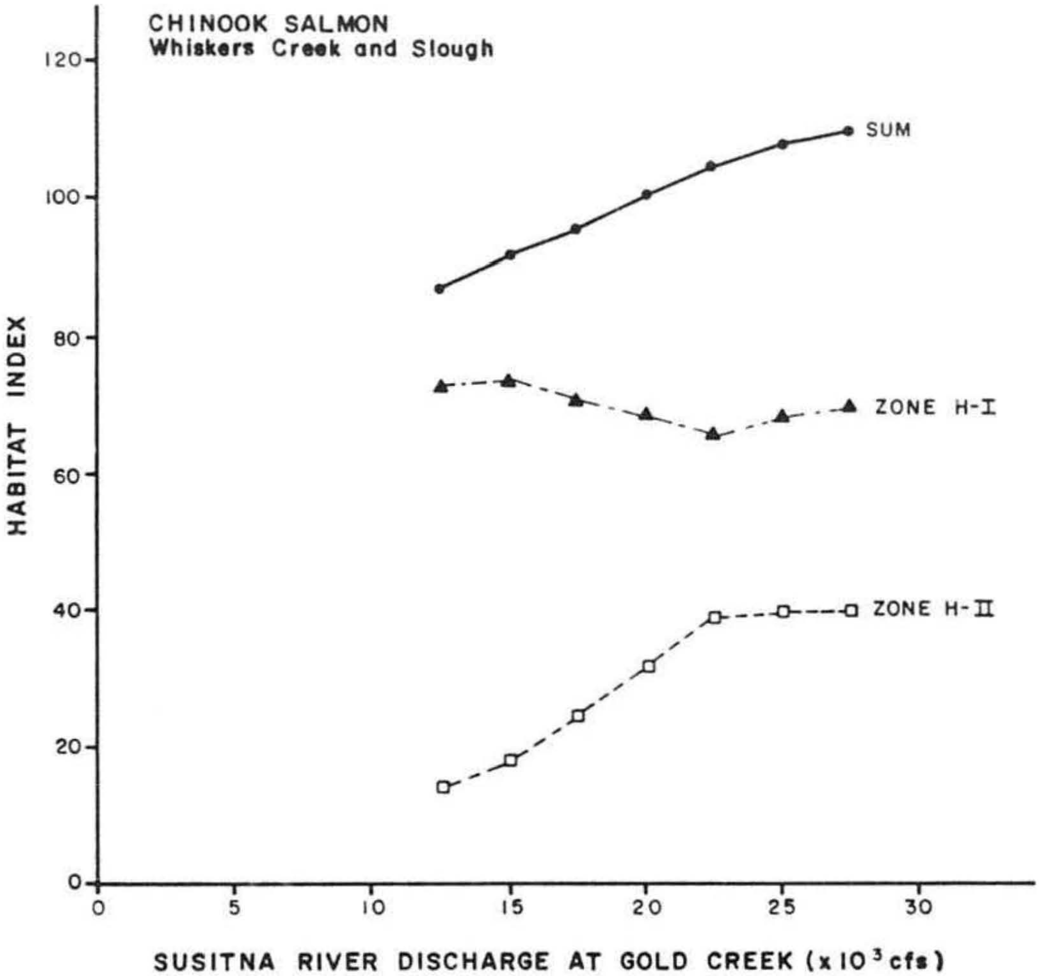
Appendix Figure F-5. Zone and site habitat indices for juvenile chinook salmon at the Birch Creek and Slough study site as a function of mainstem discharge, June through September, 1982.

F-13), both zones had nearly equal weight in compiling the site habitat index. If the ZQI for each zone had been equal to 0.5, which means that chinook salmon showed no preference for either zone over the other, then the shape of the site habitat index curve would be similar to the shape of the total wetted surface area. In this case, if one zone decreased in areal extent, the fish would simply move to the other zone. In fact, the fish might remain where they were, but the zone designation (and habitat characteristics) at that location would change. The site habitat index would decrease as the total wetted surface area decreased.

The site habitat index for chinook salmon at the Whiskers Creek and slough site shows a steady increase with increasing discharge (Appendix Figure F-6). The shape of the zone H-II curve is typical for sites in the reach in that it steadily increases with an increase in mainstem discharge and then levels off. The zone H-I surface area curve is relatively flat. At the lower discharge levels, the length of zone H-I increased (downstream) as the backwater zone (zone H-II) receded. At the same time, however, the width of zone H-I was decreasing. The net result of the two was a slight increase in zone H-I surface area as discharge decreased below about 22,000 cfs.

Juvenile Coho Salmon

Juvenile coho salmon showed a strong preference for zone H-I at all of the sites (Appendix Table F-14). This preference was least apparent at the Sunshine Creek and Side Channel site, where the zone H-II area was not greatly different from the zone H-I area in physical and habitat



Appendix Figure F-6. Zone and site habitat indices for juvenile chinook salmon at the Whiskers Creek and Slough study site as a function of mainstem discharge, June through September, 1982.

Appendix Table F-14. Habitat indices for juvenile coho salmon for aggregate hydraulic zones at three sites, June through September, 1982.

	Sunshine Creek and Slough			Birch Creek and Slough		
Susitna Discharge at Sunshine (cfs)	Zone H-I (ZQI=0.71)	Zone H-II (ZQI=0.45)	Site Habitat Index (ΣHI)	Zone H-I (ZQI=0.88)	Zone H-II (ZQI=0.18)	Site Habitat Index (ΣHI)
35,000	99	11	110	245	15	260
40,000	87	25	112	194	26	220
45,000	74	39	113	197	27	224
50,000	62	53	115	200	28	228
55,000	59	67	126	142	40	182
60,000	60	80	140	26	66	92
65,000	98	58	156	19	68	87
70,000	106	54	160	18	69	87

	Lane Creek and Slough 8		
Susitna Discharge at Gold Creek (cfs)	Zone H-I (ZQI=0.94)	Zone H-II (ZQI=0.17)	Site Habitat Index (ΣHI)
12,500	18	1	19
15,000	19	2	21
17,500	20	2	22
20,000	21	2	23
22,500	21	3	24
25,000	7	8	15
27,500	2	8	10

Appendix Table F-14. Habitat indices for juvenile coho salmon for aggregate hydraulic zones at three sites, June through September, 1982.

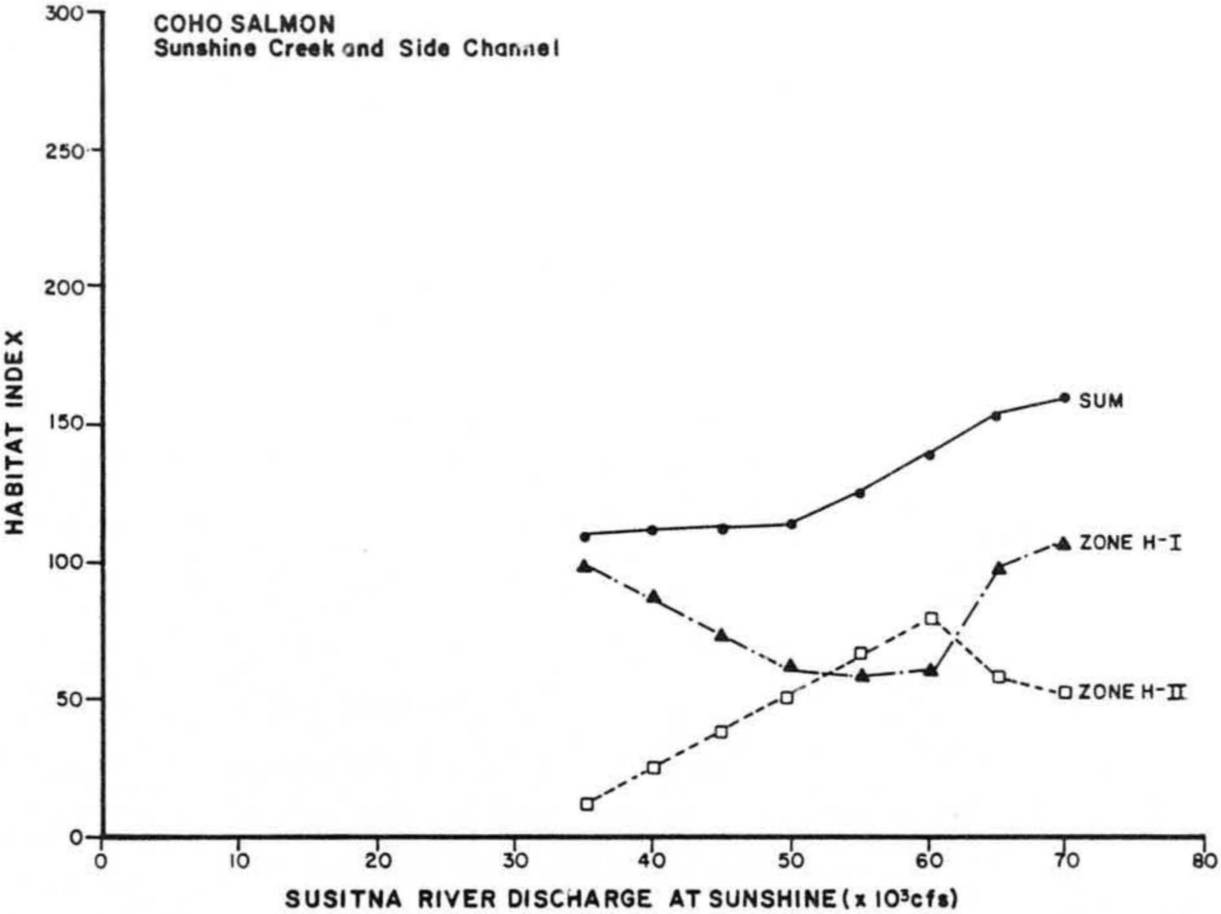
Susitna Discharge at Sunshine (cfs)	Sunshine Creek and Slough			Birch Creek and Slough		
	Zone H-I (ZQI=0.71)	Zone H-II (ZQI=0.45)	Site Habitat Index (ΣHI)	Zone H-I (ZQI=0.88)	Zone H-II (ZQI=0.18)	Site Habitat Index (ΣHI)
35,000	99	11	110	245	15	260
40,000	87	25	112	194	26	220
45,000	74	39	113	197	27	224
50,000	62	53	115	200	28	228
55,000	59	67	126	142	40	182
60,000	60	80	140	26	66	92
65,000	98	58	156	19	68	87
70,000	106	54	160	18	69	87

Susitna Discharge at Gold Creek (cfs)	Lane Creek and Slough 8		
	Zone H-I (ZQI=0.94)	Zone H-II (ZQI=0.17)	Site Habitat Index (ΣHI)
12,500	18	1	19
15,000	19	2	21
17,500	20	2	22
20,000	21	2	23
22,500	21	3	24
25,000	7	8	15
27,500	2	8	10

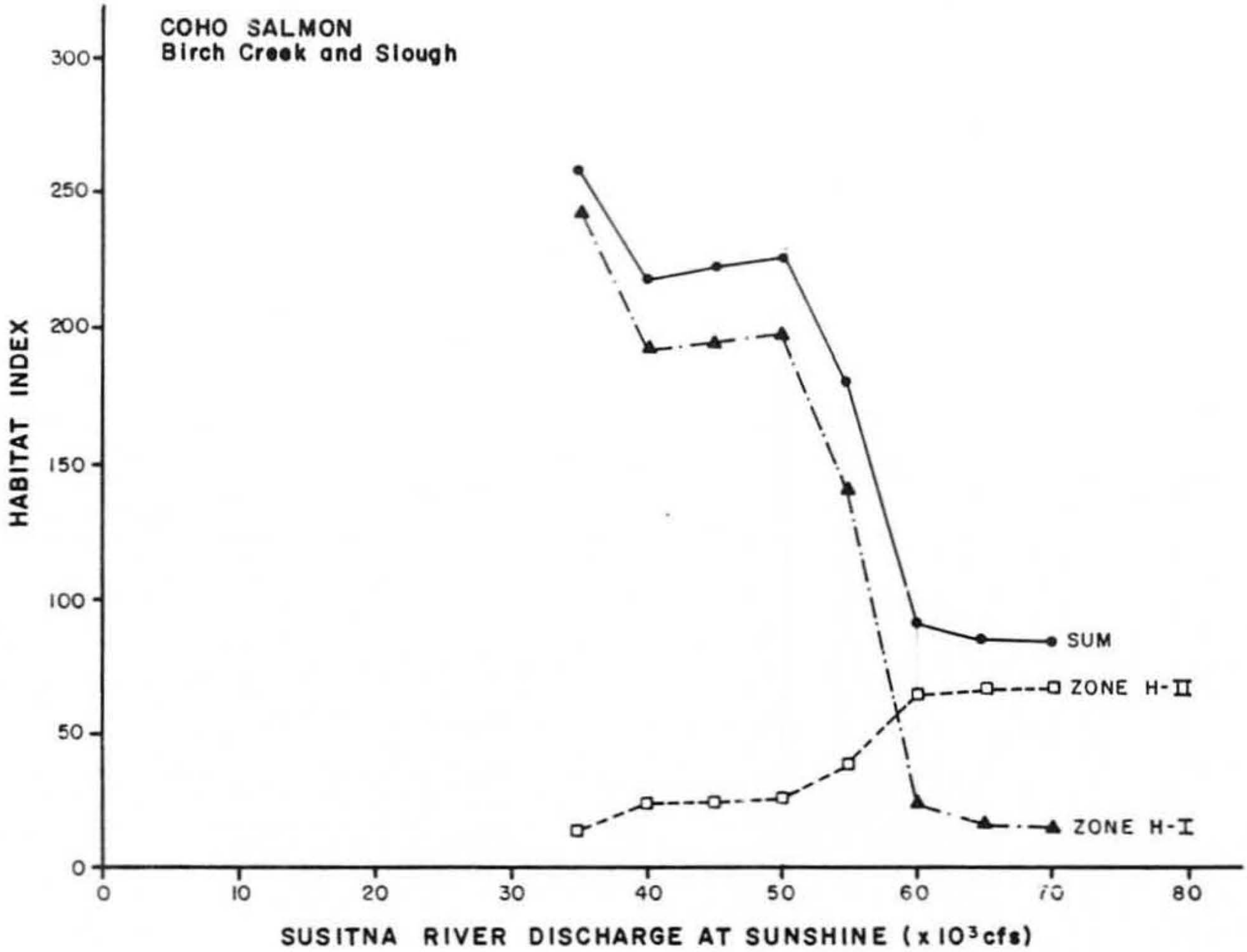
characteristics. Both areas had a low gradient, abundant aquatic vegetation for cover, and provided excellent habitat for rearing coho salmon. As a result, the habitat index for zone H-II has a greater weight than at other sites and the site habitat index shows a steady increase with increasing mainstem discharge (Appendix Figure F-7). This situation was not typical for coho at most other sites.

The shape of the coho salmon habitat index curves for zones H-I and H-II at the Birch Creek and Slough site reflect a pattern which was more common for the study sites (Appendix Figure F-8). With increasing mainstem discharge, the zone H-I habitat index decreases and then levels off while the zone H-II habitat index increases and then also levels off. The zone H-I surface area decreases because the zone H-II (backwater area) encroaches upon it as mainstem discharge level increases. Because zone H-I was strongly preferred by coho salmon (Appendix Table F-14), the site habitat index curve is heavily weighted by the zone H-I habitat index and the two curves have a similar shape (Appendix Figure F-8). Basically, this means that a loss of zone H-I reflects an important loss of habitat for coho salmon at this site, because they apparently do not have the capability of compensating for a decrease in zone H-I surface area by moving into zone H-II.

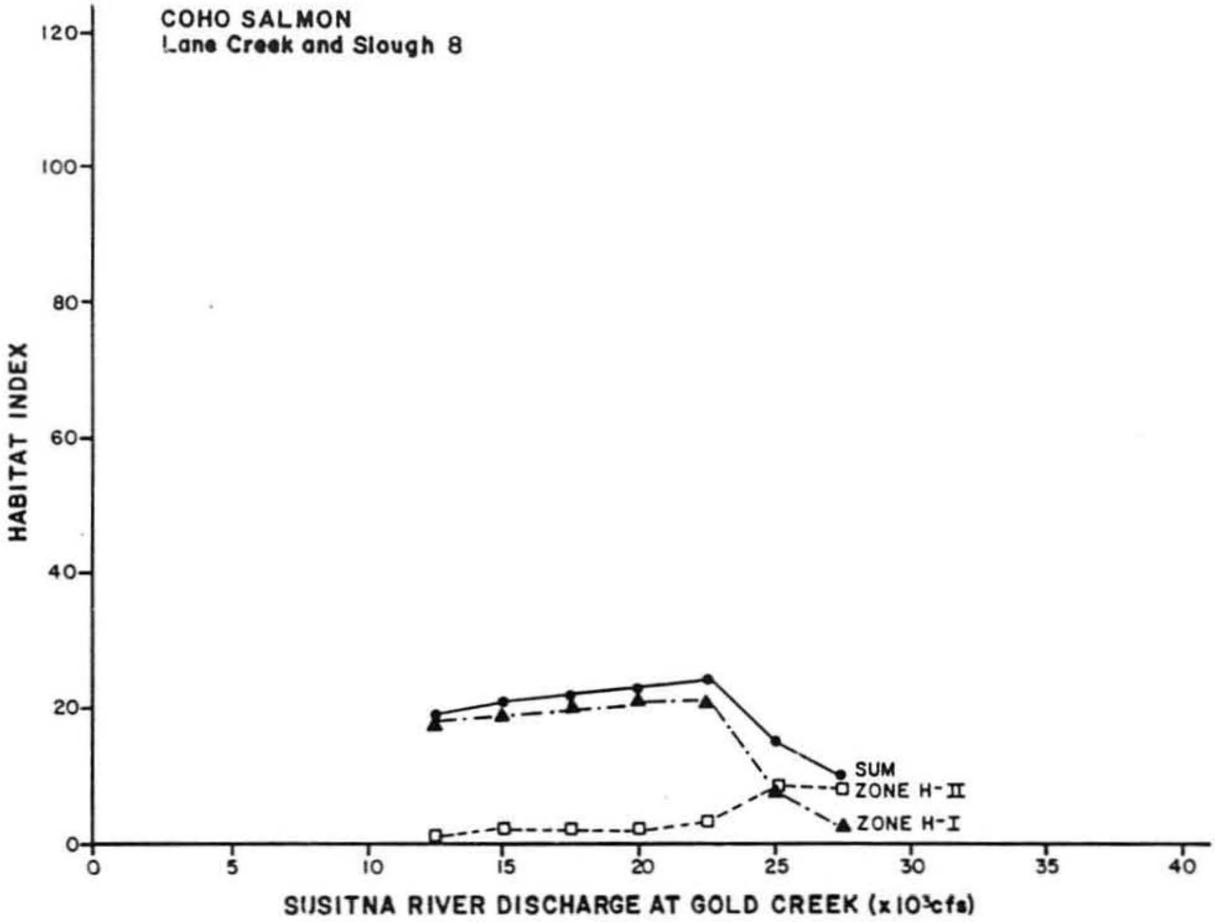
The site habitat index at the Lane Creek and Slough 8 site closely parallels the habitat index for zone H-I because of the strong weighting given zone H-I by the ZQI (Appendix Figure F-9). The changes at about 25,000 cfs were related to the breaching of the slough head at this discharge level.



Appendix Figure F-7. Zone and site habitat indices for juvenile coho salmon at the Sunshine Creek and Side Channel study site as a function of discharge, June through September, 1982.



Appendix Figure F-8. Zone and site habitat indices for juvenile coho salmon at the Birch Creek and Slough study site as a function of discharge, June through September, 1982.



Appendix Figure F-9. Zone and site habitat indices for juvenile coho salmon at the Lane Creek and Slough 8 study site as a function of mainstem discharge, June through September, 1982.

Juvenile sockeye salmon

Juvenile sockeye salmon at most of the sites showed a strong preference for zone H-II, a preference opposite that of rearing coho salmon. However, as mentioned previously, there were several sites where sockeye juveniles also occurred in small low velocity pools within zone H-I. At Slough 19, this occurred often enough so that the ZQI for zone H-I was greater than that of zone H-II (Appendix Table F-15). The sockeye ZQI at the Birch Creek and Slough site and the Slough 8A site were more typical.

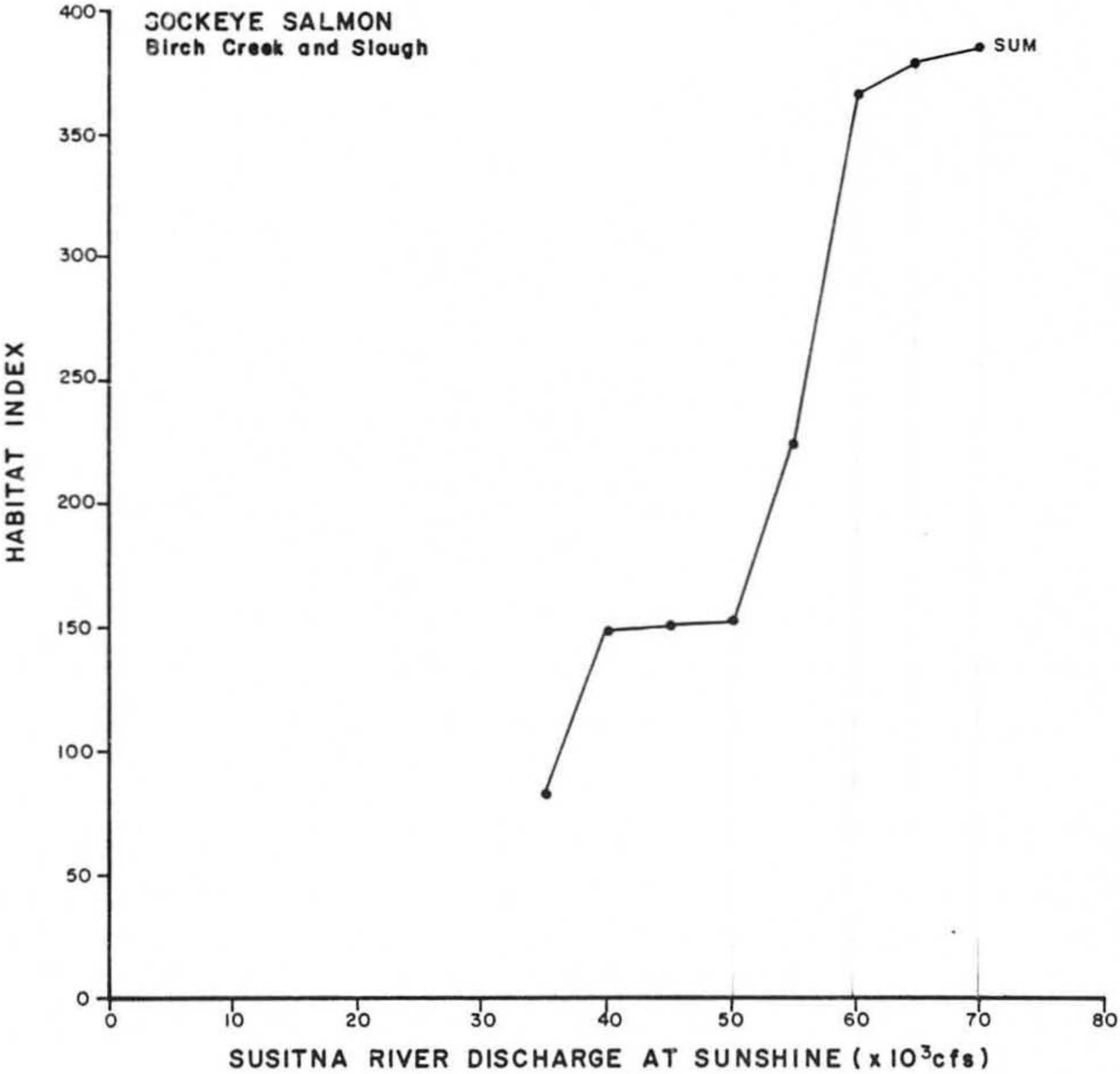
Because the ZQI for zone H-I at Birch Creek and Slough was equal to zero, the site habitat index was equal to the habitat index for zone H-II (Appendix Figure F-10). As the mainstem backwater area increased with an increase in mainstem discharge, the value of the site increased for rearing sockeye salmon.

Juvenile sockeye salmon at Slough 8A preferred the zone H-II area (ZQI = 0.66) over the zone H-I area (ZQI = 0.55) (Appendix Table F-15). This, along with the fact that the surface area of the zone H-I area changed very little with variation in discharge, gave a site habitat index for Slough 8A for sockeye salmon which closely resembled the shape of the zone H-II habitat index (Appendix Figure F-11). The flatness of the zone H-I curve at Slough 8A is in part due to the gradually sloping banks of the H-II zone at Slough 8A. The increasing backwater area

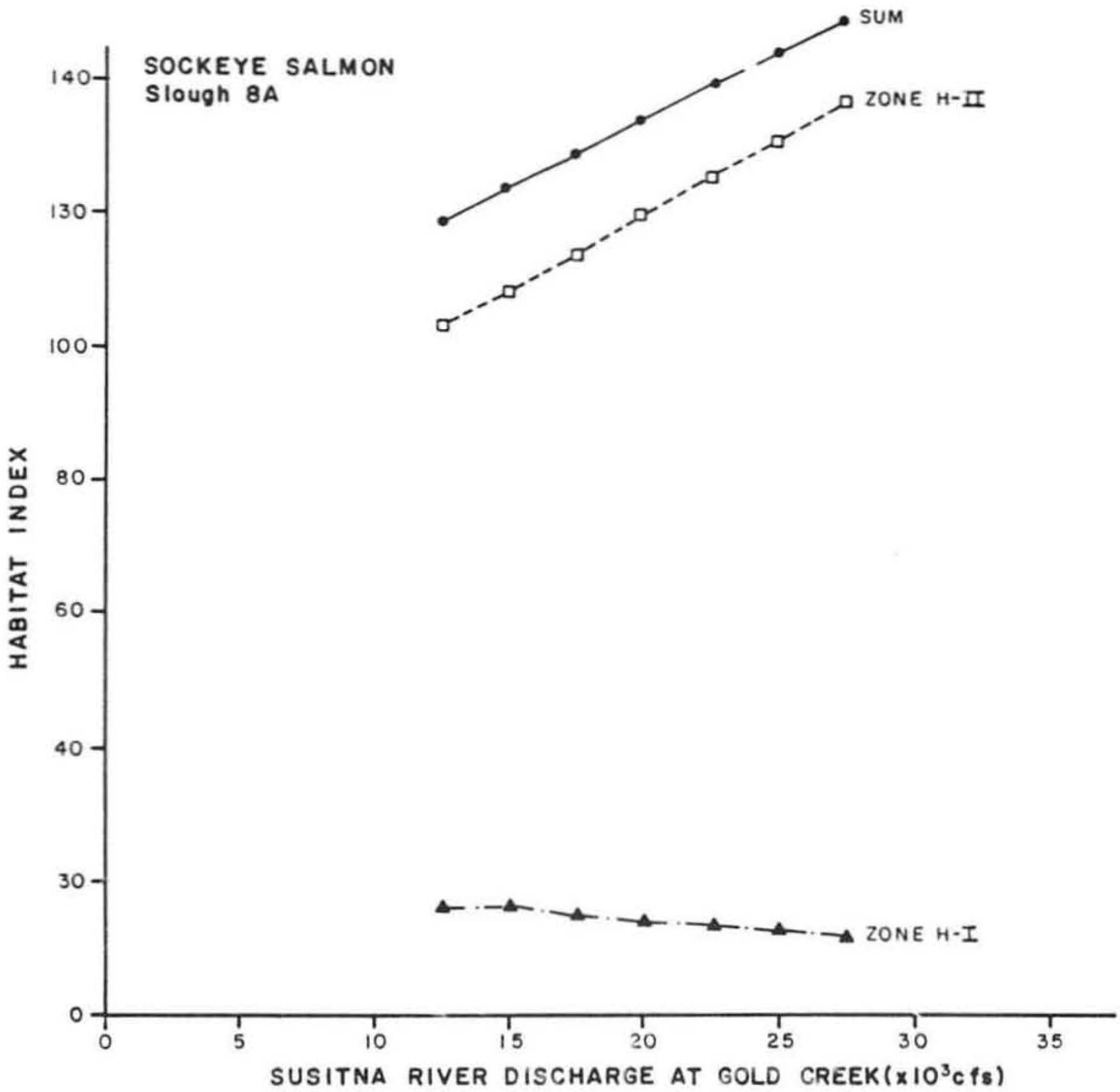
Appendix Table F-15. Habitat indices for juvenile sockeye salmon for aggregate hydraulic zones at three sites, June through September, 1982.

	Birch Creek and Slough		
Susitna Discharge at Sunshine (cfs)	Zone H-I (ZQI=0.0)	Zone H-II (ZQI=1.00)	Site Habitat Index (ΣHI)
35,000	0	84	84
40,000	0	147	147
45,000	0	150	150
50,000	0	153	153
55,000	0	225	225
60,000	0	365	365
65,000	0	378	378
70,000	0	385	385

	Slough 8A			Slough 19		
Susitna Discharge at Gold Creek (cfs)	Zone H-I (ZQI=0.55)	Zone H-II (ZQI=0.66)	Site Habitat Index (ΣHI)	Zone H-I (ZQI=1.00)	Zone H-II (ZQI=0.33)	Site Habitat Index (ΣHI)
12,500	16	103	119	11	1	12
15,000	16	108	124	14	0	14
17,500	15	114	129	3	3	6
20,000	14	120	134	3	4	7
22,500	14	125	139	3	4	7
25,000	13	131	144	0	9	9
27,500	12	137	149	0	9	9



Appendix Figure F-10. Zone and site habitat indices for juvenile sockeye salmon at the Birch Creek and Slough study site as a function of mainstem discharge, June through September, 1982.



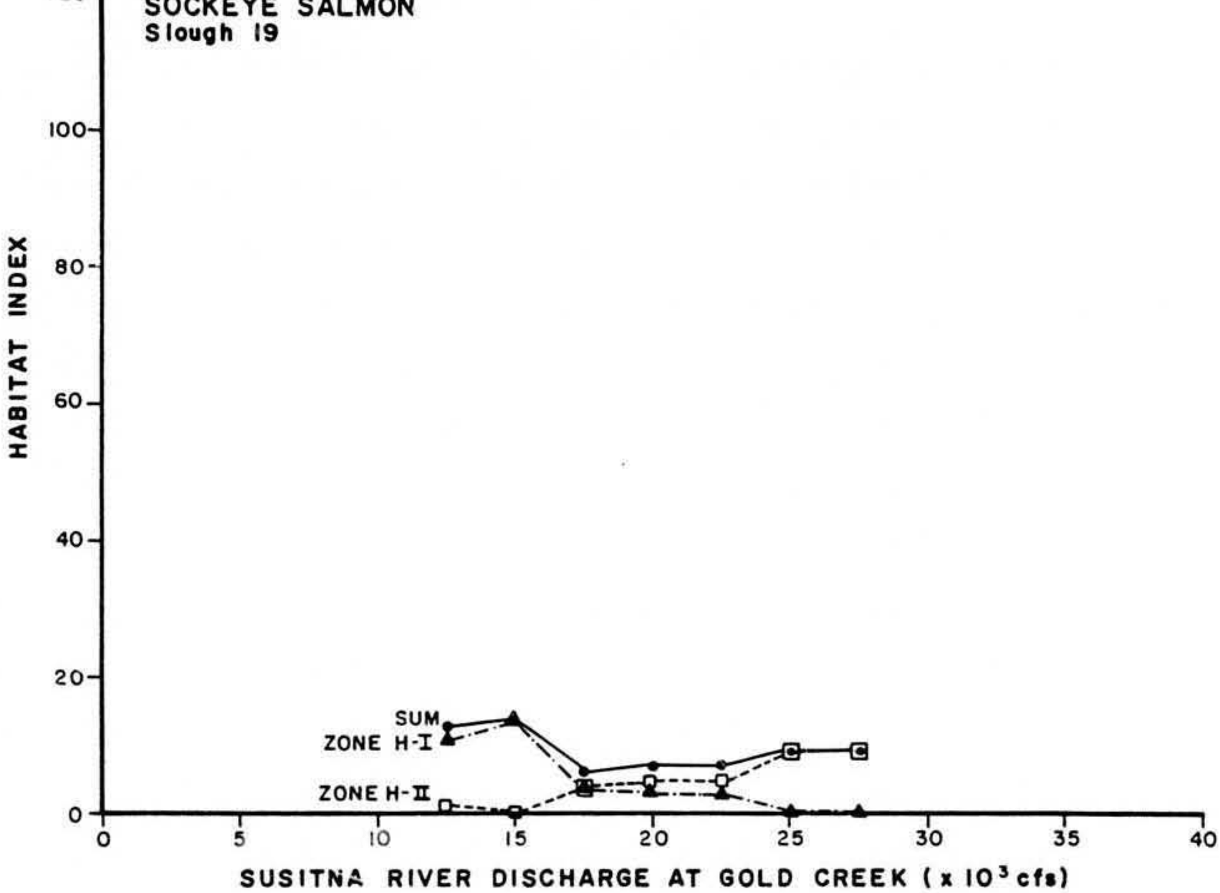
Appendix Figure F-11. Zone and site habitat indices for juvenile sockeye salmon at the Slough 8A study site as a function of mainstem discharge, June through September, 1982.

caused by an increasing mainstem discharge was absorbed by these low gradient banks and the H-I area was not greatly encroached upon.

The site habitat index at Slough 19 is atypical of the sites in that rearing sockeye salmon at this site were frequently captured in zone H-I in greater numbers than in zone H-II and the resulting site habitat index does not resemble the shape of the H-II habitat index (Appendix Figure F-12). A hydraulic situation occurred at Slough 19 which was similar to what occurred at Rabideux Creek and Slough (as discussed for juvenile coho salmon). Early in the season, juvenile sockeye were present in an area of the slough which was backed up by the mainstem (hence, this was zone H-II). As the flow decreased, the slack water area no longer resulted from mainstem stage, yet it continued to exist in the same area because of a morphological control at the mouth of the slough. The rearing sockeye also remained in this area, now designated zone H-I. These events are reflected in Appendix Figure F-12. Aggregating the individual habitat zones using water velocity as a criterion, rather than the presence of a mainstem backwater zone, would group both slack water areas, regardless of the causative factor.

Juvenile chum salmon

Juvenile chum salmon always preferred the zone H-II area at the selected sites (Appendix Table F-16); this was typical of most of the fourteen sites sampled. As a result, the site habitat indices closely resemble the shape of the habitat indices for zone H-II (Appendix Figures F-13 to F-15). The results at Birch Creek and Slough in the lower reach

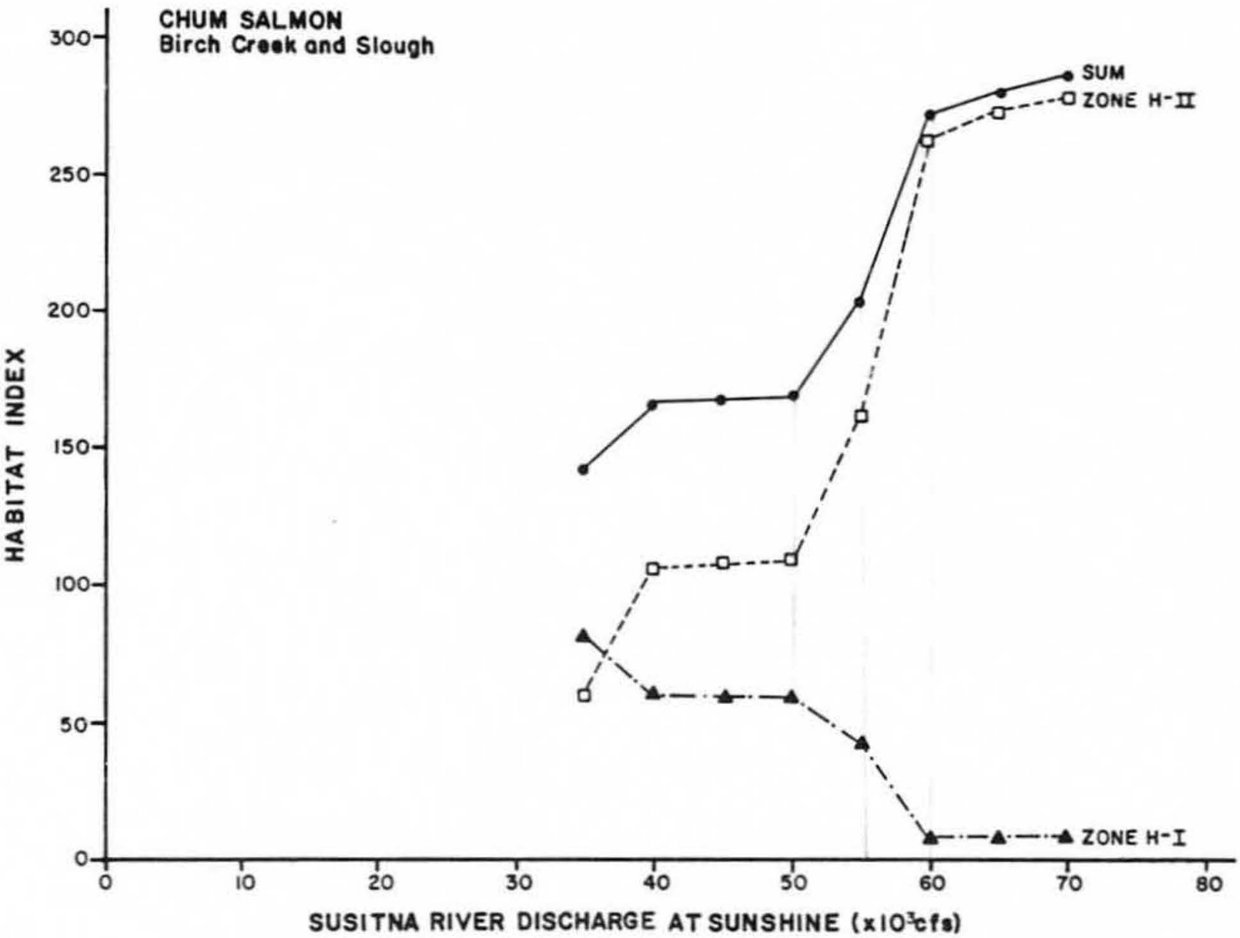


Appendix Figure F-12. Zone and site habitat indices for juvenile sockeye salmon at the Slough 19 study site as a function of mainstem discharge, June through September, 1982.

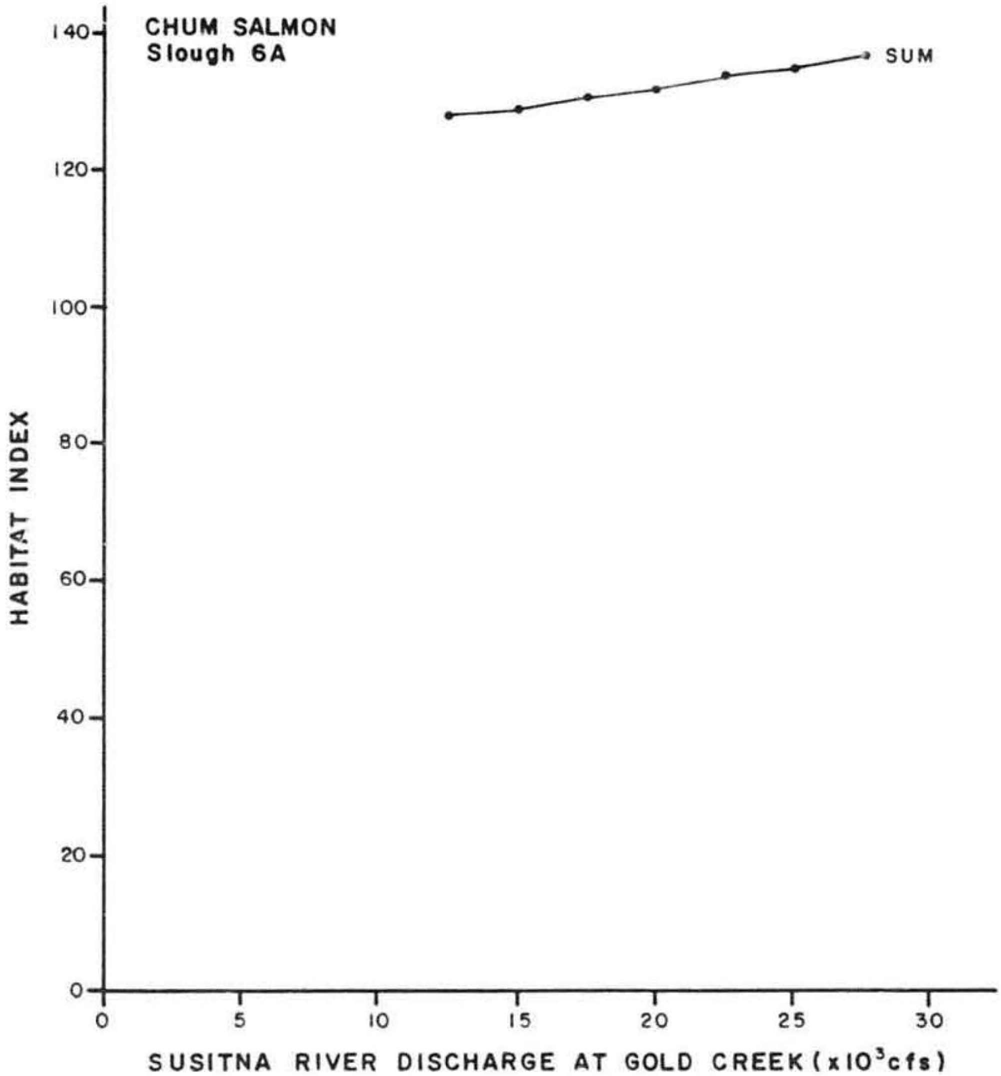
Appendix Table F-16. Habitat indices for juvenile chum salmon for aggregate hydraulic zones at three sites, June through September, 1982.

Susitna Discharge at Sunshine (cfs)	Birch Creek and Slough: Zone H-I (ZQI=0.28)	Zone H-II (ZQI=0.72)	Site Habitat Index (ΣHI)
35,000	82	60	142
40,000	60	106	166
45,000	59	108	167
50,000	59	110	169
55,000	42	162	204
60,000	8	263	271
65,000	8	272	280
70,000	8	277	286

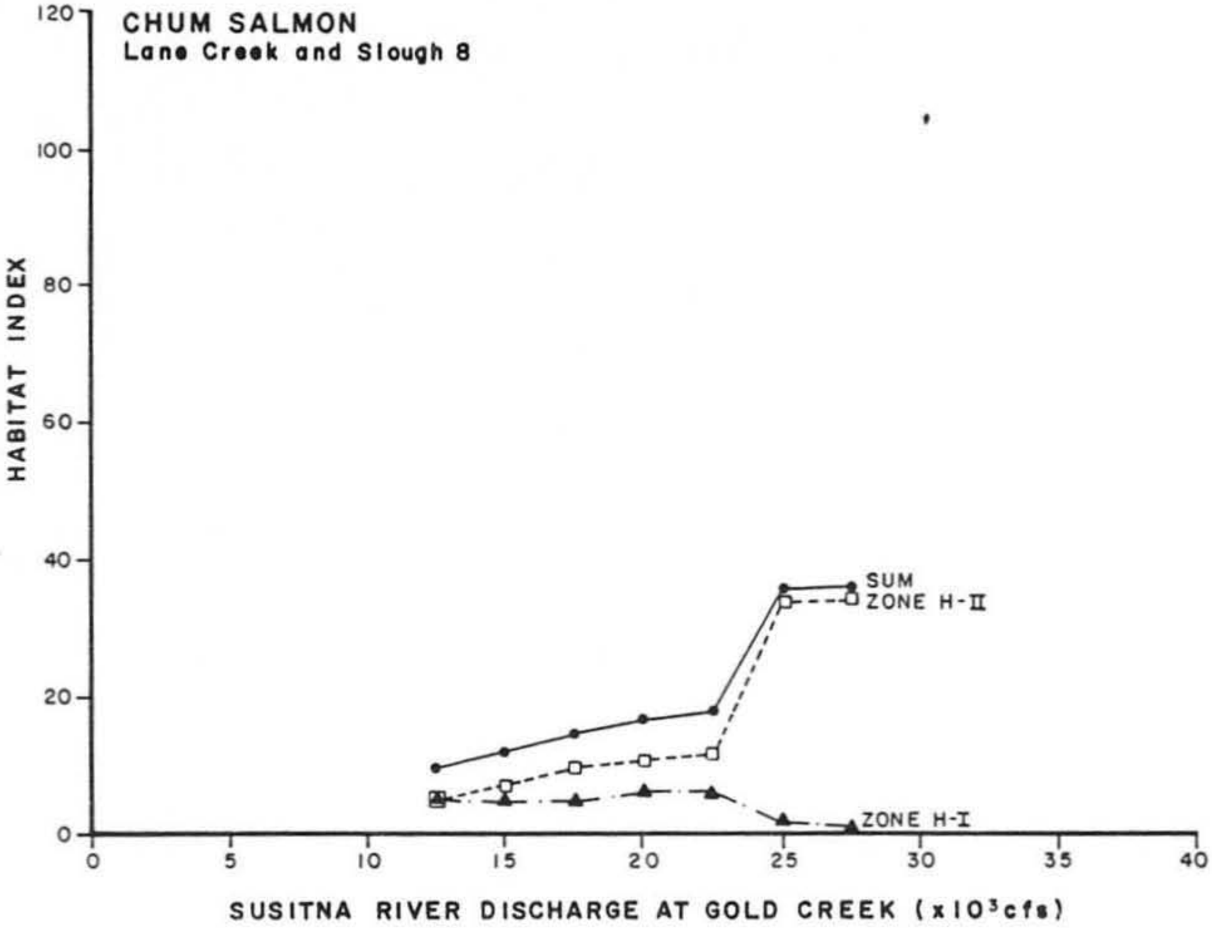
Susitna Discharge at Gold Creek (cfs)	Slough 6A: Zone H-I (ZQI=N/A)	Zone H-II (ZQI=1.00)	Site Habitat Index (ΣHI)	Lane Creek and Slough 8: Zone H-I (ZQI=0.25)	Zone H-II (ZQI=0.75)	Site Habitat Index (ΣHI)
12,500	--	128	128	5	5	10
15,000	--	129	129	5	7	12
17,500	--	131	131	5	10	15
20,000	--	132	132	6	11	17
22,500	--	134	134	6	12	18
25,000	--	135	135	2	34	36
27,500	--	137	137	1	35	36



Appendix Figure F-13. Zone and site habitat indices for juvenile chum salmon at the Birch Creek and Slough study site as a function of mainstem discharge, June through September, 1982.



Appendix Figure F-14. Zone and site habitat indices for juvenile chum salmon at the Slough 6A study site as a function of mainstem discharge, June through September, 1982.



Appendix Figure F-15. Zone and site habitat indices for juvenile chum salmon at the Lane Creek and Slough 8 study site as a function of mainstem discharge, June through September, 1982.

(Appendix Figure F-13) and at Lane Creek and Slough 8 in the upper reach (Appendix Figure F-15) are very similar in form.

The study boundary for Slough 6A, an upland slough, did not include an H-I zone. This slough has steep banks and a deep entrance channel, so the surface area of the slough showed only a small response to variations in mainstem discharge. All of the juvenile chum salmon captured at this site were in the H-II zone, which gives that zone a seasonal ZQI of 1.00 and zone H-III a ZQI of 0.00. The net result of the above is that the site habitat index is exactly the same as the zone H-II habitat index and that this index did not vary much with variations in discharge (Appendix Figure F-14). The flatness of the site habitat index curve is not typical of the sites. This situation occurs only at steep banked upland sloughs which are completely backed up by the mainstem.

CONCLUSIONS

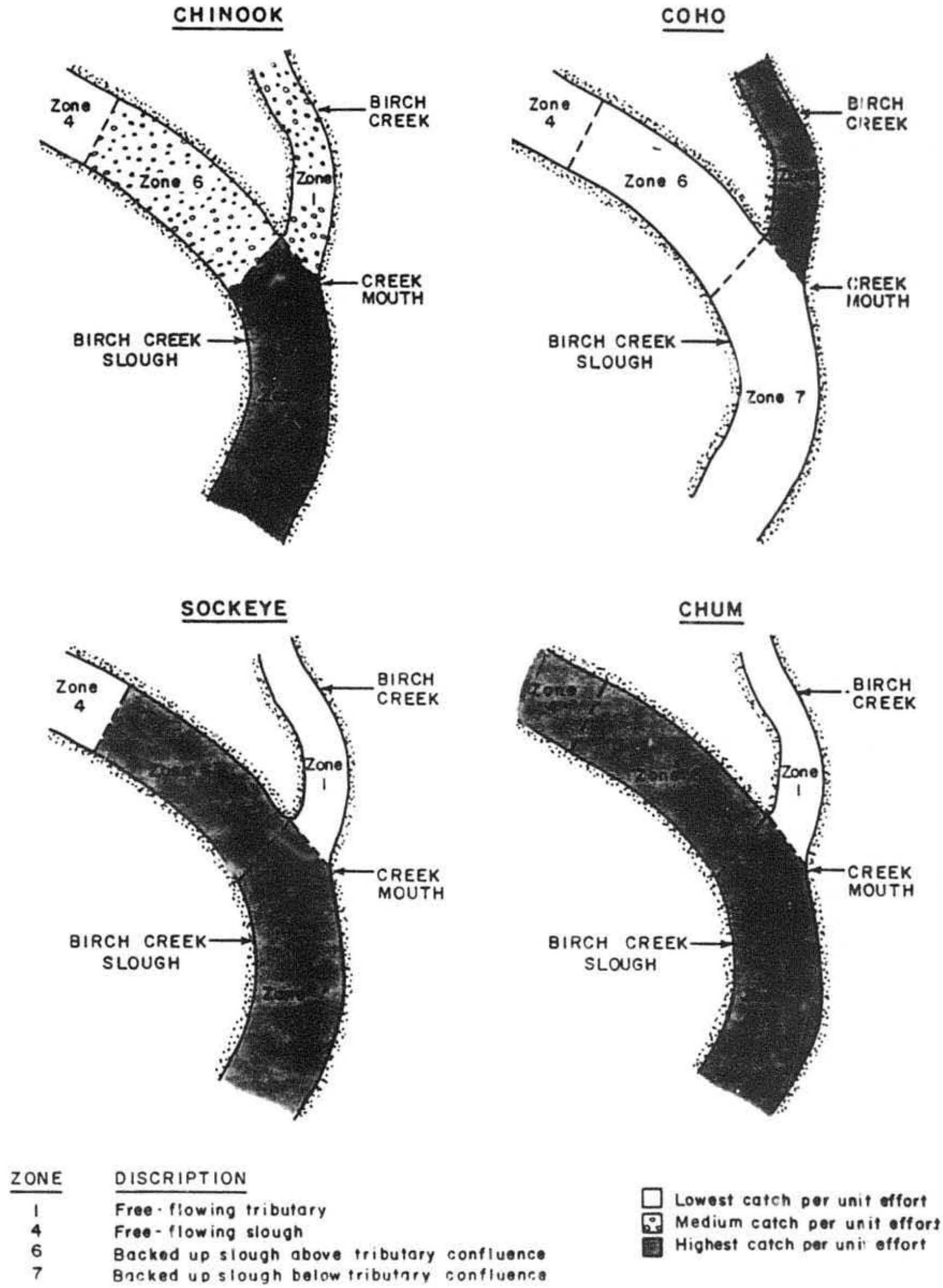
The results have established that the sampling zones were distinctly different habitats. These differences were maintained over the course of the season and over variations in mainstem discharge. Significant differences in distribution of fish among these zones demonstrated that the fish respond to the variability of the habitat components. Some possible causes for fish preference for one zone instead of another were explored by examining the relationship of fish abundance with key habitat variables. The validity of calculating zone quality indices from the catch data was established by demonstrating the above statistical differences.

The measure of habitat quality which was derived for this study, the zone quality index (ZQI), provides logical results which reflect actual juvenile salmon habitat preferences as established by statistical analysis of the catch data. Again, this index is not an index of absolute abundance nor does it consider the differences in quality among the sites; it only considers differences in quality among the zones.

The zone and site habitat indices which were presented in this report represent only one of the several possible approaches using this kind of analysis. The nine individual habitat zones could be treated separately or they could be aggregated using criteria other than the influence of the mainstem backwater. These other approaches could provide further insight into the factors controlling fish distribution and abundance. The approach used in this appendix (aggregate hydraulic zones) was chosen for its relative strength in relating habitat to mainstem discharge.

In interpreting the zone and site habitat index curves, one should be careful about extending the curves beyond the range of mainstem discharge which was observed, because the trends may not hold outside that range and large errors could result. Also, it is important to keep in mind that these curves reflect the situation only within the study boundaries. These boundaries usually included a tributary or slough mouth, some of the area above, and a small area of the mainstem mixing zone below. A decrease in surface area of a preferred habitat within the study boundary does not mean that the habitat was completely lost. For example, the coho salmon present in zone H-I at Birch Creek and Slough may be able to move further up the creek as a rising mainstem discharge causes the backwater zone to advance on zone H-I. However, there may not be replacement habitat available for decreasing areas of backwater zones, such as are used by sockeye and chum salmon. Since the study sites were chosen in part because of their importance to the fish populations, the loss of surface area within a study boundary can correctly be interpreted as a habitat loss which will influence the populations.

Analysis of the conditions at the Birch Creek and Slough study site provides a good summary of the conclusions that have resulted from the site habitat index method. Juveniles of the four salmon species showed a good segregation by habitat zone at this site (Appendix Figure F-16). Most of chinook juveniles were captured in the slough below the tributary mouth (zone 7), the rest were evenly distributed between the tributary (zone 1) and the backed-up slough above the tributary confluence (zone 6). Almost all of the rearing coho were captured in the tributary (zone 1). Most of the sockeyes were captured in the mainstem backwater zone above (zone 6), and below (zone 7), the tributary confluence; a few were captured in the slough above the mainstem backwater area (zone 4). Juvenile chum salmon were captured in the slough above the mainstem backwater zone (zone 4) and in the mainstem backwater area (zones 6 and 7). A summary of the zone quality indices for juveniles of each species at this site is as follows



Appendix Figure F-16. Generalized distribution of juveniles of four species of salmon at the Birch Creek and Slough study site, open water season, 1982.

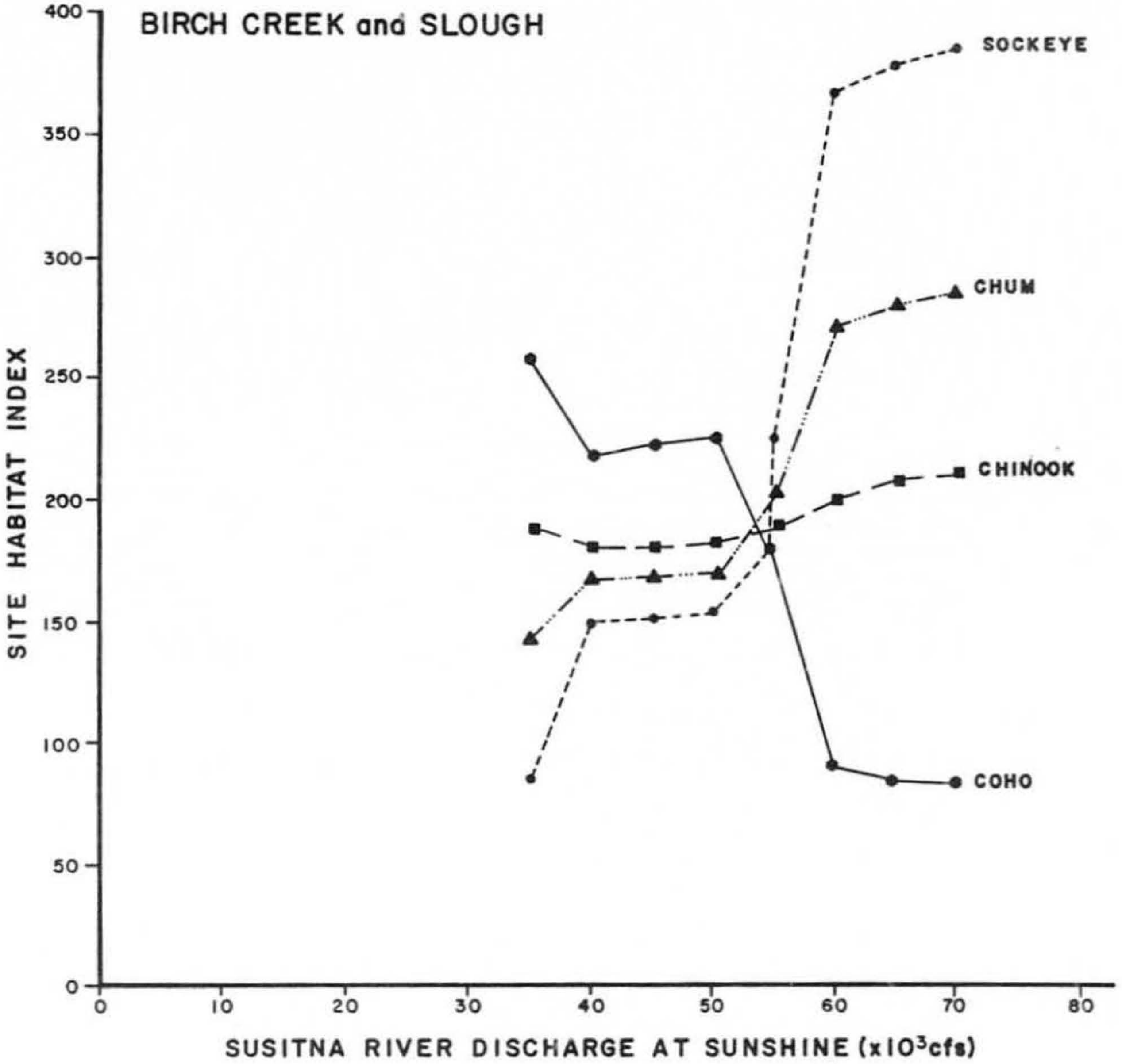
(aggregate hydraulic Zone H-I includes habitat zones 1 and 4 and aggregate hydraulic zone H-II includes habitat zones 6 and 7):

Species	Zone H-I	Zone H-II
Chinook	0.49	0.51
Coho	0.88	0.18
Sockeye	0.00	1.00
Chum	0.28	0.72

The zone quality indices (ZQI) for each species are typical of those shown by the species at the fourteen different sites.

The site habitat indices for juveniles of each of the four salmon species at the Birch Creek and Slough site are shown together in Appendix Figure F-17. The relative values between species have no meaning; only the shape of the curves is comparable from one species to another. All four of the species show an inflection at a discharge of around 53,000 cfs. This is the discharge at which the head of the slough is breached.

The shape of each site habitat index curve in Appendix Figure F-17 is representative of the majority of the fourteen sites. The ZQI for chinook salmon juveniles is approximately 0.5 for each zone, so the site habitat index curve for chinook is a function of total wetted surface area. The site habitat index curve for coho salmon, which are strongly associated with zone H-I, declines with an increase in discharge because the mainstem backwater zone (H-II) encroaches upon zone H-I. Chum salmon, which tend to occur in zone H-II, have a site habitat index which increases with increasing discharge. The site habitat index curve



Appendix Figure F-17. Site habitat indices for juveniles of four species of salmon at the Birch Creek and Slough study site as a function of mainstem discharge, June through September, 1982.

for sockeye salmon, which are even more strongly associated with zone H-II, shows a sharper increase. Variations in mainstem discharge affect habita+ of different species in different ways, both in direction and in magnitude.

LITERATURE CITED

Alaska Department of Fish and Game. 1983a. Resident and juvenile anadromous fish studies on the Susitna River below Devil Canyon. Volume 3 of ADF&G Susitna Hydro Aquatic Studies Program, Phase II, Basic Data Report. Anchorage, Alaska.

______. 1983b. Aquatic habitat and instream flow studies. Volume 4 of ADF&G Susitna Hydro Aquatic Studies Program, Phase II, Basic Data Report. Anchorage, Alaska.

______. Bovee, K.D. 1982. A guide to habitat analysis using the instream flow incremental methodology. Instream Flow Information Paper. No. 12. FWS/035-82/26.

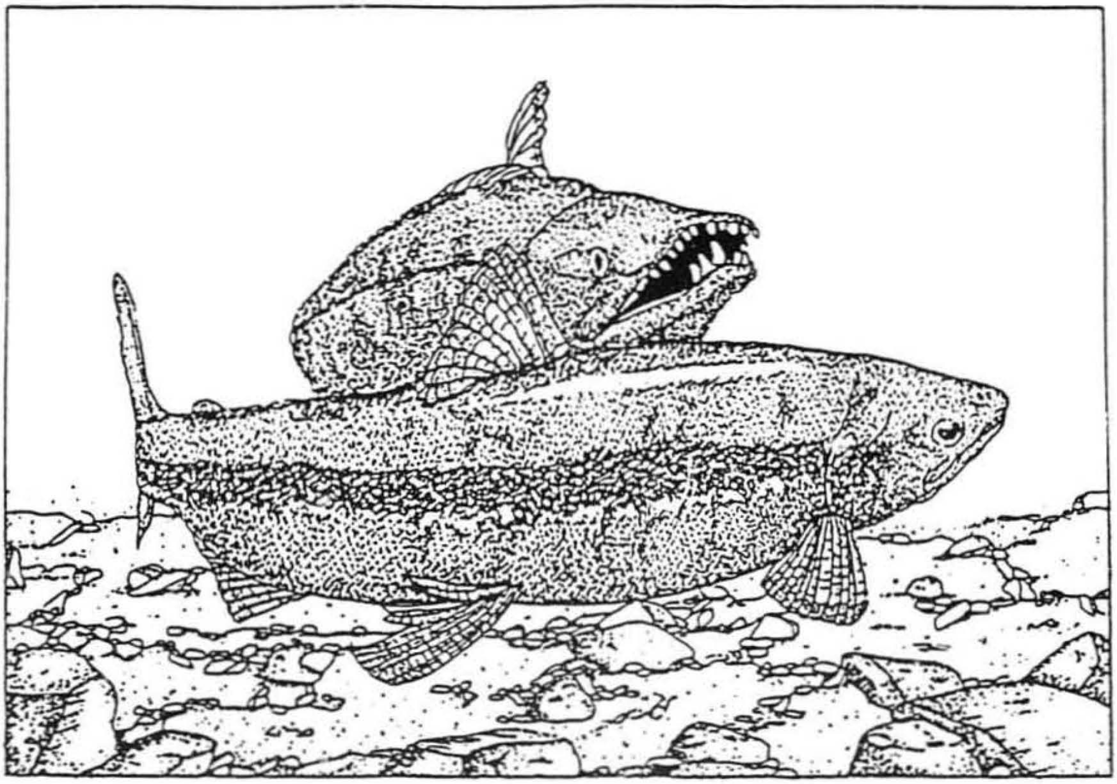
Snedecor, G.W., and W.G. Cochran. 1967. Statistical methods. The Iowa State University Press, Ames. 593 pp.

Summary table of habitat zones sampled at Designated Fish Habitat sites, June through September, 1982.

Zone Code	Description
1	Areas with a tributary or ground water source which are not influenced by mainstem stage and which usually have an appreciable[a] surface water velocity.
2	Backwater areas resulting from a hydraulic barrier created at the mouth of a tributary or slough by mainstem stage, which have a tributary or ground water source.
3	Areas of appreciable water surface velocities, primarily influenced by the mainstem, where tributary or slough water mixes with the mainstem water.
4	Areas of appreciable surface water velocities which are located in a slough or side channel above a tributary confluence (or in a slough where no tributary is present) when the slough head is open.
5	Areas of appreciable surface water velocities which are located in a slough or side channel below a tributary confluence, when the slough head is open.
6	Backwater areas resulting from a hydraulic barrier created by mainstem stage which occur in a slough or side channel above a tributary confluence (or in a slough or side channel where no tributary is present), when the head of the slough is open.
7	Backwater areas resulting from a hydraulic barrier created by mainstem stage which occur in a slough or side channel below a tributary confluence, when the head of the slough is open.
8	Backwater areas consisting of mainstem eddies.
9	A pool with no appreciable surface water surface velocities which is created by a geomorphological feature of a free-flowing zone or from a hydraulic barrier created by a tributary; not created as a result of mainstem stage.

[a]"Appreciable" surface water velocity means a velocity of at least 0.5 ft/sec. However, there are site-specific exceptions to this, based on local morphology.

Appendix F: Influence of Habitat Parameters on Distribution and Relative Abundance of Juvenile Salmon and Resident Species.



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