HARZA-EBASCO SUSITNA JOINT VENTURE

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Attention: Mr. William J. Wilson
Principal Investigator

Subject: Susitna Hydroelectric Project
Document Transmittal

Dear Mr. Wilson:

Enclosed for your review and comment is a draft copy of Availability of Invertebrate Food Sources for Rearing Juvenile Chinook Salmon in Turbid Susitna River Habitats.

Please return your comments to me by May 31, 1985.

Very truly yours,

Larry Gilbertson
Aquatic Group Leader

sdw

Enc: as noted

cc w/o Enc:
J. Thrall, HE

425751/5

ALASKA DEPARTMENT OF FISH AND GAME
SUSITNA HYDRO AQUATIC STUDIES

REPORT NO. 8

DRAFT

Availability of Invertebrate Food Sources for Rearing Juvenile Chinook Salmon in Turbid Susitna River Habitats

Prepared for:

Alaska Power Authority
334 W. FIFTH AVE.
ANCHORAGE, ALASKA 99501

DRAFT

PREFACE

This report is one of a series of reports prepared for the Alaska Power Authority (APA) by the Alaska Department of Fish and Game (ADF&G) to provide information to be used in evaluating the feasibility of the proposed Susitna Hydroelectric Project. The ADF&G Susitna Hydro Aquatic Studies program was initiated in November 1980. Reports prepared by the ADF&G Susitna Hydro Aquatic Studies program prior to 1983 are available from the APA. Reports prepared after 1983 are sequentially numbered as part of the Alaska Department of Fish and Game Susitna Hydro Aquatic Studies Report Series. Titles in this report series are:

Report Number	Title	Publication Date
1	Adult Anadromous Fish Investigations: May - October 1983	April 1984
2	Resident and Juvenile Anadromous Fish Investigations: May - October 1983	July 1984
3	Aquatic Habitat and Instream Flow Investigations: May - October 1983	September 1984
4	Access and Transmission Corridor Aquatic Investigations: May - October 1983	September 1984
5	Water Aquatic Investigations: September 1983 - May 1984	March 1985
6	Adult Anadromous Fish Investigations: May - October 1984	1985
7	Resident and Juvenile Anadromous Fish Investigations: May - October 1984	1985
8	Availability of Invertebrate Food Sources for Rearing Juvenile Chinook Salmon in Turbid Susitna River Habitats	1985
9	Summary of Salmon Fishery Data for Selected Middle Susitna River Sites	1985

This report, Report Number 8, summarizes the results and findings of the juvenile chinook salmon food availability study conducted during the 1984 open water (May - October) field season.

AVAILABILITY OF INVERTEBRATE FOOD SOURCES FOR REARING JUVENILE CHINOOK SALMON IN TURBID SUSITNA RIVER HABITATS

1985 Report Number 8

by

Tim F. Hansen and J. Craig Richards

Alaska Department of Fish and Game
Susitna Hydro Aquatic Studies
Third Floor, Michael Building
620 East Tenth Avenue
Anchorage, Alaska 99501

ABSTRACT

The availability of invertebrate food resources in mainstem affected side channel and side slough habitats and the overall rearing capabilities of these habitats for juvenile chinook salmon was assessed by the Alaska Department of Fish and Game Susitna Aquatic Studies Program from May through October 1984 to evaluate the quantity of available food sources and their relation to mainstem river discharge and to evaluate the gain and loss of benthic invertebrate habitat resulting from changes in flow in these habitats. Four side channel and side slough sites were sampled at head and mid-section locations for the amount of invertebrate drift and at mid-section locations only for benthos, using drift nets and modified Hess type samplers. Juvenile chinook salmon were also sampled at the mid-section locations using electro-fishing techniques to correlate the available food sources with that being utilized.

A total of 52 invertebrate taxa were identified in drift and benthic samples, with chironomidae being the dominant taxa. The proportions of invertebrates found in the stomachs of juvenile chinook salmon was closely correlated with the proportions of invertebrates available in the drift. Drift samples collected under breached conditions indicated that invertebrates were being transported from the mainstem into the side channels and side sloughs. Drift in side channels and side sloughs under unbreached conditions was negligible compared to the drift under breached conditions when total drift was considered.

Categorizing invertebrates which were common to drift, benthos, and the diet of juvenile chinook salmon by behavioral type (i.e. burrower, swimmer, clinger, and sprawler) proved to be a valuable means for projecting weighted usable area of benthic invertebrate habitat when the density of species was low as occurred in this study. The densities of each of the behavioral groups were found to be generally well correlated to water velocity and substrate type, whereas depth of water did not appear to be an important factor influencing the density of organisms. Water velocities less than 0.4 ft/sec and substrates comprised of silts and sands generally supported the highest mean densities of burrowers which were made up primarily of Chironomidae. Rubble substrates with components of large gravel or cobble and water velocities between 1.6 ft/sec and 2.6 ft/sec generally supported the highest mean densities of swimmers and clingers. Sprawlers did not appear to preferentially utilize any particular substrate or water velocity.

Projected weighted usable area for each of the behavioral groups was clearly a function of mainstem discharge. The minimum controlling mainstem discharge for each of the study sites generally produced the greatest amount of burrower habitat weighted usable area. The maximum amount of weighted usable area for swimmer, clinger, and sprawler habitat at study sites was reached at a mainstem discharge above 25,000 cfs.

In conclusion, naturally fluctuating flows above 19,000 cfs appear to maintain a diverse benthic fauna and appear to provide drifting food organisms to mainstem affected side channels and side sloughs thereby contributing to the rearing capabilities of these habitats for juvenile chinook salmon.

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1.0 INTRODUCTION

Instream habitat variables such as cover, riparian vegetation, water depth and velocity, and food supply have all been determined to be important variables influencing the overall suitability of instream habitats for rearing juvenile salmon (Stalnaker and Arnette 1976). Although there is no definite evidence that any of these variables is the ultimate factor limiting the carrying capacity of a particular habitat for rearing by juvenile salmonids, it is clear that the availability of suitable food is of considerable importance.

Food sources utilized by juvenile salmon have generally been found to consist of aquatic invertebrates which inhabit the various niches of the instream environment. Many researchers have examined the instream hydraulic conditions which influence the distribution and abundance of these invertebrate food organisms and have concluded that water depth, water velocity, and substrate type are three of the most important controlling factors (Kimble and Wesche 1975, Cummins 1975). There is some controversy however as to which of these factors exerts the greatest control. It is likely, however, that invertebrate species select their habitats on the basis of combinations of the above factors rather than on the basis of the factors individually (Ulfstrand 1967). Ulfstrand based this conclusion on the ability of different combinations of depth, velocity, and substrate to entrap debris which could be used as food by invertebrates.

Additional studies have also suggested that optimum invertebrate habitat could be identified according to combinations of available depth, velocity, and substrate type. Pearson et al. (1970) suggested that optimum habitat conditions for invertebrate organisms were reached when streamflows resulted in the greatest amount of riffle-like habitat having water velocities of approximately 2.0 feet per second (ft/sec). Banks et al. (1974) made optimum streamflow recommendations for invertebrate habitat by assuming that the most preferred streamflow would be that which would provide the maximum surface acreage with water velocities of 1.5-3.49 ft/sec and depths of 0.50-2.99 feet. The California Department of Fish and Game (1975) based streamflow recommendations for invertebrate habitat on habitat curves with streamflow as the independent variable generated from weighted depth, velocity, and substrate measurements collected along transects. Nuwell (1976) used linear regression analysis with streamflow as the independent variable to predict macroinvertebrate densities at different flows in the Yellowstone River, Montana. One of the most recent predictive modelling procedures for describing benthic invertebrate habitat has been developed by the U.S. Fish and Wildlife Service (USFWS) Instream Flow Group (IFG) (Judy and Gore 1979). The IFG used many of the same modelling techniques which were developed for evaluating instream fish habitat for the assessment of the instream flow requirements of benthic invertebrate populations (Bovee and Cochnauer 1977, Bovee and Milhous 1978, Bovee et al. 1979 and Bovee 1979). These modelling techniques utilize water depth, velocity, and substrate type as the dominant hydraulic variables to quantify the responses of benthic invertebrate habitat to changes in streamflow.

Information concerning the density and the number of different kinds of invertebrate foods available to rearing juvenile salmon and the habitat requirements of these invertebrate organisms is not well known for the Susitna River as only limited studies of invertebrate organisms have been conducted to date (ADF&G 1977, 1978 and 1983a). The studies conducted to date have been limited to describing the diet of juvenile chinook, coho, and sockeye salmon and the kinds of invertebrate foods available to them. No habitat modelling evaluations have been conducted describing the density and flow requirements of invertebrates in habitats utilized by juvenile salmon.

This report presents the results of the 1984 Alaska Department of Fish and Game Susitna Hydro Aquatic Studies Food Availability Study (FAS). The study was designed to quantify invertebrate habitat and the invertebrate food organisms available to juvenile chinook salmon in selected side channel and side slough habitats of the middle Susitna River at different mainstem flows. Side channel and side slough habitats of the middle Susitna River were selected as evaluation habitats as these habitat types are located along the lateral margins of the river flood plain and are subject to dewatering if naturally occurring summer discharges are significantly reduced by the proposed hydroelectric facility. Juvenile chinook salmon were selected as evaluation species as they have been shown to utilize these habitats for summer rearing (ADF&G 1983b, Schmidt et al. 1984).

The FAS was divided into three parts: 1) an evaluation of invertebrate drift; 2) an analysis of the flow requirements of macrobenthos; and, 3) a confirmatory study of juvenile chinook feeding habits. The specific objectives of the three part study were to:

1. Evaluate the available food sources in mainstem affected side channel and side slough habitats and verify their relative importance to juvenile chinook salmon;

2. Evaluate the relative importance of the contribution of mainstem invertebrate drift in mainstem affected side channel and side slough habitats;

3. Estimate the response of selected groups of invertebrates of mainstem affected side channel and side slough habitats to various water depths, velocities, and substrate types; and,

4. Quantify the area of mainstem affected side channel and side slough habitats usable to selected invertebrate groups at different mainstem discharges.

Three side channels and one side slough were selected for study between River Mile (RM) 129 and RM 142 (Figure 1). These study sites were selected to utilize previously established IFG modelling transects located in areas found to contain significant numbers of juvenile chinook salmon. Data collected within the study sites included: benthic and drift invertebrate samples and, point specific water depth, mean column water velocity, and substrate composition. These data were

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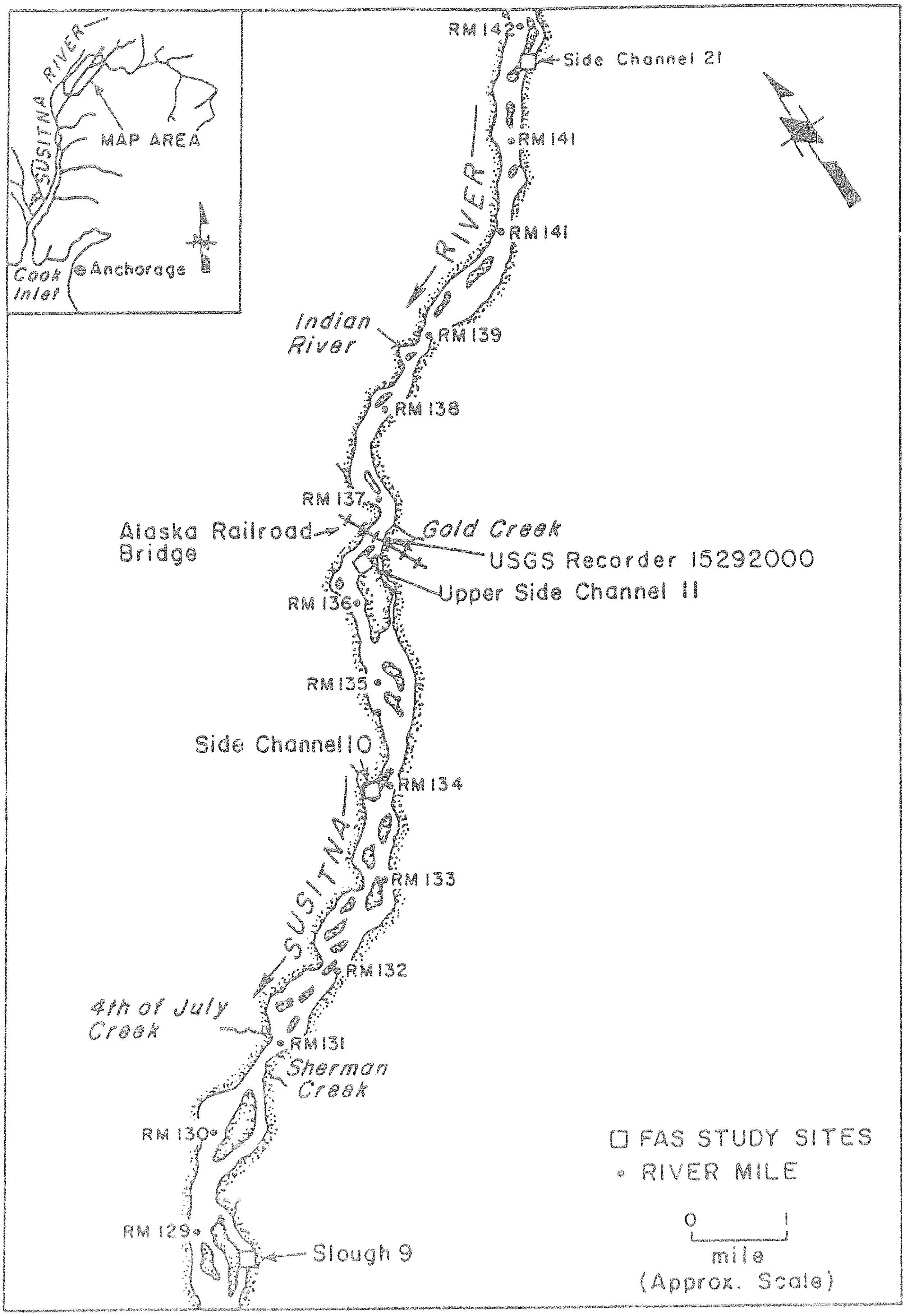

Figure 1 Map of the middle Susitna River from River Mile 129 to River Mile 142, showing the four sampling sites for the Food Availability Study, 1984.

combined with existing hydraulic simulation model data to estimate the response of invertebrate habitat to changes in discharge. In addition, juvenile chinook salmon were collected for stomach content analyses to verify food habitats.

Because of the limited number of invertebrates per unit area at each sampling site, a somewhat different approach to grouping invertebrates was utilized in the study over that suggested by Judy and Gore (1979). Whereas Judy and Gore constructed preference curves for species of benthic invertebrates representing different functional groups, curves in this study were constructed curves for groups of invertebrates representing behavioral types which reflect basic habitat preference (e.g., burrowing organisms might prefer smaller substrate size classes).

The findings of this study should provide resource managers with the information necessary for a better understanding of the mainstem discharges required for the maintenance of adequate production of fish food organisms in juvenile chinook salmon rearing areas.

2.0 METHODS

2.1 Field Sampling

2.1.1 Study Site Selection

Juvenile salmon distribution and abundance studies in the middle Susitna River have shown that juvenile chinook salmon utilize mainstem affected side channel and side slough habitats for summer rearing (ADF&G 1983b, Schmidt et al. 1984). For this reason, four sites (Figure 1) representing a cross section of the side channel and side slough habitats available to rearing juvenile chinook salmon in the middle Susitna River were chosen for study. The sites selected for study were: Side Slough 9 (RM 128), Side Channel 10 (RM 134), Upper Side Channel 11 (RM 136), and Side Channel 21 upstream of over flow channel A5 (i.e., upper Side Channel 21) (RM 142).

Each of these sites are affected by mainstem discharge to varying degrees and contain existing hydraulic simulation models (IFG-4) sites which can be used for invertebrate habitat analysis. In previous studies, significant numbers of juvenile chinook salmon have been captured at each location (ADF&G 1983b, Schmidt et al. 1984). A complete physical description of each study site can be found in Quane et al. (1984b). Available hydrographs, rating curves, and discharge data for each of the study sites are presented in Appendix A.

2.1.2 Invertebrate Drift

To evaluate differences in the number of invertebrates originating in mainstem habitats versus mainstem affected side channel and side slough habitats, invertebrate drift was sampled at two locations within each of the four study sites. One pair of drift nets were located at the head of each study site where the mainstem breaches into the side slough or side channel, and another pair of nets were located within the IFG modelling study area (Figures 2 through 5).

Drift nets were constructed of 500 micron Nitex netting and measured 12 x 18 x 39 inches (Figure 6). The downstream end of each drift net consisted of a detachable collection bucket constructed of a 15 inch section of plastic pipe with 500 micron Nitex net windows and base. While in the water, each net was supported by two one inch diameter steel rods that were pounded into the substrate. Four three inch chrome rings, attached to the corners of each net frame, allowed easy setting and removal of nets from the steel rods.

To ensure the greatest catch size, drift was sampled during the evening, which is generally considered to be a period of increased activity for many aquatic invertebrate taxa (Hynes 1970, Waters 1972). Each site was sampled three times during the sampling season (Table 1). Nets were set approximately two hours before sunset for two consecutive days at each site. The sampling duration for each net pair was dependent on river stage and debris load and ranged from 0.12 hours to 1.20 hours. If the

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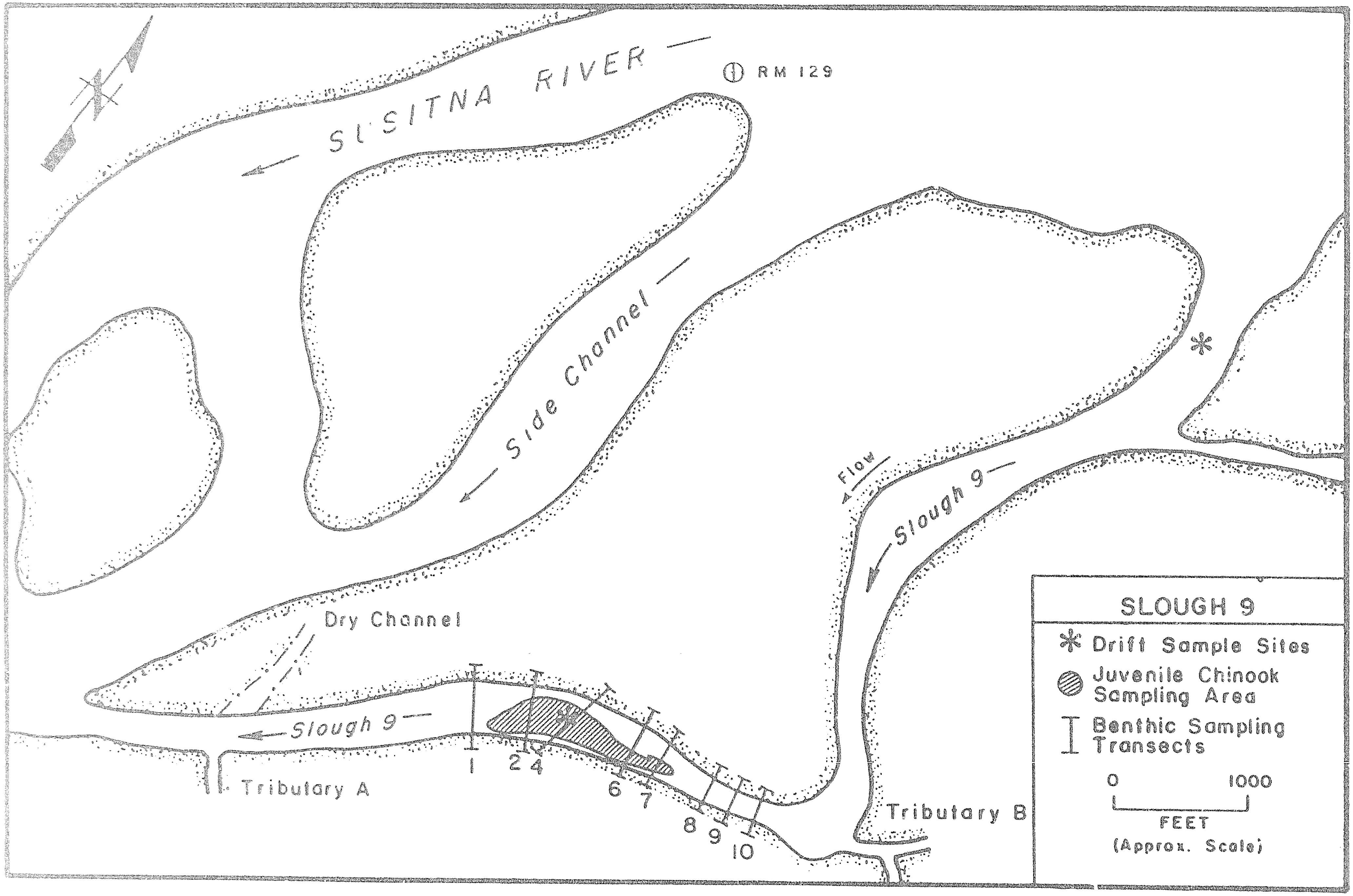

Figure 2 Map of Slough 9 showing invertebrate and juvenile chinook salmon sampling locations, June through August, 1984.

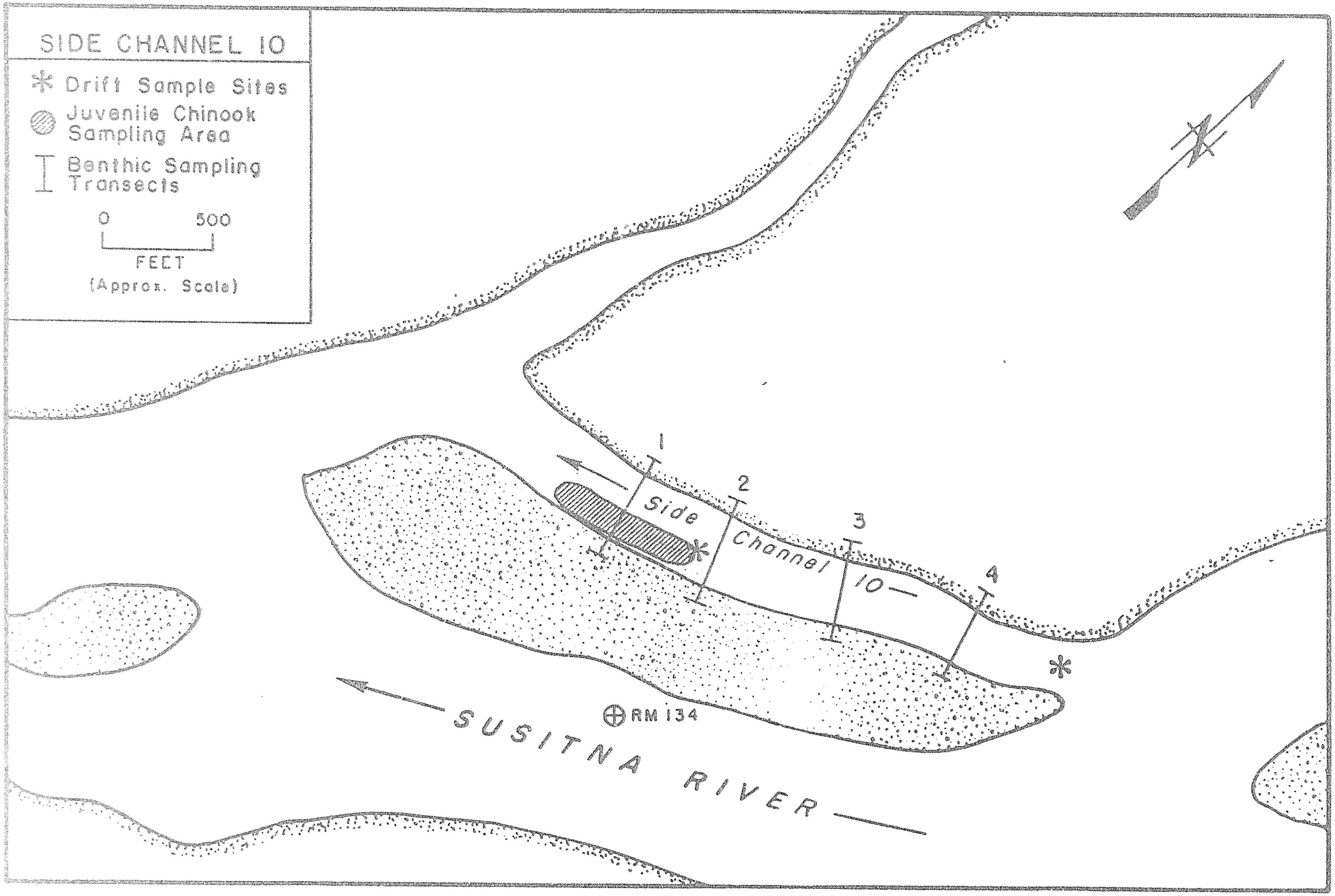

Figure 3 Map of Side Channel 10 showing invertebrate and juvenile chinook salmon sampling locations, June through August, 1984.

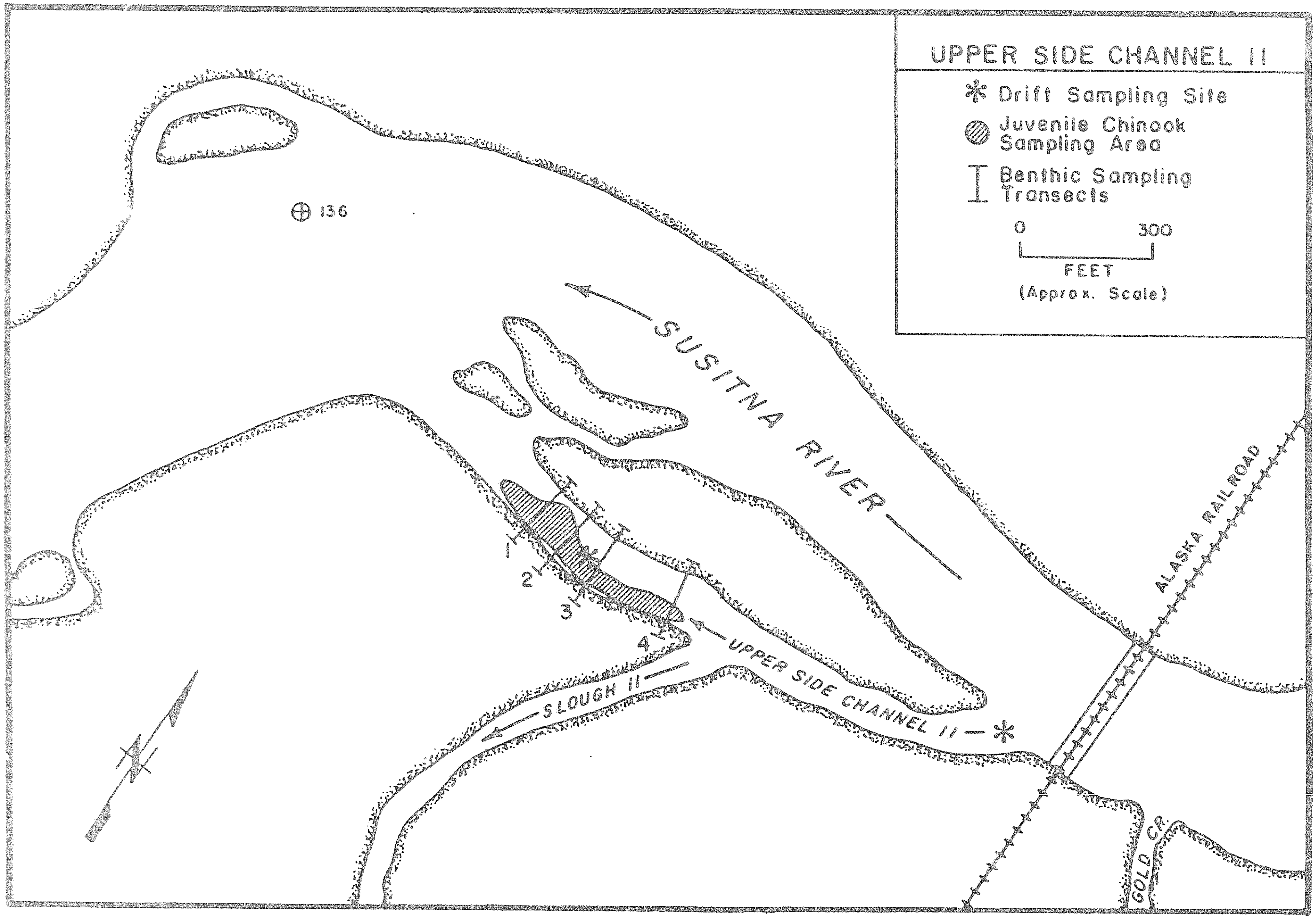

Figure 4 Map of Upper Side Channel 11 showing invertebrate and juvenile chinook salmon sampling locations, June through August, 1984.

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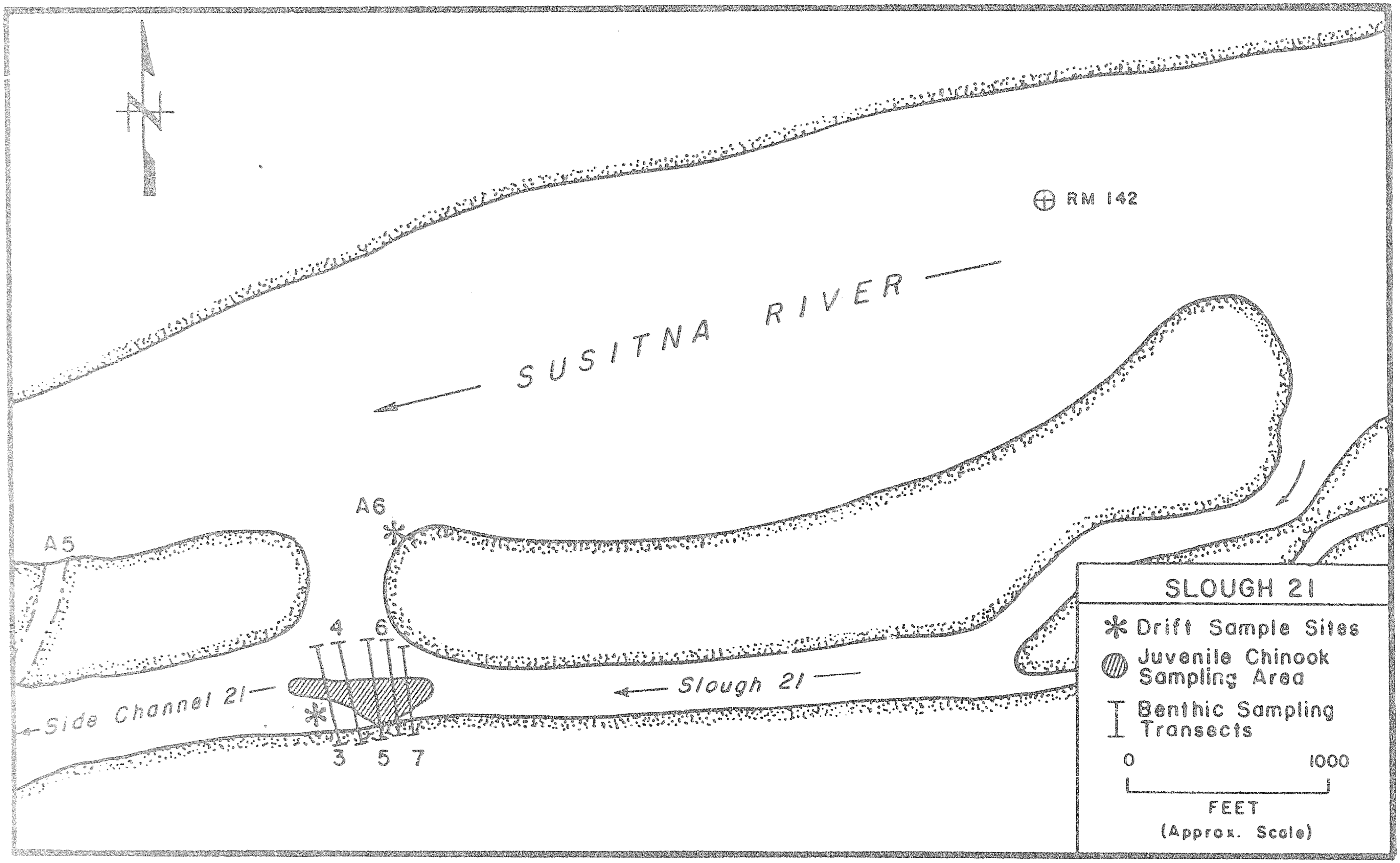
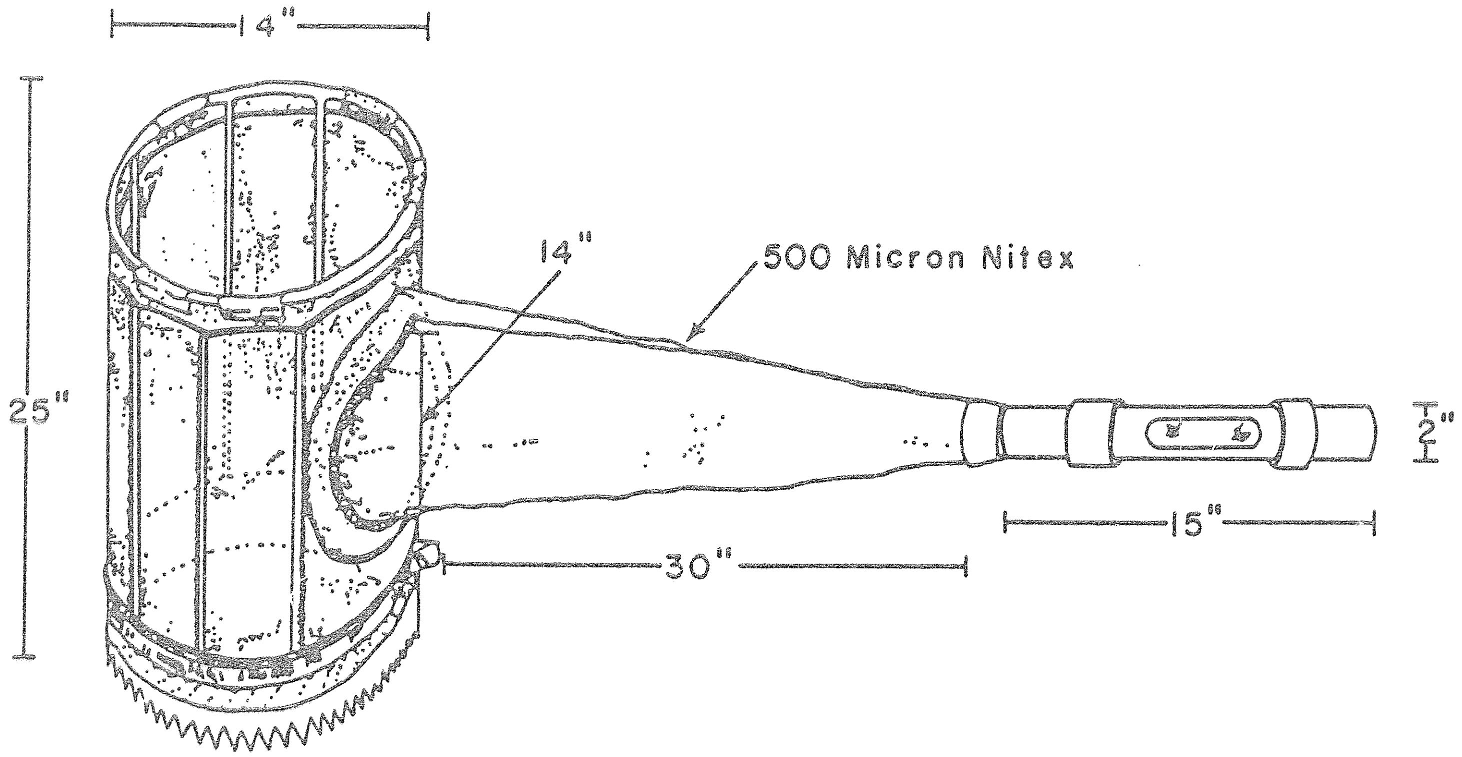


Figure 5 Map of upper Side Channel 21 and Slough 21 showing invertebrate and juvenile chinook salmon sampling locations, June through September, 1984.

Benthic Sampler



Drift Sampler

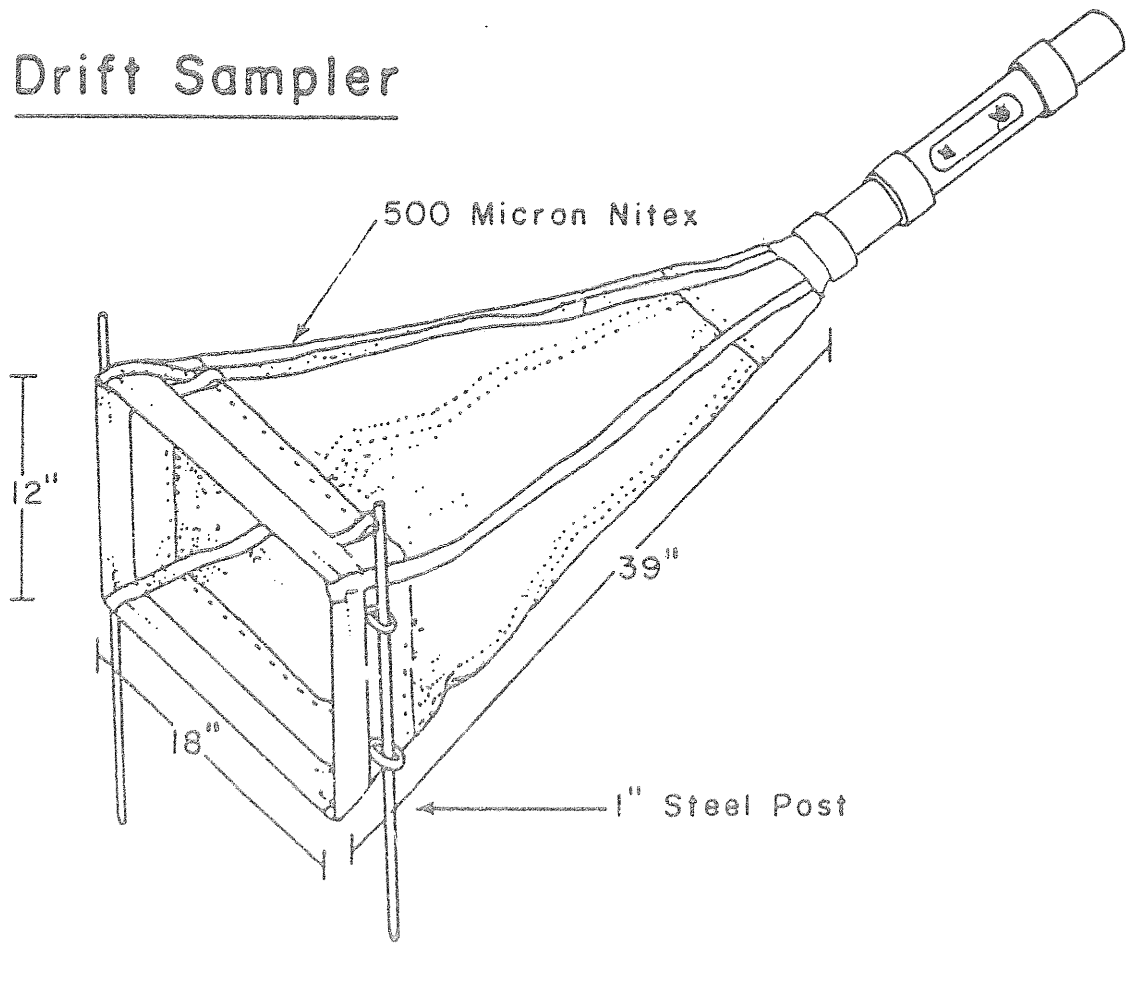


Figure 6 Invertebrate sampling gear used in the Food Availability Study, 1984. Adapted from Merritt and Cummins (1978).

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Table 1. Food availability study sampling dates, middle Susitna River, Alaska, 1984.

	June													July									August										September		
Sampling Type	7	8	9	10	11	12	13	14	24	25	26	27	28	6	7	8	9	10	11	12	13	14	9	10	11	12	13	14	15	16	23	24	8	9	10
SLOUGH 9																																			
Benthic														X																				X	
Drift					X	X													X	X							X	X							
Juvenile Chinook												X									X								X						
Temperature					X	X								X					X	X							X	X						X	
Turbidity					X	X								X					X	X							X	X						X	
SIDE CHANNEL 10																																			
Benthic											X																						X		
Drift								X	X												X	X							X	X					
Juvenile Chinook											X										X								X						
Temperature								X	X		X										X	X							X	X			X		
Turbidity								X	X		X										X	X							X	X			X		
UPPER SIDE CHANNEL 11																																			
Benthic																	X														X				
Drift	X	X													X	X							X	X											
Juvenile Chinook										X									X									X							
Temperature	X	X													X	X	X						X	X							X				
Turbidity	X	X													X	X	X						X	X							X				
SIDE CHANNEL 21																																			
Benthic									X																							X			
Drift		X	X														X	X						X	X										
Juvenile Chinook													X						X								X								X
Temperature		X	X						X									X	X					X	X							X			
Turbidity		X	X						X									X	X					X	X							X			

side slough or side channel being sampled was not breached, only the IFG-4 drift sampling location was sampled.

Water velocity and depth were measured in the center of each net opening at the beginning and end of each sampling period using a Marsh/McBirney electrical current meter and wading rod using procedures described in ADF&G (1984). The two depth and velocity measurements for each net were averaged and used to calculate the total volume (ft^3) of water filtered.

2.1.3 Benthic Invertebrates

Benthic samples were collected along existing IFG-4 modelling transects at each sampling site twice during the open water season to determine invertebrate habitat preferences (Table 1). The number of samples taken at each study site during a sampling date was determined by the variety of microhabitat conditions available (i.e., the variety of depth, velocity, and substrate combinations present).

Benthic samples were taken with a 25 inch high 1.08 ft^2 cylindrical benthic sampler constructed of aluminum and covered with 500 micron Nitex netting (Figure 6). The same detachable collection bucket used on the drift nets was used on the benthic sampler.

Benthic samples were taken by forcing the sampler into the substrate to a depth of four inches and agitating the enclosed substrate by hand until all suspended materials were washed downstream into the collection bucket. When sampling large substrates such as boulders, the sampler was placed on the boulder surface and the substrate was scraped by hand to remove any invertebrates present. Similarly, the uppermost layer of medium sized substrates (eg. rubble, or cobble) were dislodged and all surfaces were scraped to remove invertebrates.

Point measurements of water depth and mean column water velocity were recorded prior to taking a benthic sample using a Marsh/McBirney electrical current meter and wading rod using methods described in ADF&G (1984). In addition, substrate type was visually determined while taking each sample using a thirteen class ranking system (Table 2). The location of each sample was determined by reading a fiberglass measuring tape stretched between the headpins of the IFG-4 modelling transect being sampled.

Additional benthic samples were collected in April, May, September, and October for determining invertebrate development using a kick screen similar to that described in ADF&G 1983a. These samples, however, were not used in the development of invertebrate suitability criteria.

2.1.4 Juvenile Chinook Salmon

To compare the diet of juvenile chinook salmon with the composition of invertebrates in drift and benthic samples, juvenile chinook salmon were captured for stomach content analysis at each side channel and side slough study site. This information was used to supplement previ-

Table 2. Substrate classification scheme utilized to evaluate substrate composition at each benthic sampling point (Vincent-Lang et al. 1984).

IFG Code	Substrate Category	Size (inches)
1.0	silt	less than 1/32
2.0	silt - sand	
3.0	sand	1/32 - 1/8
4.0	sand - small gravel	
5.0	small gravel	1/8 - 1
6.0	small gravel - large gravel	
7.0	large gravel	1 - 3
8.0	large gravel - rubble	
9.0	rubble	3 - 5
10.0	rubble - cobble	
11.0	cobble	5 - 10
12.0	cobble - boulder	
13.0	boulder	greater than 10

ously collected data on juvenile chinook salmon diet in the middle Susitna River (ADF&G 1978, ADF&G 1983b).

Study sites were electrofished three times during the field season using a Coffelt (model no. BP1C) backpack electroshocker (Table 1). From each catch, four to seven juveniles were collected for future stomach content analysis. A small incision penetrating the body cavity was made superior to the pelvic girdle on the fish's left side to ensure adequate preservation of its stomach contents. The fish were then stored intact in 70% ethyl alcohol (ETOH).

2.1.5 Turbidity

Water samples for turbidity measurement were taken during both drift and benthic sampling at each study site. All samples were stored in 125 milliliter (ml) Nalgene bottles, kept cool in a darkened storage container, and analyzed within 72 hours of collection. Turbidity was measured in Nephalometric Turbidity Units (NTU) with an H.F. Instruments DRT-15B Portable Turbidimeter following procedures outlined in ADF&G (1984).

2.2 Laboratory Analysis

2.2.1 Sample Storage and Handling

All invertebrate samples were placed in polyethylene bags and preserved with 70% ETOH. Rose Bengal dye was added to the alcohol to dye invertebrates for easy sorting. Invertebrates were hand sorted from debris and stored in glass vials containing 70% ETOH for later identification and enumeration.

Juvenile chinook salmon preserved for stomach content analysis were measured for total length and their stomachs removed by making cuts at the anterior esophagus and pyloric sphincter. After removal, stomachs were stored in glass vials containing 70% ETOH for later invertebrate identification and enumeration.

2.2.2 Invertebrate Identification and Enumeration

Invertebrates from benthic, drift, and juvenile chinook stomach samples were identified to the family taxonomic level and counted. If identification to the family level was not possible, invertebrates were identified to order.

Invertebrates from juvenile chinook stomachs were counted using whole individuals when possible or body parts if items were partially digested or dismembered. Head capsules were used to count chironomid larvae (midges), whereas the head and thorax regions were used to count dismembered plecopterans (stoneflies) and ephemeropterans (mayflies). Other dismembered invertebrates were counted by piecing together identifiable body parts to estimate the kind and number of individuals present. Unidentifiable parts were not counted. Keys used to identify organisms include: Johansen and Thomsen (1934), Usinger (1956), Edmunds et al. (1976), Bauman et al. (1977), Wiggins (1977), Merrit and Cummins (1978), Pennak (1978), and Borror et al. (1981).

2.3 Data Analysis

2.3.1 Invertebrate Drift

In this study, density (i.e., number of individuals per unit volume of water), reported in English units (e.g., cubic feet and cubic yards), was used to describe the abundance of drifting invertebrates in samples. Densities were standardized by dividing the number of individuals in a taxa or group by the volume of water filtered. The relative density of an organism or group at a particular sample site was determined by placing the standardized mean density of that organism or group into one of four classes representing different orders of magnitude. The classes used were: Rare (0.001-0.009/yd^3), Sparse (0.010-0.099/yd^3), Common (0.100-0.999/yd^3), and Abundant (1.000-9.999/yd^3).

The differences in drift density at head and IFG-4 sampling locations within study sites was evaluated by placing sorted and identified invertebrates into eight taxanomic groups. The groups were: Collembola (springtails), Ephemeroptera (mayflies), Plecoptera (stoneflies), Trichoptera (caddisflies), Diptera larva (flies), Diptera adults, Other Insects, and Other Invertebrates. Multiple regression analysis was then used to determine the relationship that the quantity of invertebrate drift present at head sites has to that present at IFG-4 sites. The dependent variable in this analysis was drift numbers at the IFG-4 site and the independent variables were drift numbers at the head sites, volume of water filtered through nets at head sites, and volume of water filtered through nets at IFG-4 sites.

The original data was transferred using a logarithmic transformation ($\log_e$) to reduce variance and skewness (i.e., $\log_e [x+1]$ where x equals number of individuals) following procedures described in Steel and Torrie (1960). The general linear model tested was:

$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \varepsilon$$

where:

β_0 = intercept term;

β_i = regression coefficients (1,2,3);

x_1 = transformed ($\log_e [x+1]$) numbers of grouped drift invertebrates collected at the head site;

x_2 = transformed ($\log_e [x]$) volume of water filtered for drift sample collected at the head site;

x_3 = transformed ($\log_e [x]$) volume of water filtered for drift sample collected at the IFG-4 site;

y = transformed ($\log_e [x+1]$) numbers of grouped drift invertebrates collected at the IFG-4 site; and

ε = Error term

The null hypothesis in this evaluation was: Numbers of drifting individuals in invertebrate groups at IFG-4 sites was not dependent (related) the numbers of drifting individuals in invertebrate groups at head sites, volume of water filtered at head sites, or volume of water filtered at IFG-4 sites.

To determine if the observed variations in the drift numbers at IFG-4 sites was due to any of the independent variables and not due to chance alone, an analysis of variance (ANOVA) was performed. The hypothesis tested was:

$$H_0: \beta_1 = \beta_2 = \beta_3 = 0$$

$$H_A: \beta_1 \neq o_2 \neq \beta_3 \neq 0$$

The F test criterion was defined as:

$$F = \frac{\text{mean square error due to regression}}{\text{residual mean square error}}$$

To determine if the partial regression coefficients had true values greater than zero, the Student's t test was applied (Steel and Torrie 1960). The hypotheses tested in this case were:

$$H_0: \beta_1 = 0,\ \beta_2 = 0,\ \beta_3 = 0$$

$$H_A: \beta_1 \neq 0,\ \beta_2 \neq 0,\ \beta_3 \neq 0$$

The test criteria are defined as:

$$t = \frac{\hat{\beta}_i}{S_{\hat{\beta}_i}} = \frac{\text{estimate of the partial regression coefficients}}{\text{standard error of the estimate of the partial regression coefficient}}$$

The probability level used in both the F test and the Student's t test was $\alpha=0.05$.

To depict the relationship between drift density at IFG-4 sites and drift density at head sites, the drift data (counts) were plotted on a two dimensional cartisian plane. The counts were plotted in three ways: 1) head counts versus IFG-4 counts for all samples collected, 2) head counts versus IFG-4 counts for each sampling month, and 3) head counts versus IFG-4 counts for each sampling location. For these plots, the number of invertebrates in each group were standardized and multiplied by 1,000 tc estimate the number of organisms caught per 1,000 cubic feet of water filtered through each net. Standardized data were transformed using the natural logarithm transformation ($\log_e [x+1]$).

2.3.2 Benthic Invertebrates

2.3.2.1 Standing Crop Estimation

Benthic samples were used to estimate the standing crop of benthic invertebrates present at each of the four study sites. Mean densities (i.e., average number of individuals per unit area) reported in English units (e.g., square feet and square yards), were used to describe the abundance of individuals. Benthic invertebrates were first identified and counted for each sample. These counts represented the number of organisms or groups occurring in an area 1.08 foot square (ft^2). The average number of organisms or groups per unit area was calculated by dividing the total number of an organism or group in all samples by the number of samples. The relative density of an organism or group at a particular study site was then determined by placing the calculated mean density of that organism or group into one of four classes representing different orders of magnitude. The classes used were: Rare (0.1 - 0.9/yd^2), Sparse (1.0 - 9.9/yd^2), Common (10.0 - 99.9/7d^2), and Abundant (100.0 - 999.9/yd^2).

The diversity and eveness of the benthic invertebrate community in riffle, run, and pool habitats in the side channels and side sloughs was calculated using the Shannon-Weaver diversity index (Poole 1974). Both insect taxa and non-insect taxa were used in the calculation of the index. The formulae for the Shannon-Weaver diversity index and the eveness index are shown in Appendix D.

2.3.2.2 Suitability Criteria Development

Weighted habitat criteria representing a particular species/life phase preference for a particular habitat variable were developed for benthic food organisms for input into a habitat simulation model used to calculate usable benthic invertebrate habitat area. Due to the small numbers of many of the benthic food taxa sampled and problems associated with interpreting numerous weighted habitat criteria for each taxa, weighted habitat criteria were only developed for four behavioral groupings of benthic food organisms: burrowers, sprawlers, swimmers, and clingers (Merritt and Cummins 1978). Table 3 lists each behavioral group, its general description, and the invertebrate taxa belonging to each category.

Weighted habitat criteria are typically expressed in the form of habitat curves which describe the relative usability of different levels of a particular habitat variable for a particular species/life phase, with the peak indicating greatest usability and the tails tapering towards less usable values. Curves are typically developed for each habitat variable considered to influence the selection of habitat for the species/life phase of interest. Three types of habitat curves are typically constructed: utilization, preference, and/or suitability. A detailed description of each curve type and its usage in habitat simulation models is presented in Vincent-Lang et al. (1984).

In this report, utilization curves were modified using pertinent literature and professional judgement to define weighted habitat suitability criteria for selected behavioral groupings of benthic invertebrates. Weighted habitat suitability criteria were developed for the three habitat variables considered of greatest importance to benthic invertebrates: depth, velocity, and substrate. Due to the limited data base that could be used for the development of weighted habitat

Table 3. Invertebrate taxa grouped by behavioral type (Merritt and Cummins, 1978).

Behavioral Type	Description	Invertebrate Taxa
Burrowers	Inhabiting the fine sediments of streams (pools). Some construct discrete burrows which may have sand grain tubes extending above the surface of the substrate or the individuals may ingest their way through the sediments (examples: Diptera, most Chironominae, Chironomini-"blood worm" midges).	Tipulidae Chironomidae Psychodidae
Clingers	Representatives have behavioral (e.g., fixed retreat construction) and morphological (e.g., long, curved tarsal claws, dorso-ventral flattening and ventral gills arranged as a sucker) adaptations for attachment to surfaces in stream riffles (examples: Ephemeroptera, Heptageniidae; Trichoptera, Hydropsychidae).	Chloroperlidae Ephemerellidae Heptageniidae Hydropsychidae Perlodidae Rhyacophilidae Simuliidae Taeniopterygidae
Sprawlers	Inhabiting the surface of floating leaves of vascular hydrophytes or fine sediments, usually with modifications for staying on top of the substrate and maintaining the respiratory surfaces free of silt (examples: Ephemeroptera, Caenidae).	Capniidae Limnephilidae Nemouridae
Swimmers	Adapted for "fishlike" swimming in lotic or lentic habitats. Individuals usually cling to submerged objects, such as rocks (lotic riffles) or vascular plants (lentic), between short bursts of swimming (examples: Ephemeroptera in the families Siphlonuridae, Leptophlebiidae).	Baetidae Siphlonuridae

suitability criteria, benthic invertebrate data were pooled from all sites and both benthic sampling periods.

The first step in the development of weighted habitat suitability criteria involved the construction of utilization curves for depth, velocity, and substrate. Because depth and velocity were measured in the field to the nearest 0.1 ft and 0.1 ft/sec, respectively, the initial utilization plots were constructed using these intervals. However, since sample numbers were low within these measurement intervals and variances were high, intervals were grouped together (Table 4). Grouping of intervals was done by best visual fit of the data by considering the relative number of samples representing each increment, the number of irregular fluctuations present between different increment sizes, and the accuracy of the depth and velocity data collected.

Substrate was determined in the field according to discrete substrate class increments (e.g., silt, sand, gravel, etc.). Since sample numbers were low within these substrate increments and variances were high substrate increments were grouped for the construction of the initial utilization plots (Table 5). As for depth and velocity, grouping of intervals was done by best visual fit of the data by considering the relative number of samples representing each increment, the number of irregular fluctuations present between different increment sizes, and the accuracy of the depth and velocity data collected.

Relative utilization for each of these habitat variables was then derived by taking the total number of individuals of within each interval at a particular depth, velocity, or substrate increment and dividing by the total number of samples having that same depth, velocity, or substrate value. The resulting means (mean number of group individuals/sample) were plotted against their corresponding depth, velocity, and substrate groupings to provide utilization curves of the three habitat variables for all four behavioral groups. To calculate a utilization index of 0.0 to 1.0 for the increments of each histogram, each increment mean was divided by the largest mean determined on that histogram. In addition, a 95% confidence interval for the mean was calculated for the increments of all histograms.

Table 4. Depth and velocity increments used for suitability criteria development

Increment Number	Velocity (ft) Increment Range	Increment Number	Depth (ft/sec) Increment Range
1	0.0 - 0.4	1	0.0
2	0.4 - 0.8	2	0.0 - 0.2
3	0.8 - 1.2	3	0.2 - 0.4
4	1.2 - 1.6	4	0.4 - 0.6
5	1.6 - 2.0	5	0.6 - 0.8
		6	0.8 - 1.0
		7	1.0 - 1.2
		8	1.2 - 1.4
		9	1.4 - 1.6
		10	1.6 - 2.0
		11	2.0 - 2.6

Table 5. Substrate class groupings used for suitability criteria development.

Class Number	Class Range	Description
1	1.0 - 4.0	Silt - Sand/Small Gravel
2	5.0 - 7.0	Small Gravel - Large Gravel
3	8.0 - 10.0	Large Gravel/Rubble - Rubble/Cobble
4	11.0 - 13.0	Cobble - Boulder

Weighted habitat suitability criteria were then developed for each habitat variable for each of the four behavioral types based on the developed utilization curves, as modified using pertinent literature and professional judgement. In general, for ranges where utilization data were present, the utilization curve was used to define weighted habitat suitability criteria. For ranges which there was no utilization data, pertinent literature, professional judgement, and the general trends in the utilization data were used to define weighted habitat suitability criteria. Literature used to help in determining weighted habitat suitability criteria included: Kennedy 1976, Newell 1976, Bjornn et al. 1977, Gore 1978, Harris and Lawrence 1978, Hubbard and Peters 1978, Surdick and Gaufin 1978, Judy and Gore 1979, White et al. 1981, and Anderson 1982.

Mean water column velocities were measured in this study as opposed to point velocities at the substrate surface so as to validate the use of the resultant weighted habitat suitability criteria in the HABTAT model which uses mean water column velocities to project usable habitat area. Use of mean water velocities is consistent with that of other researchers involved with habitat simulation modelling for benthic invertebrates (Judy and Gore 1979).

2.3.2.3 Weighted Usable Area

The HABTAT habitat simulation model of the IFG (Milhous et al. 1981) was used to project weighted usable area (WUA) of benthic invertebrate habitat at each site. To calculate WUA, weighted habitat suitability criteria for depth, velocity, and substrate for each behavioral group were inputed using the standard calculation technique to calculate a Joint Preference Factor (Judy and Gore 1979) along with the IFG-4 hydraulic simulation modelling details for each study site (Vincent-Lang et al. 1984), into the HABTAT habitat simulation computer model. Use of the physical simulation models developed during the 1983 open water field season (Vincent-Lang et al. 1984) was considered valid in this analysis as, although specific changes in channel geometry and morphology may have occurred at a particular study site, such change probably reflect a dynamic, but generally stable equilibrium at the study site. Therefore, such changes are believed to exert only a limited influence on the long-term habitat availability at a study site, validating the use the models in this analysis. A detailed explanation of the steps involved in calculating WUA is provided in Vincent-Lang et al. (1984).

Gross surface area at each study site and WUA for each behavioral group at each study site were projected over the range of site flows from 5.0-600.0 cfs at Slough 9, 5.0-100.0 cfs at Side Channel 10, 5.0-250.0 cfs at Upper Side Channel 11, and 5.0-400.0 cfs at upper Side Channel 21. Resultant WUA projections were then plotted as a function of site flow to graphically show the relationship between site flow and WUA for each behavioral group. In addition, gross surface area was plotted on each respective figure.

The relationships between WUA and gross surface area to mainstem discharge were also plotted for periods when the site flow was directly controlled by mainstem discharge. Additional plots using an expanded WUA scale were constructed for each site to better depict and compare trends of WUA as a function of mainstem discharge at and between study sites. The x-coordinate values on these plots were derived using site-specific flow/mainstem discharge rating curves presented in Appendix A.

2.3.3 Invertebrate Larval Development

The amount of growth or development of the larva of hemimetabolis insects was determined by visual inspection of the amount of wing development within the wing pads. Three categories of larvae were determined: early instar (i.e., the insect shortly after hatching from the egg), middle instar, and late instar (the insect shortly before emergence as adult). If no wing pads were discernible or if no wing development was discernible within the wing pads, the insects were considered to be in the early instar stage. Middle instars were considered to be individuals having wing pads in which the developing wings had the appearance of venation. If wing pads contained flight wings which appeared near full development, the insects were considered to be in the late instar stage. Wing pads in this last stage of development appeared dark as a result of the tight folding of the flight wing inside the pads.

2.3.4 Juvenile Chinook Salmon

The stomach content data from juvenile chinook salmon were pooled for all sites and sampling dates and grouped into the eight taxonomic categories listed in Section 2.3.1. Percent composition of each category was determined and displayed as pie diagrams. In addition to the taxonomic groupings, the aquatic insects found in the juvenile chinook stomachs were grouped by behavioral type as shown in Table 3. The percent composition of each behavioral group was determined and also represented as pie diagrams. In addition to the pie diagrams, juvenile chinook salmon stomach content data were presented in the form of bar diagrams. For these diagrams, all sites were pooled for comparison of the relative contribution of the different taxonomic groups on the four sampling dates.

Benthic invertebrate and invertebrate drift data were also presented in pie diagrams for comparison with the juvenile chinook stomach content data. Pie diagrams of the benthic and drift data were made with the same eight taxonomic groupings and the four aquatic insect behavioral types.

3.0 RESULTS

3.1 Invertebrate Drift

Six orders, representing 30 families of aquatic and semi-aquatic insects, and eight orders not identified to the family level were collected within the four study sites during the 1984 open water study period. In addition, eleven non-insect aquatic and non-aquatic groups were also collected (Appendix Table B-1).

The most frequently occurring invertebrate groups in drift samples were dipteran flies and ephemeropterans (mayflies) with Plecopterans (stoneflies) being the third most frequently encountered insect group (Appendix Table B-2 through B-5). Chironomid flies and baetid mayflies made up the majority of individuals in Diptera and Ephemeroptera, respectively, whereas no family was dominant in Plecoptera. Chironomids were relatively abundant throughout the entire sampling period while ephemeropterans were relatively common only in early June. Plecopterans were more common in early August than in early June. The density of these three insect groups was generally greater at head sampling sites than at IFG-4 sampling sites (Table 6).

Scatter plots, showing the linear relationship between drifting invertebrates grouped as Collembola, Ephemeroptera, Plecoptera, Trichoptera, Diptera larvae, Diptera adults, Other Insects, and Other Invertebrates are shown in Figures 7 and 8. These two figures show the relationships of drifting invertebrates under breached conditions. The plots reveal

Table 6. Relative density of invertebrate drift per cubic yard of water by site and drift net location, June through August 1984, Middle Susitna River, Alaska. R=Rare ($0.001-0.009/yd^3$), S=Sparse ($0.010-0.09/yd^3$), C=Common ($0.100-0.90/yd^3$), A=Abundant ($1.000-9.90/yd^3$).

	Slough 9		Side Channel 10		Upper Side Channel 11		Slough 21	
Site	Head	IFG-4	Head	IFG-4	Head	IFG-4	Head	IFG-4
INSECTA								
Protura	-	-	-	-	R	-	-	-
Collembola	-	-	-	-	-	R	-	-
Isotomidae	S	S	S	S	C	S	S	R
Poduridae	-	R	-	-	R	R	S	R
Sminthuridae	R	R	R	-	R	R	S	R
TOTAL Collembola	S	S	S	S	C	S	C	R
Ephemeroptera	-	-	-	-	-	R	-	-
Baetidae	S	S	C	S	A	C	-	R
Ephemerellidae	S	S	S	S	S	R	S	R
Heptageniidae	S	S	S	S	S	S	S	R
Siphlohuridae	-	-	S	S	S	R	S	-
TOTAL Ephemeroptera	S	S	C	S	A	C	S	R
Plecoptera	S	S	-	-	S	S	-	R
Capniidae	R	R	-	R	R	R	-	R
Chloroperlidae	R	R	S	R	S	S	-	-
Nemouridae	R	-	S	R	S	S	-	R
Perlodidae	S	R	S	R	S	R	S	R
Pteronarcidae	-	-	-	-	R	-	-	-
Taeniopterygidae	S	S	R	R	-	-	-	-
TOTAL Plecoptera	S	S	S	S	S	S	S	S
Psocoptera	R	R	-	R	R	-	-	R
Thysanoptera	S	S	-	R	S	S	-	S
Hemiptera	R	S	S	R	R	R	R	R
Homoptera	S	R	S	R	S	S	-	S
Neuroptera	-	-	-	-	-	R	S	-
Coleoptera	S	S	R	S	S	S	S	R
Dytiscidae	-	-	-	-	R	R	-	-
Hydrophilidae	-	-	-	-	-	R	-	-
TOTAL Coleoptera	S	S	S	S	S	S	S	R
Trichoptera	S	S	-	-	R	R	-	S
Glossosomatidae	-	-	-	R	-	R	-	-
Hydropsychidae	S	R	S	S	R	R	-	-
Limnephilidae	S	S	R	R	R	-	-	R
Rhyacophilidae	-	-	-	-	S	R	-	-
TOTAL Trichoptera	S	S	S	S	S	S	-	R
Lepidoptera	R	R	R	R	S	S	-	R

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Table 6 (Continued).

Site	Slough 9 Head	Slough 9 IFG-4	Side Channel 10 Head	Side Channel 10 IFG-4	Upper Side Channel 11 Head	Upper Side Channel 11 IFG-4	Slough 21 Head	Slough 21 IFG-4
Diptera	S	R	S	-	S	S	S	R
Ceratopogonidae	R	R	R	S	S	R	S	S
Chironomidae	A	C	A	C	A	A	C	A
Culcidae	-	-	-	-	-	R	-	-
Dixidae	-	-	-	-	R	R	-	-
Empididae	R	S	S	S	S	S	C	R
Muscidae	-	-	-	-	R	R	-	R
Psychodidae	-	R	-	R	R	R	-	-
Simuliidae	C	S	C	C	C	S	S	R
Stratiomyidae	-	-	-	-	R	-	-	-
Syrphidae	-	-	-	-	R	R	-	-
Tipulidae	R	R	S	R	S	S	S	R
TOTAL Diptera	A	C	A	A	A	A	A	A
Hymenoptera	S	S	S	S	S	S	C	C
HYDROZOA	-	-	-	-	-	-	-	R
NEMATODA	-	-	S	R	R	R	-	-
OLIGOCHAETA	S	S	C	S	S	S	-	S
CRUSTACEA								
Cladocera	S	S	-	-	R	R	-	-
Podocopa	R	R	S	-	-	R	-	R
Eucopepoda	S	S	S	S	R	S	-	-
Amphipoda	-	-	-	-	R	R	-	-
TOTAL CRUSTACEA	S	S	S	S	S	S	-	R
ARACHNIDA								
Araneae	R	R	R	R	S	R	-	R
Acari	S	S	S	S	S	S	-	S
TOTAL ARACHNIDA	S	S	S	S	S	S	-	S
CHILOPODA	-	-	-	-	R	-	-	-
GASTROPODA	-	-	-	-	R	R	-	-

HEAD VERSUS IFG DRIFT SAMPLES

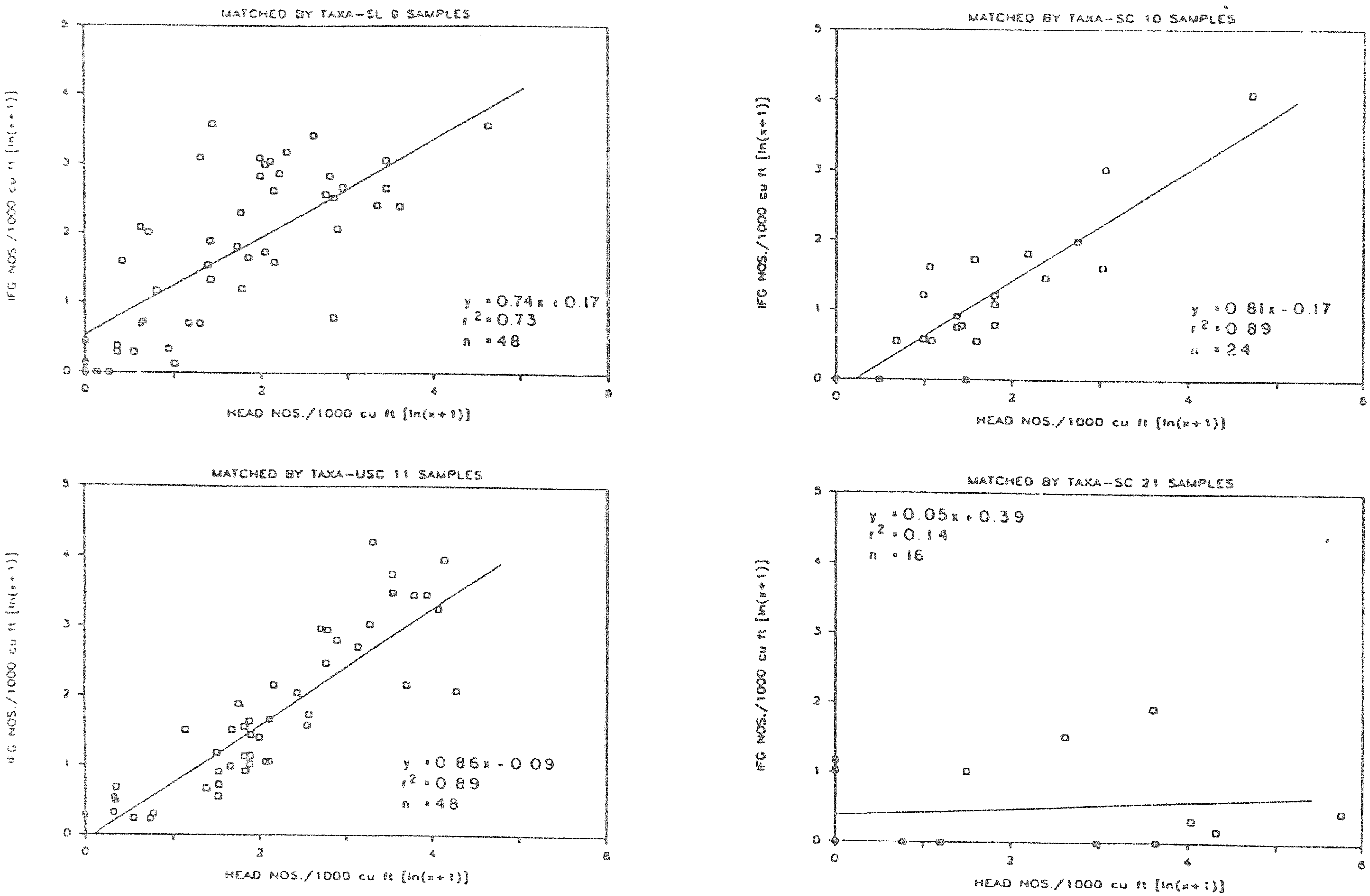

Figure 7 Scatter plots of standardized drift densities (no/1000³ feet of water) of eight invertebrate groups, head numbers vs. IFG-4 numbers. Densities are transformed $\log_e$ (x+1).

HEAD VERSUS IFG DRIFT SAMPLES

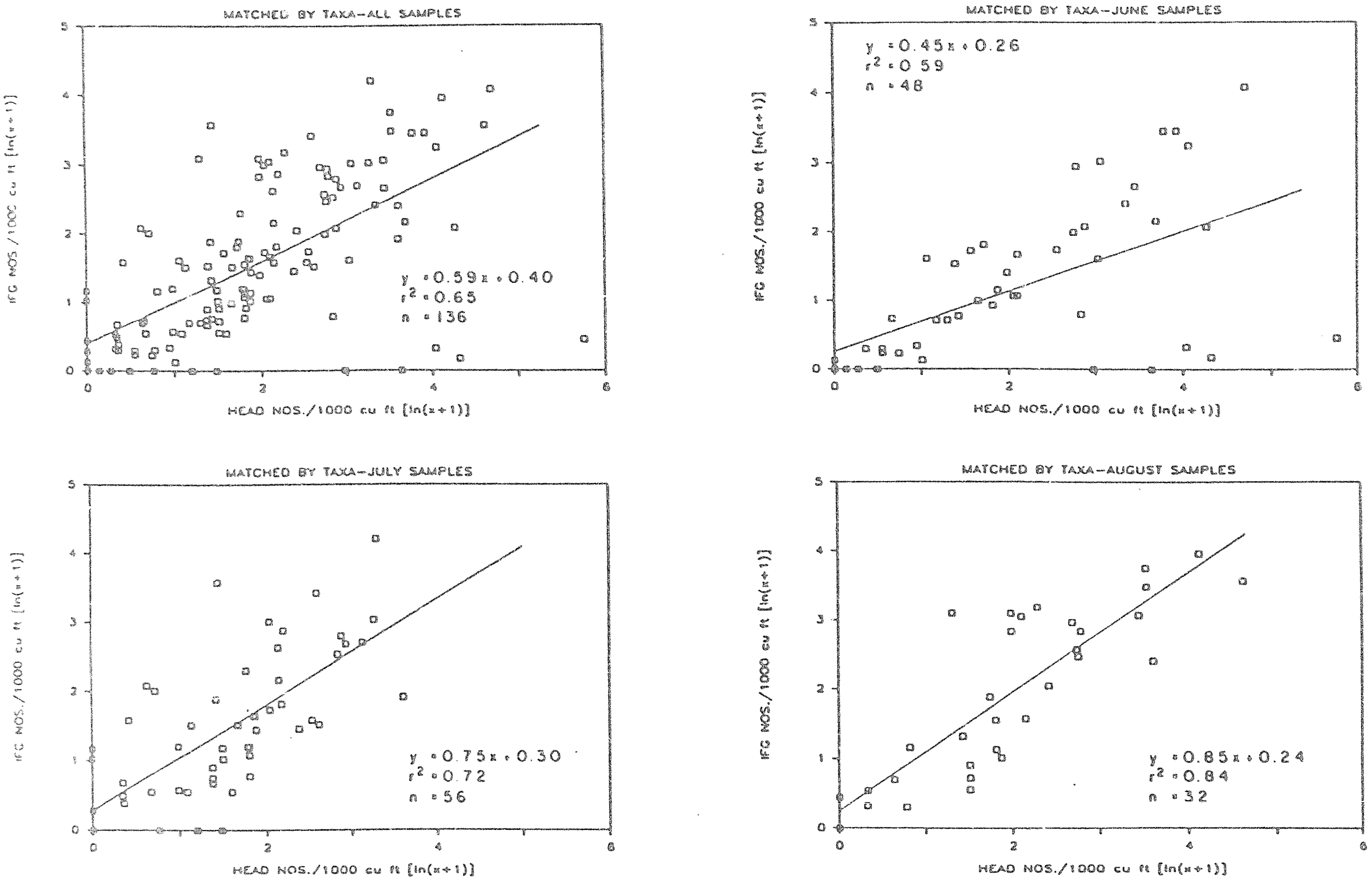

Figure 8 Scatter plots of standardized drift densities (no/100³ feet of water) of eight invertebrate groups, head numbers vs. IFG-4 numbers. Densities are transformed $\log_e (x+1)$.

in all cases that the numbers of individuals at IFG-4 sites increase as the number of individuals at head sites increase. The slope of the regression equation for all plots, however, suggest that proportionately fewer invertebrates were found in the drift at IFG-4 sampling sites than at head sampling sites. Coefficient of determination values (r^2) for the plots ranged from 0.14 to 0.89 with the upper Side Channel 21 data having the lowest value. This sampling location was frequently unbreached or at initial breaching during sampling periods resulting in few drift samples being taken at this location.

The results of the multiple regression F test indicated that the variation in drift numbers at the IFG-4 sites (y) could be "explained" by the variation in drift numbers at the head sites (x_1), volume of water filtered at head sites (x_2), and volume of water filtered at the IFG-4 sites (x_3). However, the results of the Student's t tests indicated that the regression coefficient (β_2) for x_2 was not significantly different from zero. Accordingly, a new general linear model was evaluated which did not utilize x_2. The new model was:

$$y = \beta_0 + \beta_1 x_1 + \beta_3 x_3 + \varepsilon$$

where the symbols are same defined in section 2.3.1. The F test for this model indicated that the variation in drift numbers at the IFG-4 sites (y) could be "explained" by the variation in drift numbers at the head sites (x_1) and the volume of watered filtered from samples at the IFG-4 sites (x_3). The Student's t test results for this model indicated that β_1 and β_3 were significantly different from zero (at $\alpha = 0.05$). Accordingly, at mainstem discharge levels which exceed controlling breaching values, there does appear to be a relationship between composition and abundance of the drift at the IFG-4 sites versus that at the head sites. The specific details of the general linear models summarized above are presented in Appendix C.

On 14 occasions, an invertebrate group was found only at the IFG-4 or the head sampling site during sampling periods. This phenomenon occurred among the Collembola, Ephemeroptera, Plecoptera, Trichoptera, Diptera larvae, and Other Invertebrates groups at least once at each of the four sampling reaches.

The density and rate of drift among the eight invertebrate groups is shown in Appendix Table B-6. This table includes densities of drifting invertebrate groups and rates of drift under breached and unbreached conditions. In general, the densities of drifting organisms and rates of drift were higher at head sampling sites than at IFG-4 sampling sites during periods of breaching. However, the rate of drift at the head or IFG-4 site was in some instances lower or higher than expected for the corresponding density for drifting organisms in the water columns. For example, in the Total Invertebrates category at the head sampling site in Slough 9 during the June 7-14 sampling period there were 149 organisms per cubic yard of water and a corresponding rate of drift of 11.98 organisms per minute. In comparison, during the August 9-16 sampling period the density of drifting organisms in a cubic yard of water was 3.03 organisms but with a lower than expected corresponding drift rate of 8.91 organisms per minute (Appendix Table B-6). In another instance, the density and rate of drift of total invertebrates at the head site of Side Channel 10 was higher than that at the IFG-4 site. During both the June 7-14 and July 7-14 sampling periods the rate of drift at this head site was not correspondingly higher than that at the IFG-4 site for both these sampling periods (Appendix Table B-6). The reason for this is that, though two equal volumes of water may have the same number of organisms, the rate at which the organisms pass a point will be different if the velocities of water are different.

3.2 Benthic Invertebrates

Benthos at the four study sites was dominated by aquatic insects (73%) and oligochaete worms (24%). The remaining 3% of benthos was made up primarily of flatworms (Turbellaria), nematodes, crustaceans, and aquatic mites (Acari), with gastropods (snails) and pelecypods (clams) being incidental. In all, six orders of aquatic and semi aquatic insect and seven classes of non-insects were identified (Appendix Table B-1).

The relative abundance of benthic invertebrates at study sites is shown in Table 7. The seasonal variation in numbers of invertebrates is indicated in Appendix Tables B-7 through B-10. In general, higher numbers of benthic invertebrates were present in study sites during late August and early September (late summer) than during late June and early July (early summer). Ephemeropterans and dipterans were the most common benthic invertebrates in early summer, whereas plecopterans and

Table 7. Relative density of benthic invertebrates per square yard by site, June through September 1984, Susitna River Alaska. R=Rare (0.1-0.9/yd²), S=Sparse (1.0-9.9/yd²), C=Common (10.0-99.9/yd²), A=Abundant (100.0-999.9/yd²).

	Slough 9 RM 128.3	Side Channel 10 RM 133.8	Upper Side Channel 11 RM 136.0	Slough 21 RM 141.8
INSECTA				
Collembola				
Isotomidae	R	-	R	R
Ephemeroptera				
Baetidae	S	S	S	S
Ephemerellidae	S	R	S	R
Heptageniidae	S	S	S	S
Siphlonaridae	R	R	R	-
TOTAL Ephemeroptera	S	S	C	C
Plecoptera				
Capniidae	S	C	S	R
Chloroperlidae	S	S	S	S
Nemouridae	R	R	S	S
Perlodidae	S	S	S	S
Taeniopterygidae	S	R	R	-
TOTAL Plecoptera	C	C	C	C
Coleoptera				
Dytiscidae	-	-	-	R
Trichoptera				
Hydropsychidae	-	-	-	R
Hydroptilidae	-	-	-	R
Limnephilidae	S	S	R	C
Rhyacophilidae	R	-	S	-
TOTAL Trichoptera	S	S	S	C
Diptera				
Ceratopogonidae	R	-	R	-
Chironomidae	C	C	C	A
Empididae	R	S	R	S
Muscidae	-	-	-	R
Psychodidae	-	-	R	R
Simuliidae	R	R	R	R
Tipulidae	R	S	R	S
TOTAL Diptera	C	C	C	A
TURBELLARIA	-	-	S	S
NEMATODA	R	R	R	R
OLIGOCHAETA	C	S	C	A
CRUSTACEA				
Cladocera	R	-	-	-
Eucopepoda	R	-	R	R
Podocopa	-	R	-	-
TOTAL CRUSTACEA	R	R	R	R
ARACHNIDA				
Acari	R	R	R	S
GASTROPODA	-	-	R	-
PELECYPODA	-	-	R	-

dipterans were the most common groups in late summer. Fewer dipterans were present in benthic samples in early summer than in late summer. Upper Side Channel 11 and upper Side Channel 21 typically had the highest numbers of benthic invertebrates present in the benthos. The most common benthic groups at these sites were dipterans and oligochaetes (Appendix Table B-8 and B-10).

Chironomid midges, oligochaetes, capniid stoneflies, and baetid and heptageniid mayflies were the most common benthic invertebrate families at the four study sites. High numbers of baetids and heptageniids were present in early summer, whereas capniids were most abundant in late summer. The highest numbers of chironomids occurred in late summer (Appendix Tables B-7 through B-10).

The mean density of benthic invertebrates commonly preyed on by juvenile salmonids are presented by behavioral type, according to macrohabitat (i.e., slough or side channel) and microhabitat type (i.e., pool, riffle, or run) in Figure 9. In general, the data showed that side slough macrohabitats had higher densities of benthic invertebrates than side channel macrohabitats. The data also showed that riffles were the only microhabitat type in which all four behavioral types were present in densities over five individuals per square yard. Pools had the least number of behavioral types. Burrowers, comprised primarily of chironomid midges, were typical in each of the microhabitat types but were most common in pools. Clingers which include such families as Heptageniidae (Ephemeroptera), Hydropsychidae (Trichoptera), and Simuliidae (Diptera),

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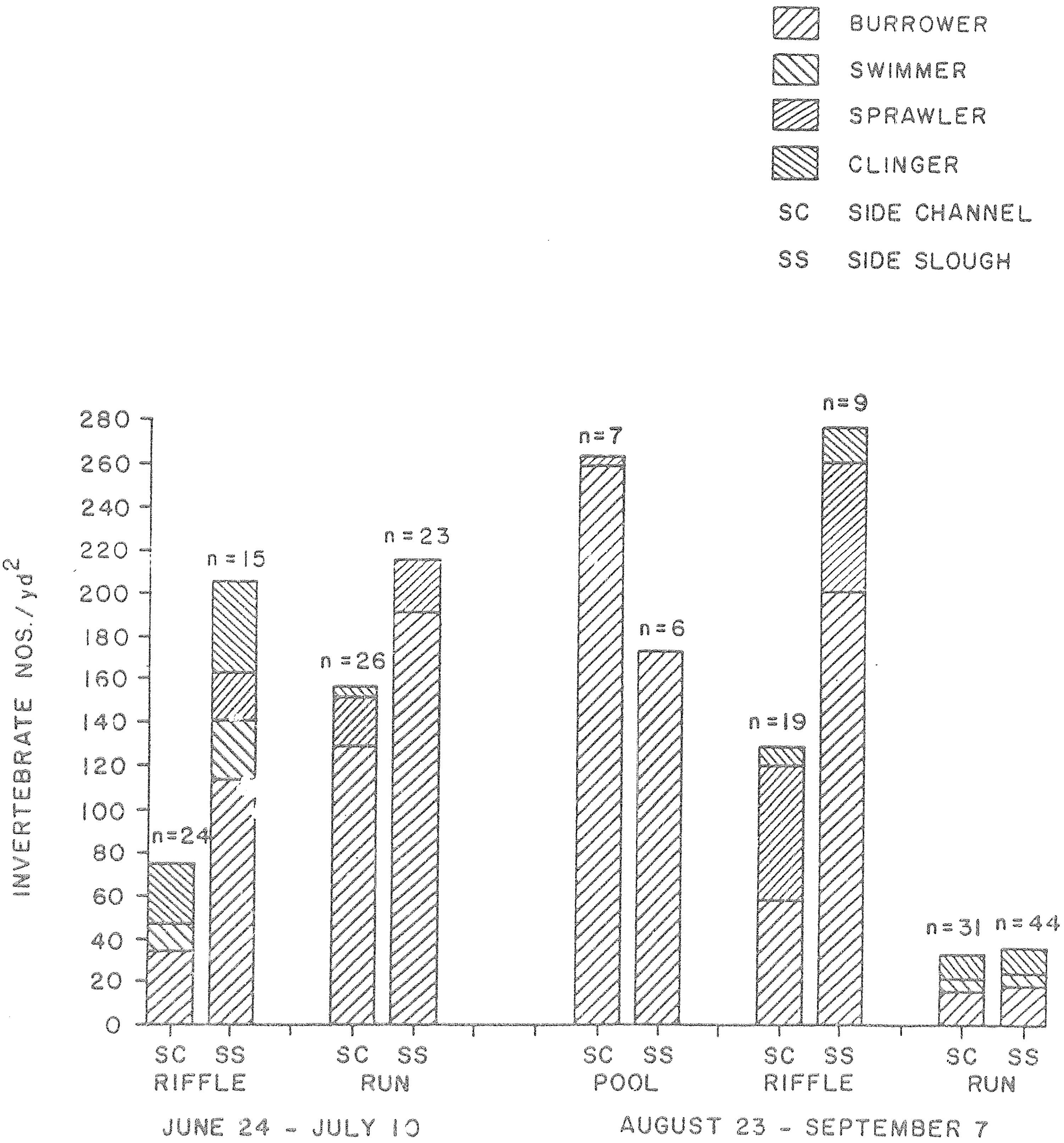

Figure 9 Average density of benthic fish food organisms (no./yd²) by behavioral type in riffle, run, and pool habitats in side channels and side sloughs, from June 24 to July 10 and August 23 to September 7, middle Susitna River, Alaska, 1984. Behavioral groups with fewer than five individuals per square yard are not shown.

and swimmers and sprawlers which include Baetidae (Ephemeroptera: swimmer), Nemouridae (Plecoptera: sprawler), and Limnephilidae (Trichoptera: sprawler) occurred in both riffle and run microhabitats but were more common in riffle microhabitat types.

3.2.1 Benthic Habitat Suitability Criteria

Utilization histograms for the habitat variables of depth, velocity, and substrate were constructed for the four benthic invertebrate behavioral groups: burrowers, swimmers, clingers, and sprawlers (Figure 10-21). These utilization curves were then modified using pertinent literature and professional judgement to derive weighted habitat suitability criteria (Table 8) for input in the HABTAT habitat simulation model. The derivation of the weighted habitat suitability criteria for each habitat variable and each behavioral grouping is presented below.

3.2.1.1 Depth

Based on frequency analysis and professional judgement, the depth utilization histograms for the four behavioral groups (Figure 10-13) did not appear to show that a clear relationship existed between the densities of benthic organisms present and the ranges of depth utilized. Because of this, a suitability index value of 0.00 was assigned to a depth of 0.0 ft. and a suitability index value of 1.00 was assigned to all depths greater than 0.0 ft.

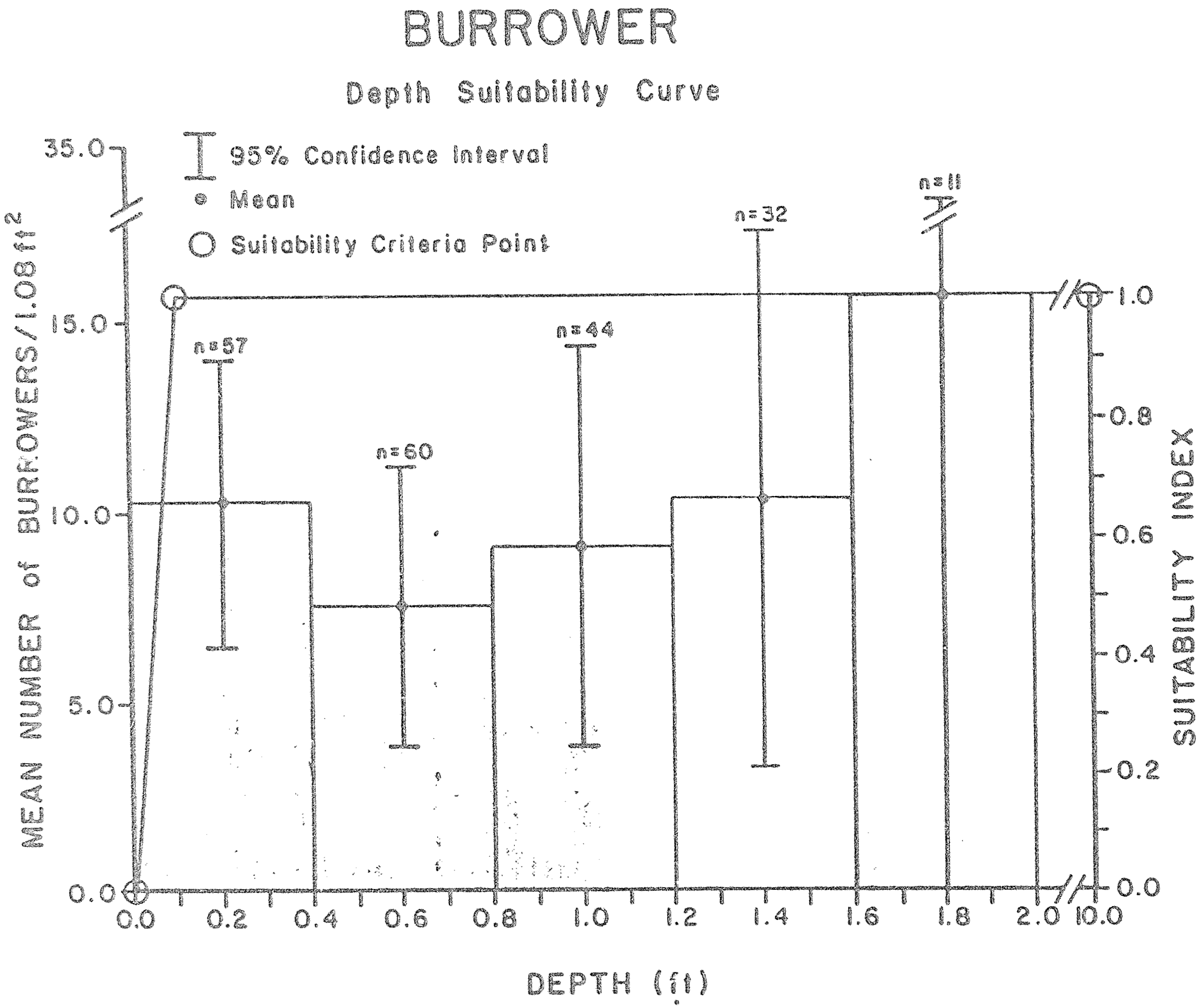

Figure 10 Average number of burrower invertebrates per benthic sample for each depth increment, with hand fitted suitability curve, middle Susitna River, Alaska, 1984.

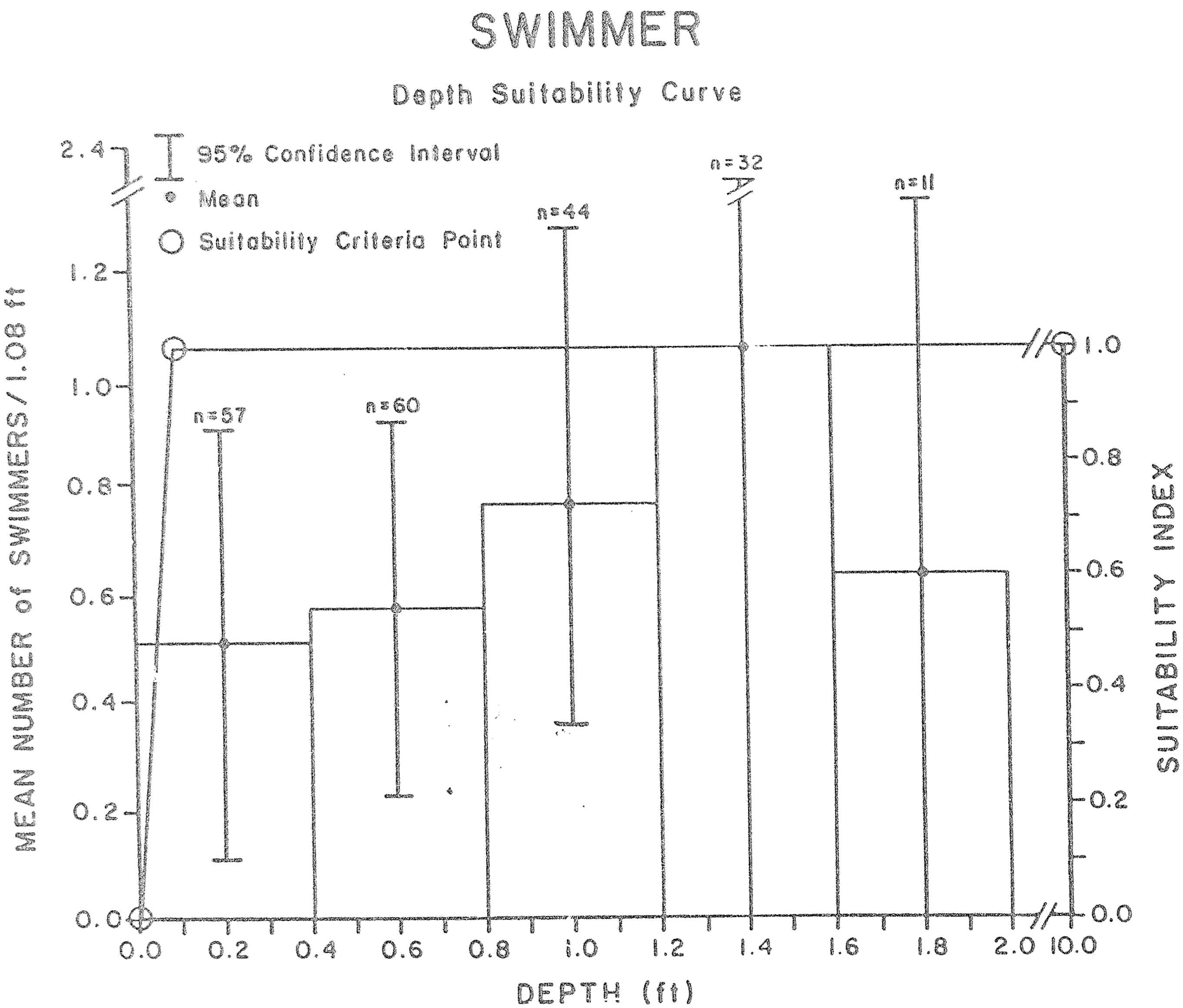

Figure 11 Average number of swimmer invertebrates per benthic sample for each depth increment, with hand fitted suitability curve, middle Susitna River, Alaska, 1984.

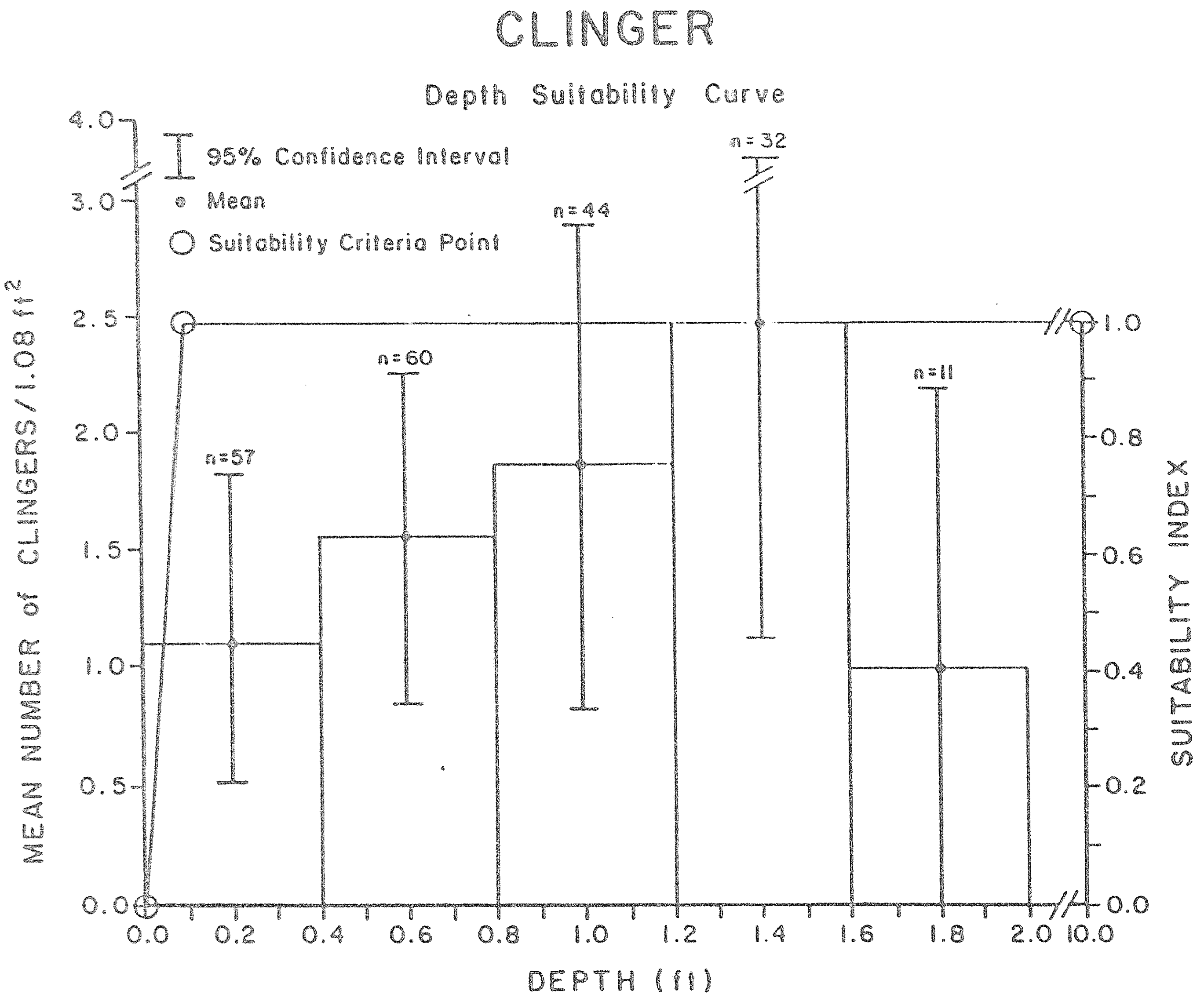

Figure 12 Average number of clinger invertebrates per benthic sample for each depth increment, with hand fitted suitability curve, middle Susitna River, Alaska, 1984.

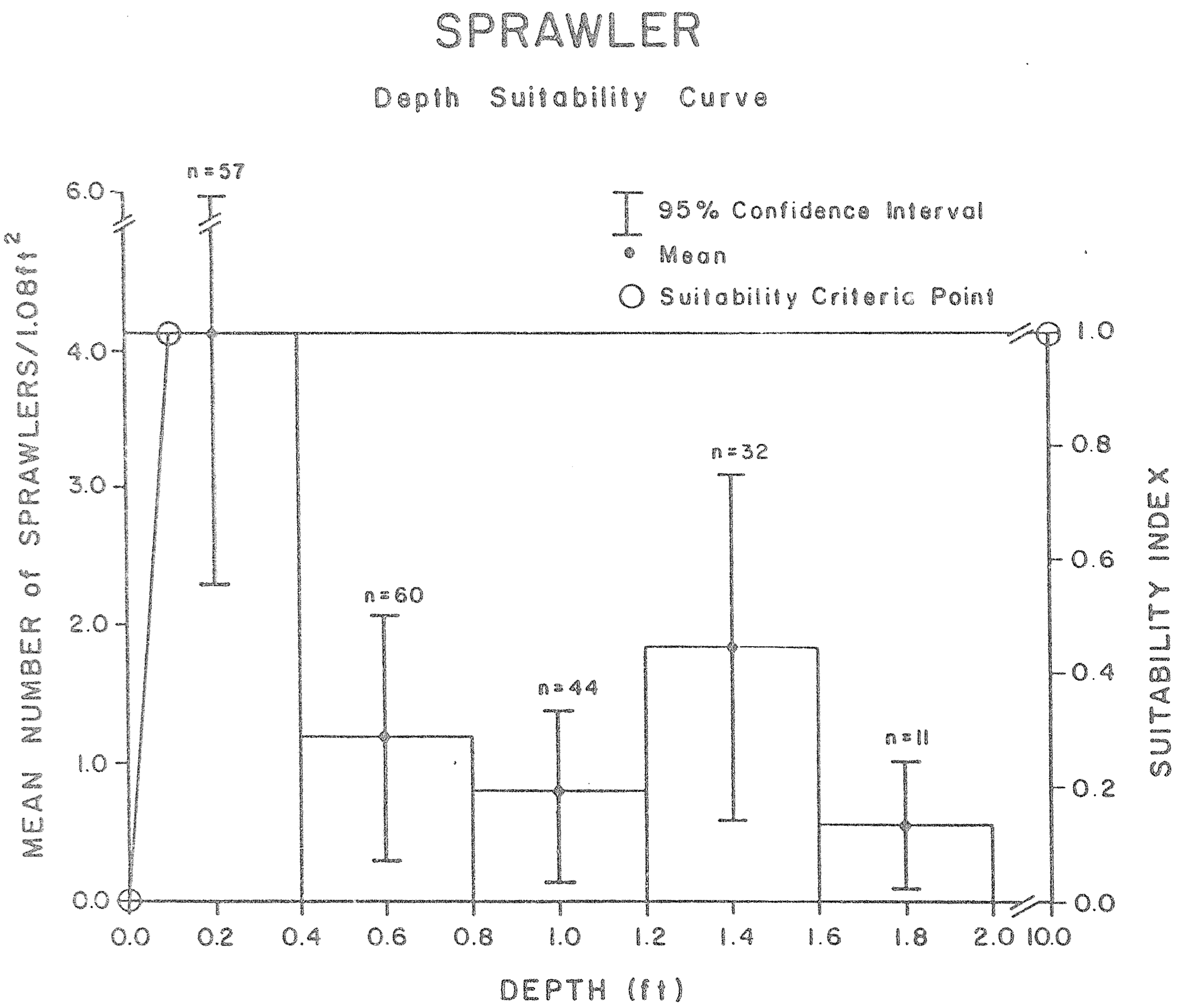

Figure 13 Average number of sprawler invertebrates per benthic sample for each depth increment, with hand fitted suitability curve, middle Susitna River, Alaska, 1984.

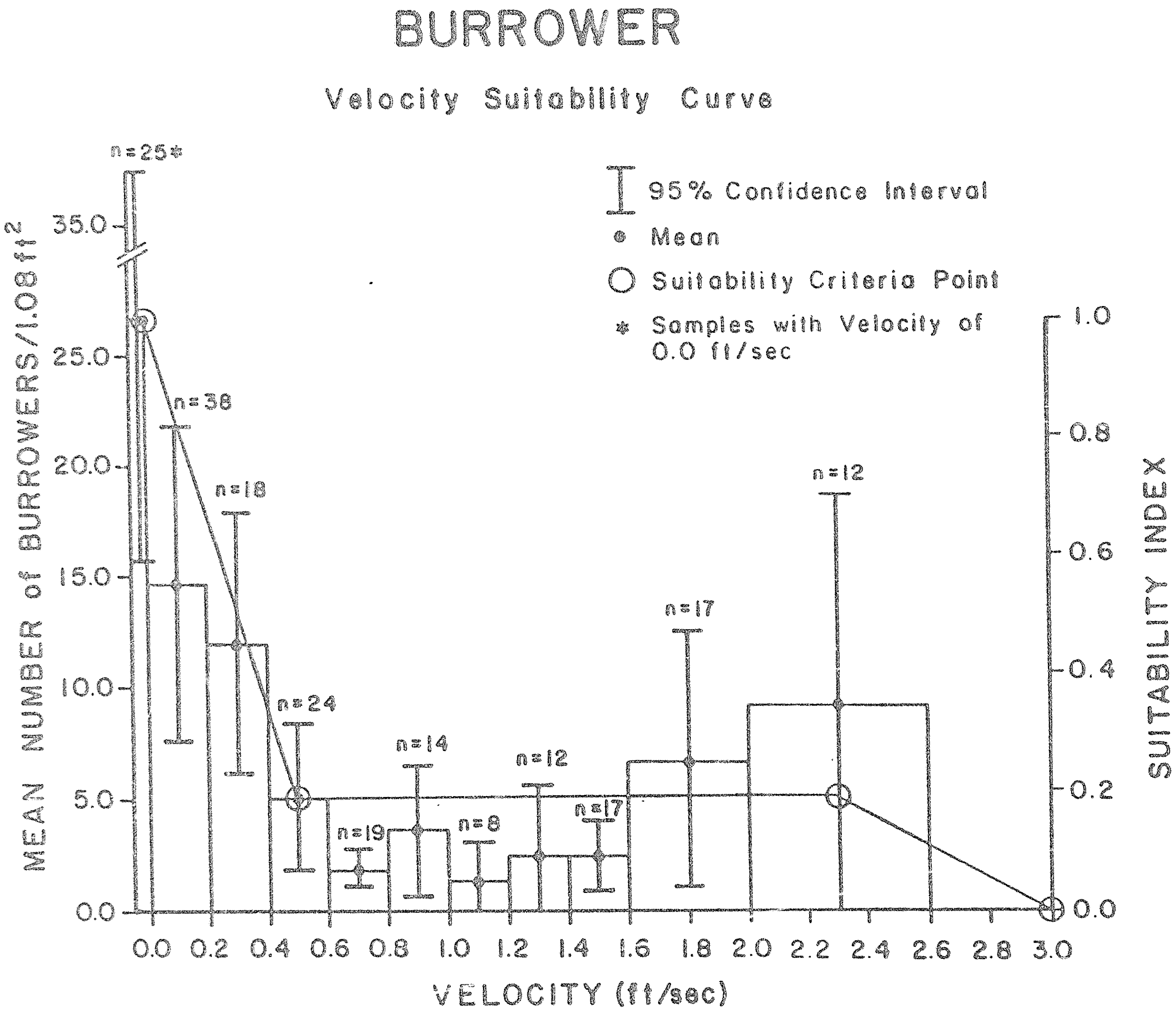

Figure 14 Average number of burrower invertebrates per benthic sample for each velocity increment, with hand fitted suitability curve, middle Susitna River, Alaska, 1984.

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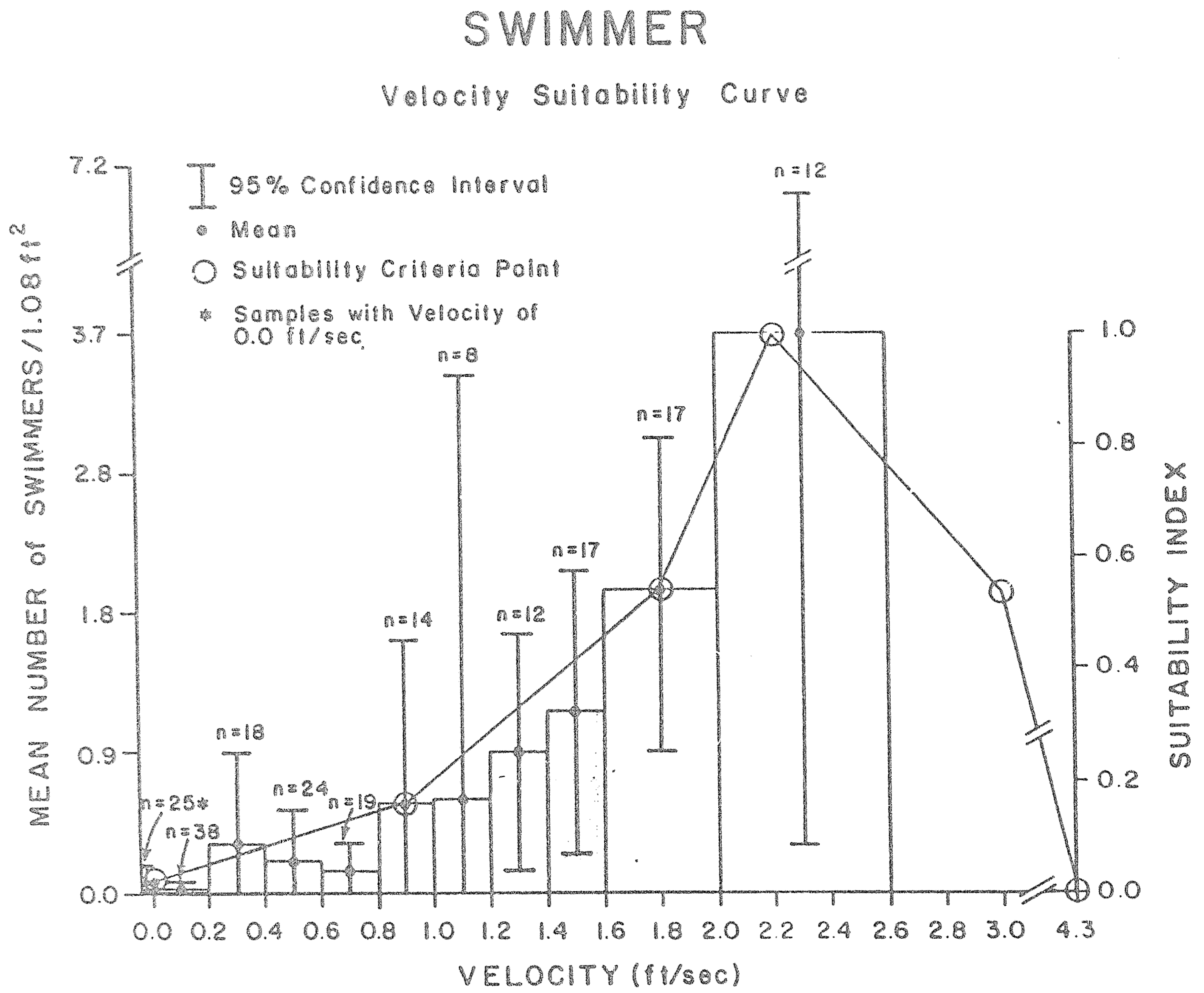

Figure 15 Average number of swimmer invertebrates per benthic sample for each velocity increment, with hand fitted suitability curve, middle Susitna River, Alaska, 1984.

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CLINGER

Velocity Suitability Curve

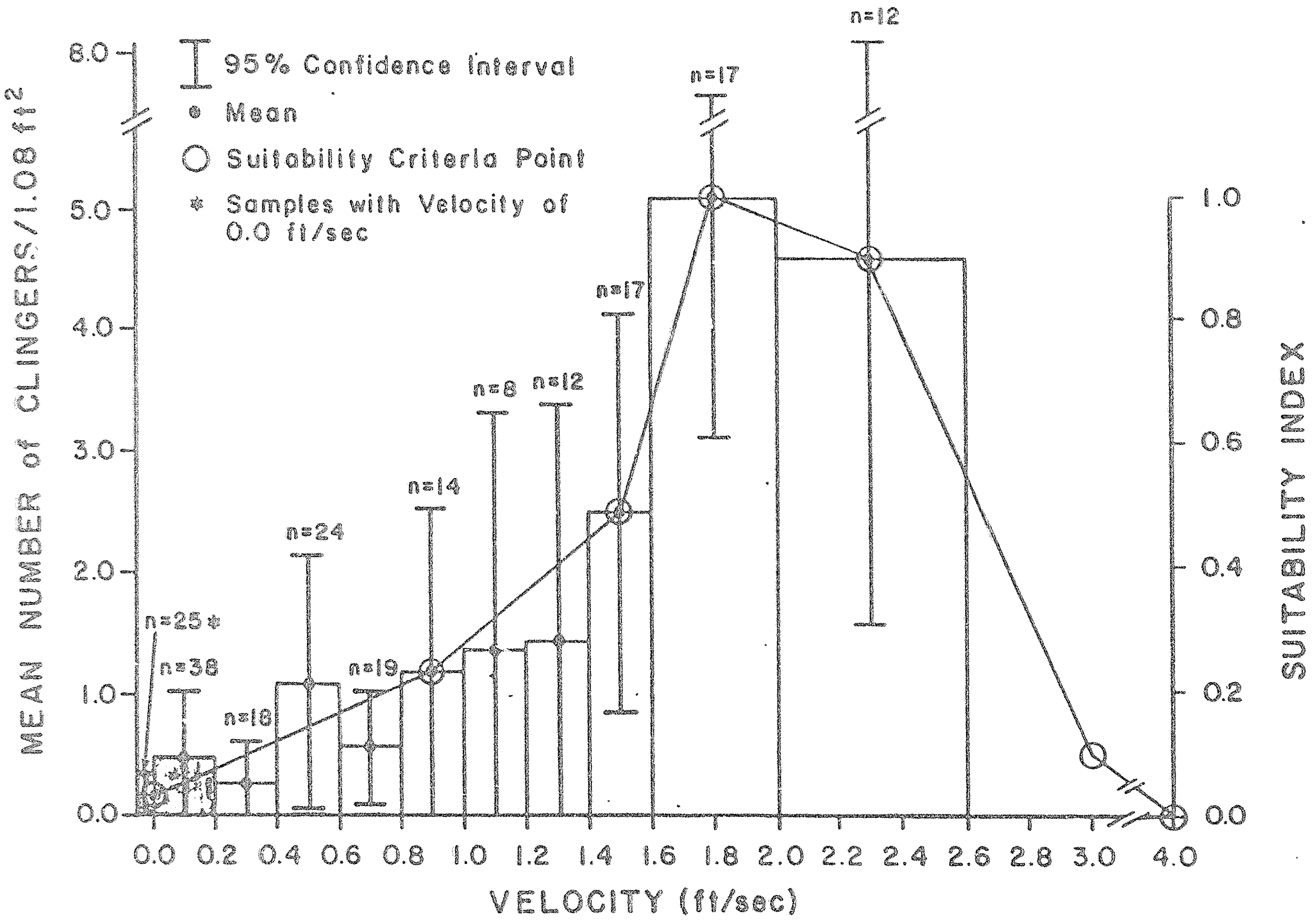

Figure 16 Average number of clinger invertebrates per benthic sample for each velocity increment, with hand fitted suitability curve, middle Susitna River, Alaska, 1984.

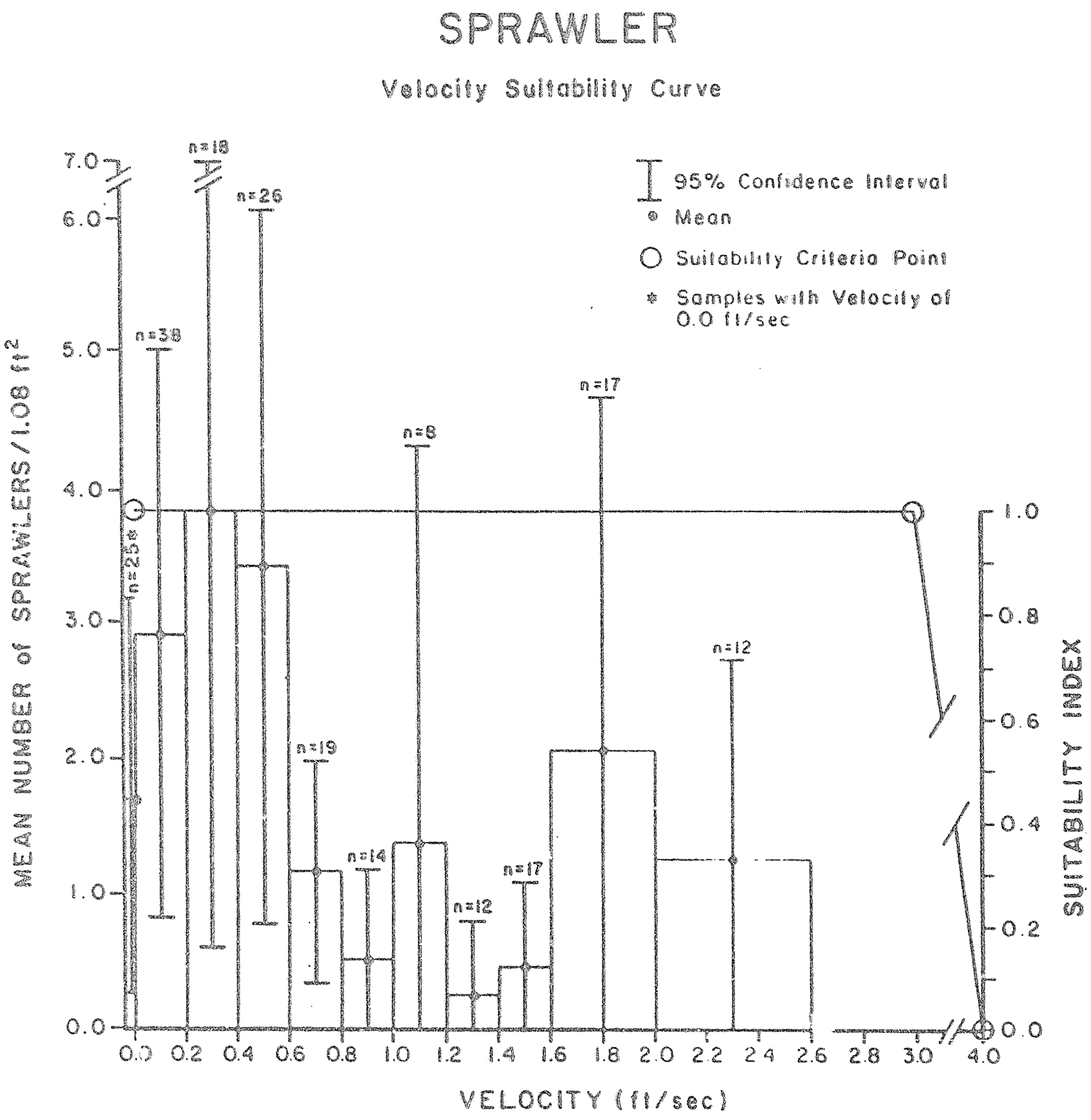

Figure 17 Average number of sprawler invertebrates per benthic sample for each velocity increment with hand fitted suitability curve, middle Susitna River, Alaska, 1984.

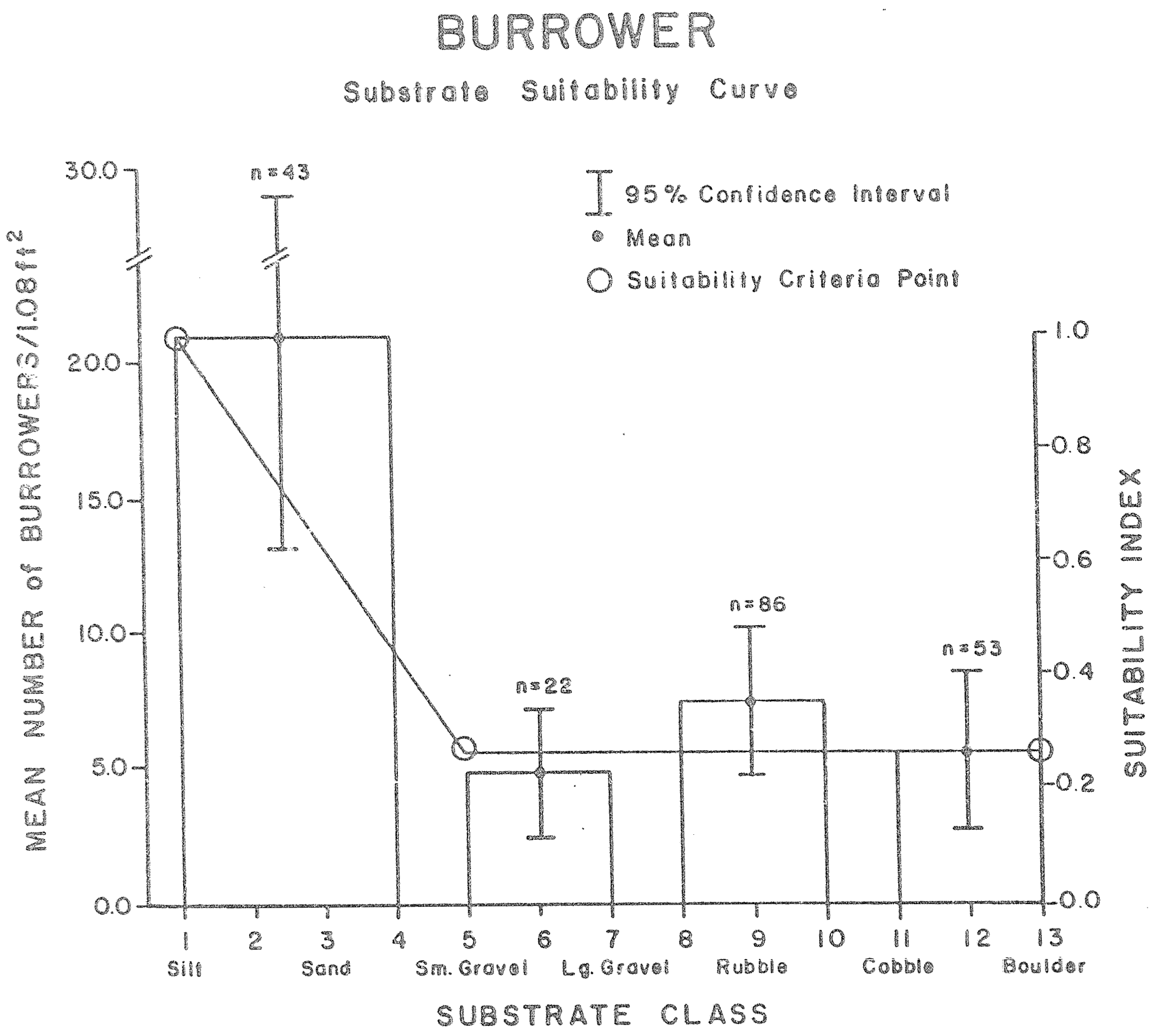

Figure 18 Average number of burrower invertebrates per benthic sample for each substrate increment, with hand fitted suitability curve, middle Susitna River, Alaska, 1984.

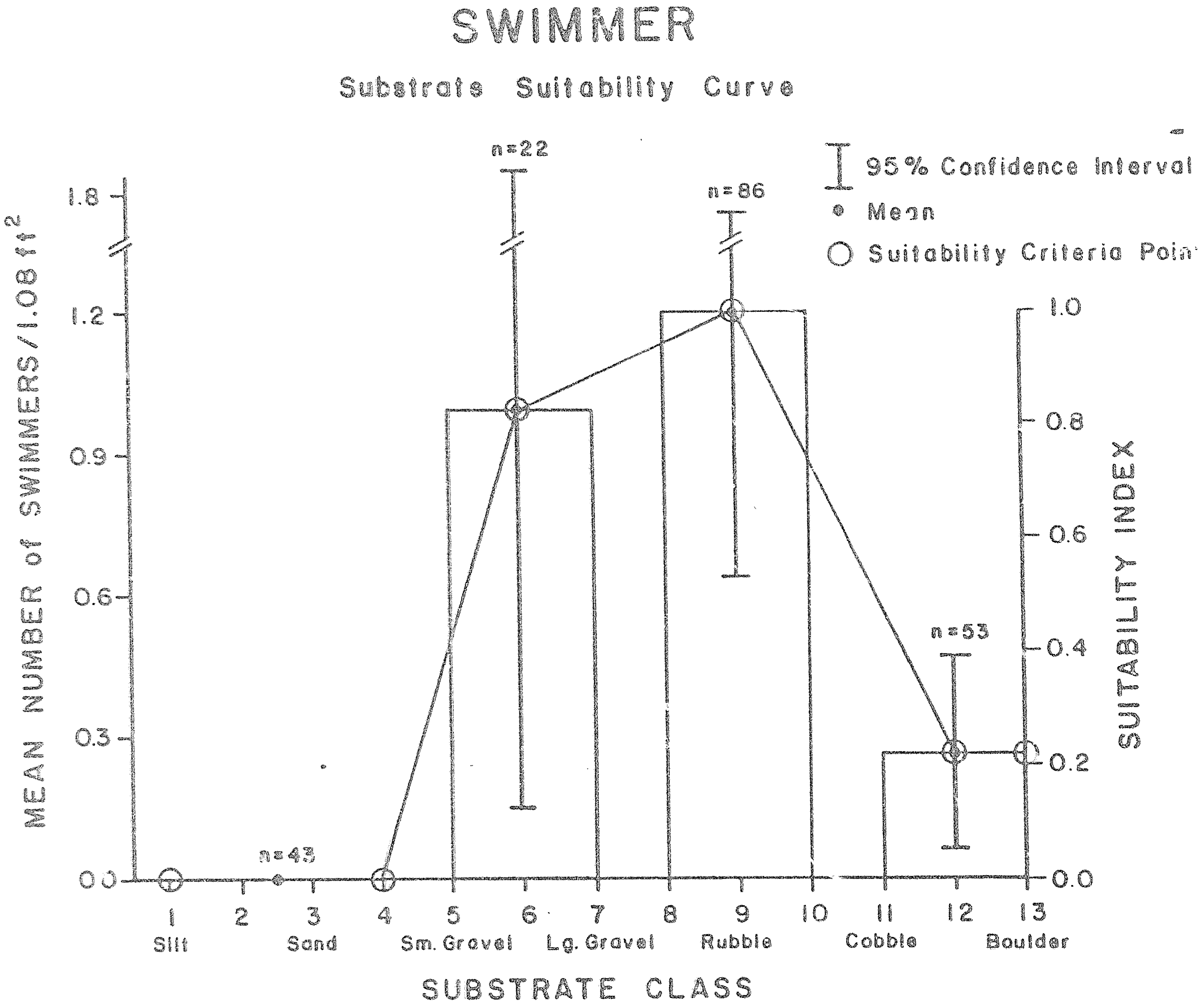

Figure 19 Average number of swimmer invertebrates per benthic sample for each substrate increment, with hand fitted suitability curve, middle Susitna River, Alaska, 1984.

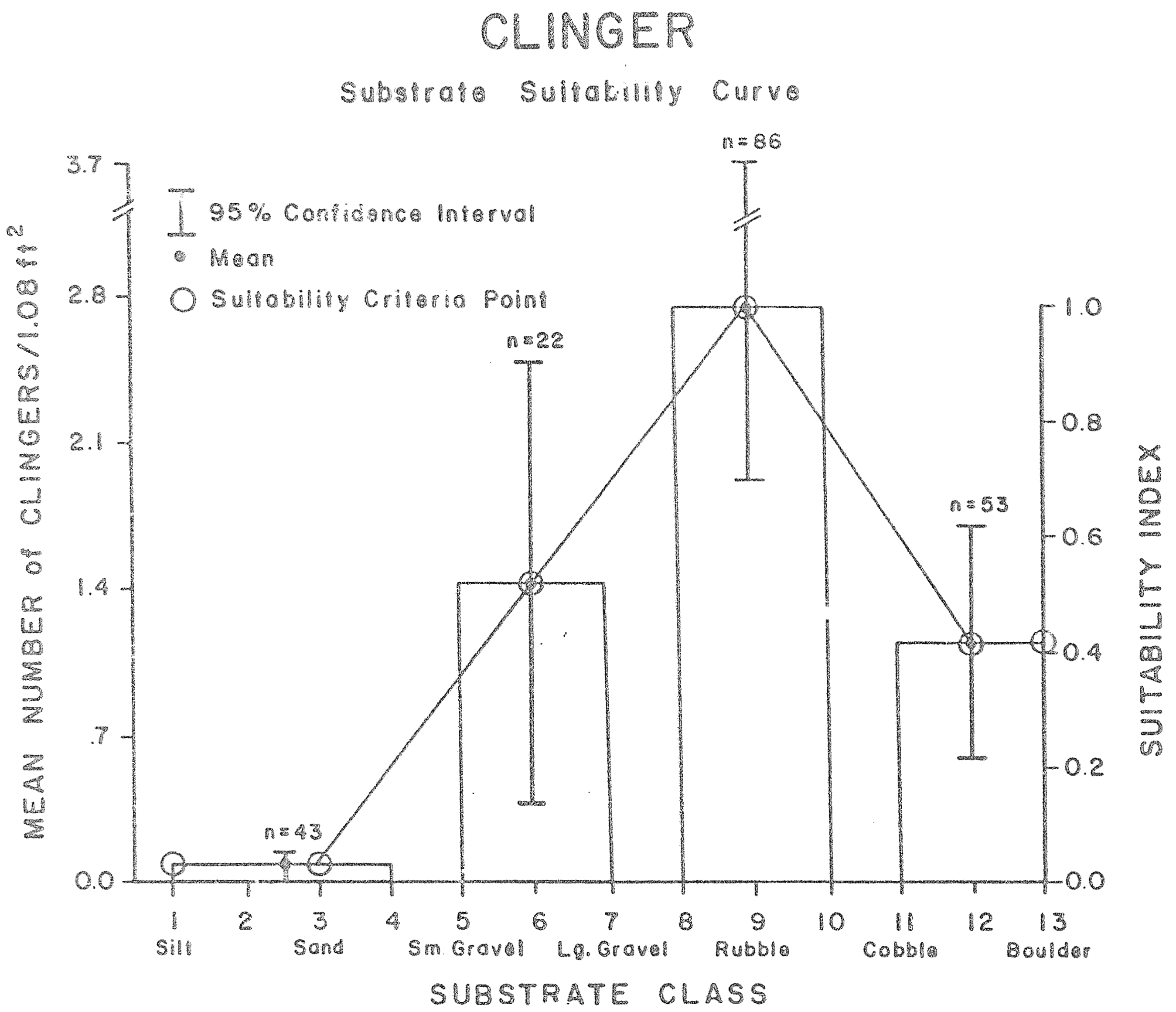

Figure 20 Average number of clinger invertebrates per benthic sample for each substrate increment, with hand fitted suitability curve, middle Susitna River, Alaska, 1984.

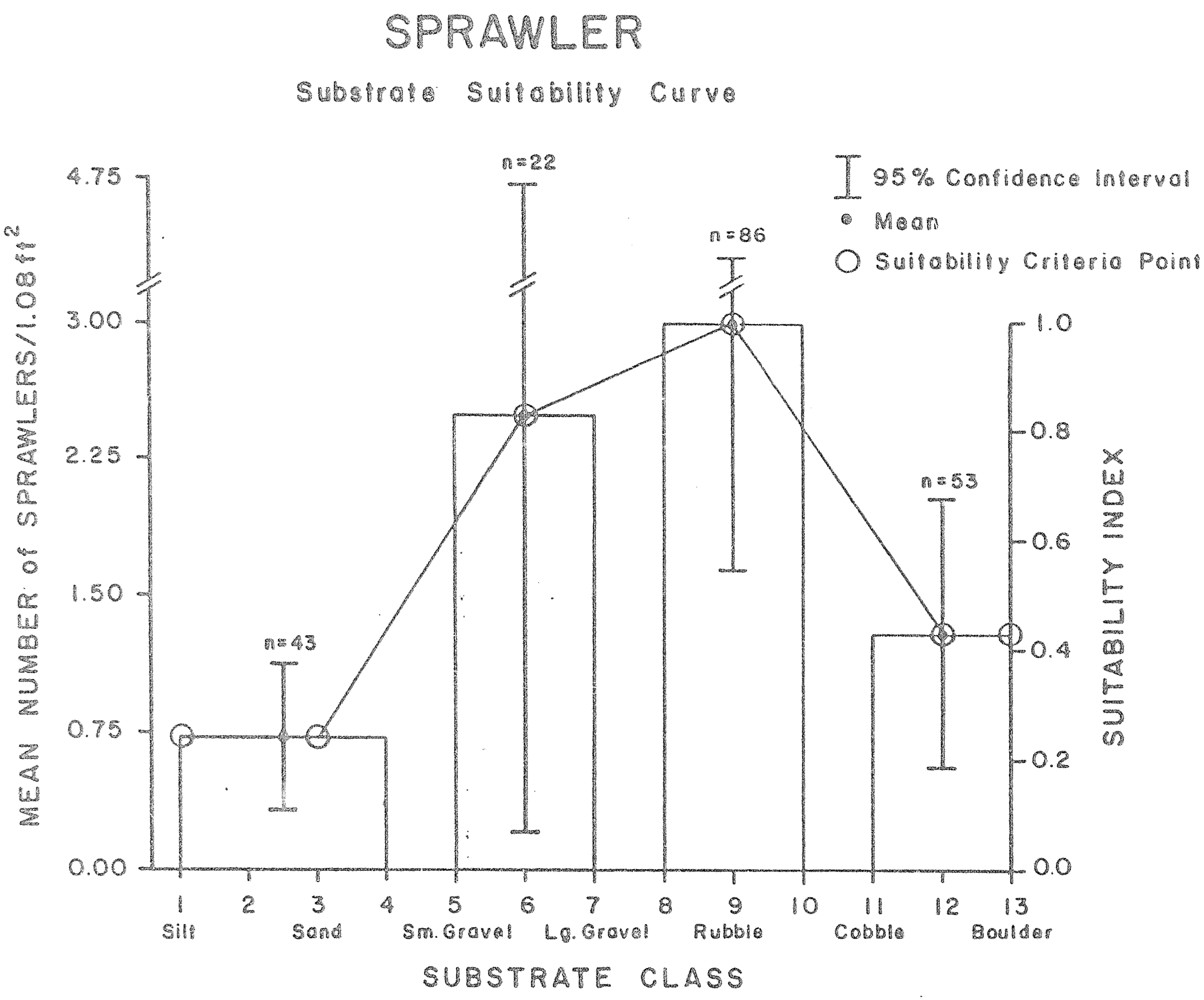

Figure 21 Average number of sprawler invertebrates per benthic sample for each substrate increment, with hand fitted suitability curve, middle Susitna River, Alaska, 1984.

Table 8. Suitability criteria values for invertebrate behavioral groups for depth, velocity, and substrate type, middle Susitna River, 1984.

	Burrower		Swimmer		Clinger		Sprawler	
	substrate	suitability	substrate	suitability	substrate	suitability	substrate	suitability
Depth	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00
	0.1	1.00	0.1	1.00	0.1	1.00	0.1	1.00
	10.0	1.00	10.0	1.00	10.0	1.00	10.0	1.00

	Burrower		Swimmer		Clinger		Sprawler	
	velocity (ft/sec)	velocity suitability	velocity (ft/sec)	velocity suitability	(ft/sec)	suitability	(ft/sec)	suitability
Velocity	0.0	1.00	0.0	0.02	0.0	0.03	0.0	1.00
	0.5	0.19	0.9	0.16	0.9	0.23	3.0	1.00
	2.3	0.19	1.8	0.54	1.5	0.49	4.0	0.00
	3.0	0.00	2.2	1.00	1.8	1.00		
			3.0	0.54	2.3	0.90		
			4.3	0.00	3.0	0.10		
					4.0	0.00		

	Burrower		Swimmer		Clinger		Sprawler	
	substrate	suitability	substrate	suitability	substrate	suitability	substrate	suitability
Substrate	1.0	1.00	1.0	0.00	1.0	0.03	1.0	0.24
	5.0	0.26	4.0	0.00	3.0	0.03	3.0	0.24
	13.0	0.26	6.0	0.83	6.0	0.52	6.0	0.83
			9.0	1.00	9.0	1.00	9.0	1.00
			12.0	0.25	12.0	0.42	12.0	0.43
					13.0	0.42	13.0	0.43

3.2.1.2 Velocity

The velocity histograms (Figure 14-17) for each of the behavioral groupings with the exception of sprawlers revealed that a clear relationship existed between the densities of organisms present and incremental changes in water velocity. The derivation of the velocity suitability criteria for each behavioral grouping is presented below.

The relationship between sprawler densities and water velocity was not clearly defined by the utilization curve for sprawlers (Figure 17). Very early instar sprawlers were dominant at low velocity (0.0 to 0.6 ft/sec) whereas early, middle, and late instar sprawlers were dominant at high water velocities (1.6-2.6 ft/sec). This coupled with the overall total small catch of sprawlers did not lead to a clear velocity utilization pattern for sprawlers. However, because sprawlers appeared to be equally distributed over the range of velocities observed to be utilized, a suitability index of 1.00 was assigned to the overall range of water velocities from 0.0 to 4.0 ft/sec. Four feet per second was used as an endpoint as this was considered the water velocity which becomes uninhabitable inhabitable by sprawler type organisms (Harris and Lawrence 1978, Surdick Gaufin 1978).

The velocity utilization histogram for burrowers (Figure 14) showed greatest densities at a water velocity of 0.0 ft/sec. As a result, this velocity was assigned a suitability index of 1.00. This is supported by findings of other researchers who have shown similar results for benthic invertebrates belonging to the burrower behavioral type (White et al. 1981, Anderson 1982). A suitability index of 0.19 was assigned to the range of water velocities from 0.5 ft/sec to 2.3 ft/sec based on the utilization data. It is possible that numerous species of chironomid midges, the predominant burrower taxa, inhabiting the Susitna River have different velocity requirements, but due to the limited data collected in this study, we did not feel confident in describing a bimodal velocity suitability curve for burrowers as the utilization data suggests. A suitability of 0.00 was assigned to 3.0 ft/sec as Anderson (1982) showed that Chironomidae, a common burrow type organisms, had the lowest mean number of individuals at this velocity.

The assignment of velocity suitability indices for swimmers generally followed the utilization histogram for this behavioral grouping. Outside the range of utilization data available, suitability indices were assigned based on literature. A water velocity of 3.0 ft/sec was assigned a suitability index of 0.54 based on findings by Judy and Gore (1979) and Anderson (1982). A suitability index of 0.0 was assigned to a velocity of 4.3 ft/sec as this is considered the limit of water velocities inhabitable by swimmer type organisms (Judy and Gore 1979).

The observed utilization patterns for clingers in this study (Figure 6) generally matched well in comparisons with work done by Newell (1976), Anderson (1982), Judy and Gore (1979). Therefor, corresponding suitability values were assigned based on the utilization histogram for this behavioral group. Newell's (1976) and Andersen's (1982) findings were used to describe suitability beyond the range of the utilization data. Based on their findings, a velocity of 3.0 ft/sec was assigned a suitability index of 0.10 and 4.0 ft/sec was assigned a suitability index of 0.00.

3.2.1.3 Substrate

All benthic invertebrate behavioral groups showed relationships between densities of benthic organisms and substrate size. Based on the utilization histogram, burrowers had their highest densities in silt to sand/small gravel substrates (Figure 18). This coupled with findings by Kennedy (1967) and Bjornn et al. (1977), which support burrower type benthic invertebrates' utilization of fine substrates, lead to the assignment of a suitability index of 1.0 to silt substrates. Because utilization of small gravel through boulder substrates was fairly uniform, a suitability index of 0.26 was assigned to this range of substrate sizes based on the relative utilization data. The uniform utilization is likely due to the presence of more than one species of chironomids.

The assignment of substrate suitability indices for swimmers generally followed the utilization histogram for this behavioral grouping (Figure 19). Because the highest densities of swimmers were on large gravel/-rubble to rubble/cobble substrates, this substrate class was assigned a suitability index of 1.00. Assignments of suitability indices for other substrate classes generally followed the utilization histogram for this behavioral grouping. These substrate utilization trends compare well with results obtained by Bjornn et al. (1977) and Judy and Gore (1979) for swimmer type benthic invertebrates.

Substrate utilization results for clingers were also similar to results obtained by Bjornn et al. (1977). As with swimmers, large gravel/rubble through rubble/cobble substrate had the highest densities of clingers (Figure 20). Assignments of suitability indices for other substrate classes generally followed the utilization histogram for this behavioral grouping.

Sprawler densities were also highest on large gravel/rubble through rubble/cobble substrate (Figure 21). As a result, this substrate class was assigned a suitability index of 1.00. Assignment of suitability indices on the tails of the sprawler utilization histogram generally followed the utilization data. These results agree well with findings by Merritt and Cummins (1975) and Anderson (1982) for sprawler type benthic invertebrates.

3.3.2 Benthic Weighted Usable Area Projections

Projections of the gross surface area and WUA of burrower, swimmer, clinger, and sprawler invertebrate habitat as a function of site flow in Slough 9, Side Channel 10, Upper Side Channel 11, and upper Side Channel 21 are shown in Figures 22-25. For the range of site flows at each study site that are directly controlled by mainstem discharge, the gross surface area and WUA projections as a function of mainstem discharge are also presented.

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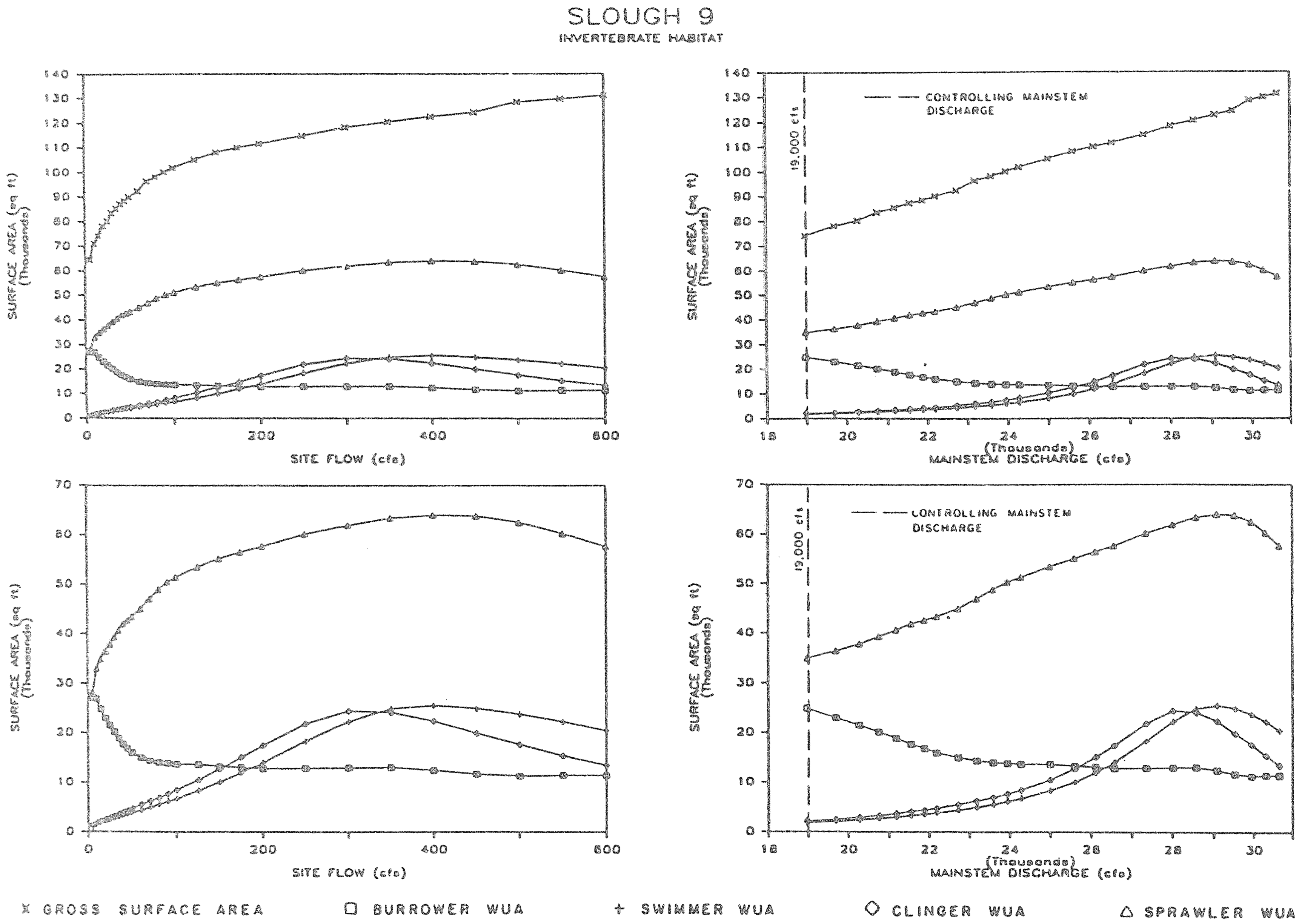

Figure 22 Projections of gross surface area and WUA of burrower, swimmer, clinger, and sprawler invertebrate habitat as a function of site flow and mainstem discharge for the Slough 9 modelling site.

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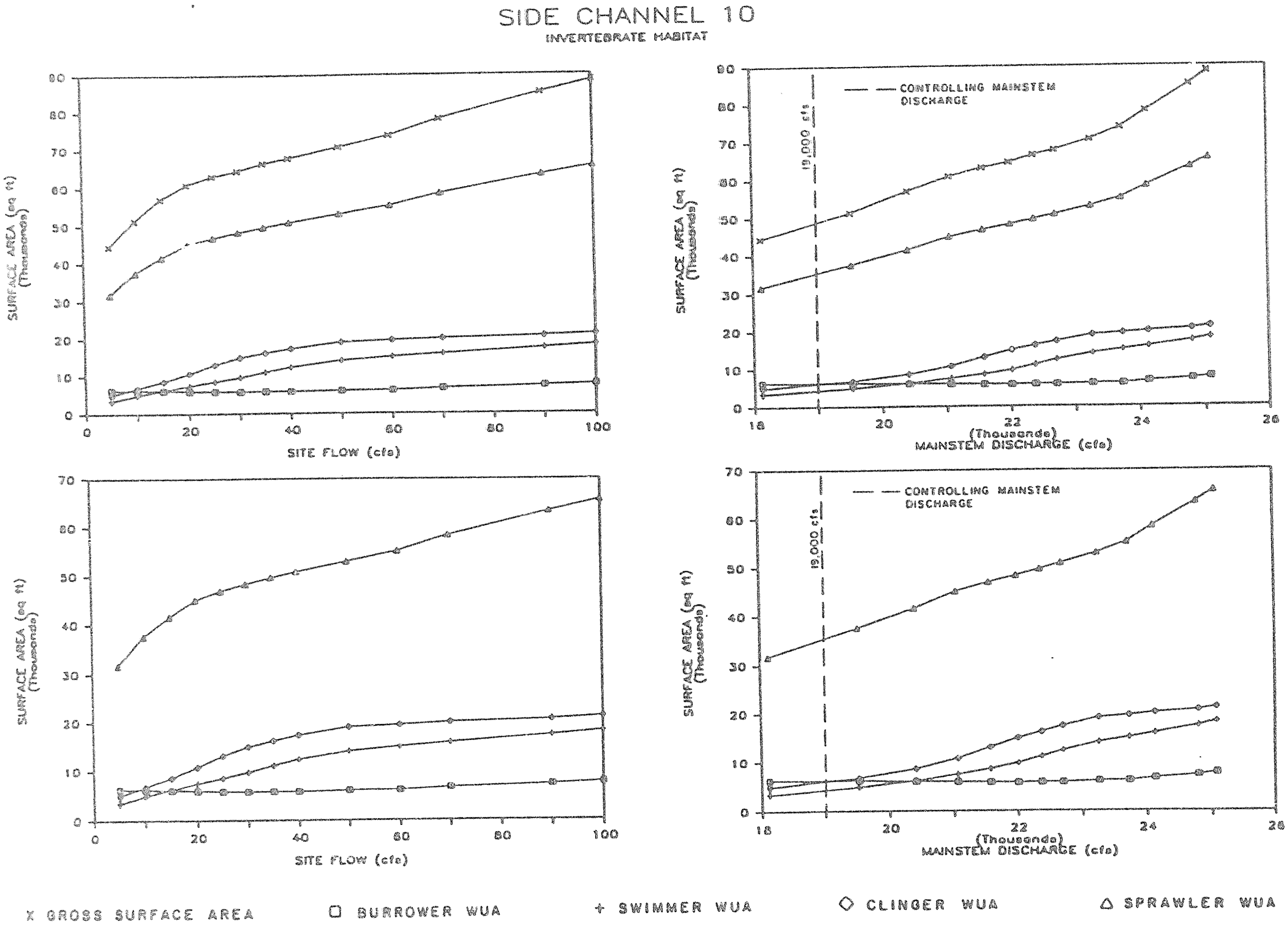

Figure 23 Projections of gross surface area and WUA of burrower, swimmer, clinger, and sprawler invertebrate habitat as a function of site flow and mainstem discharge for the Side Channel 10 modelling site.

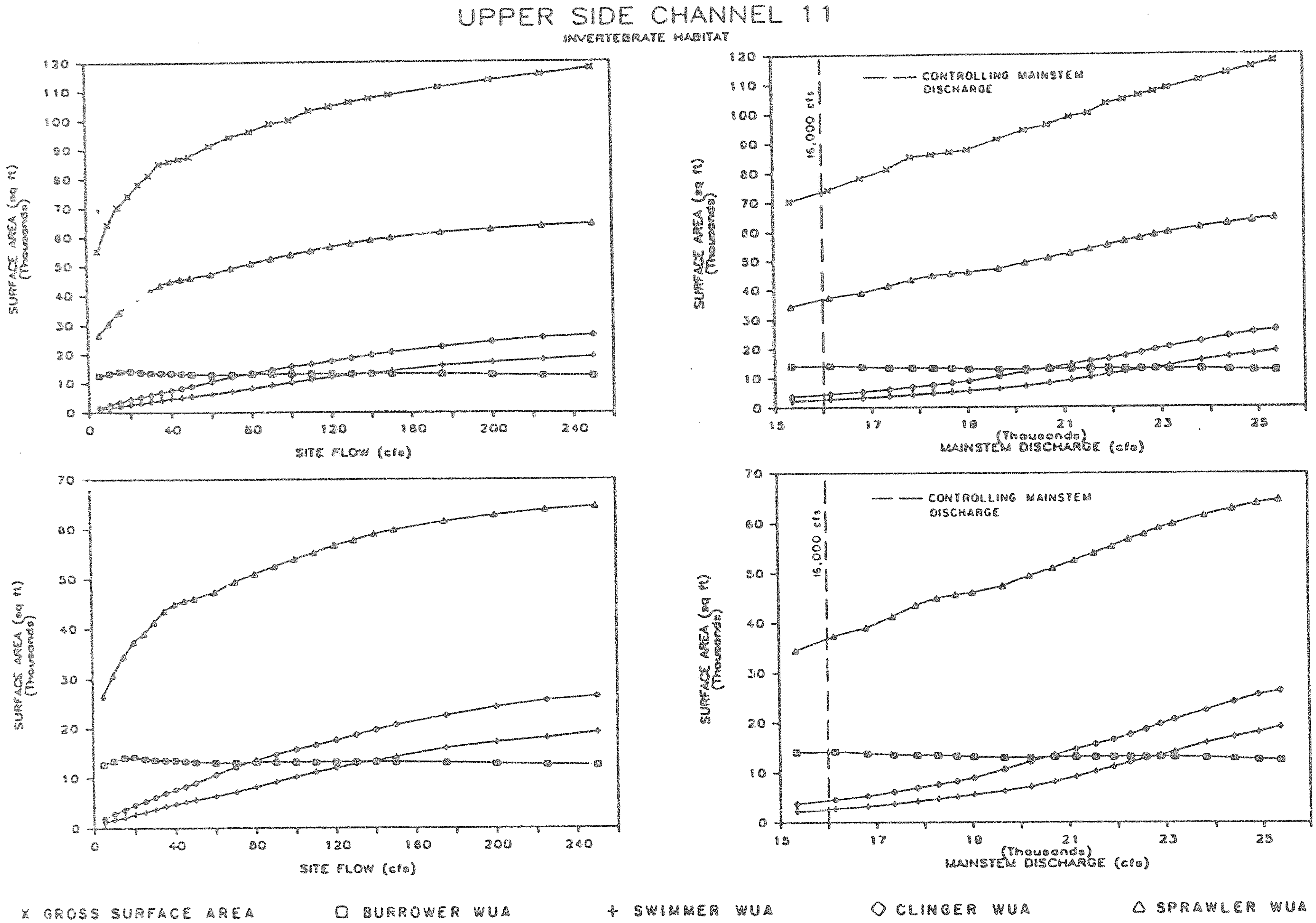

Figure 24 Projections of gross surface area and WUA of burrower, swimmer, clinger, and sprawler invertebrate habitat as a function of site flow and mainstem discharge for the Upper Side Channel 11 modelling site.

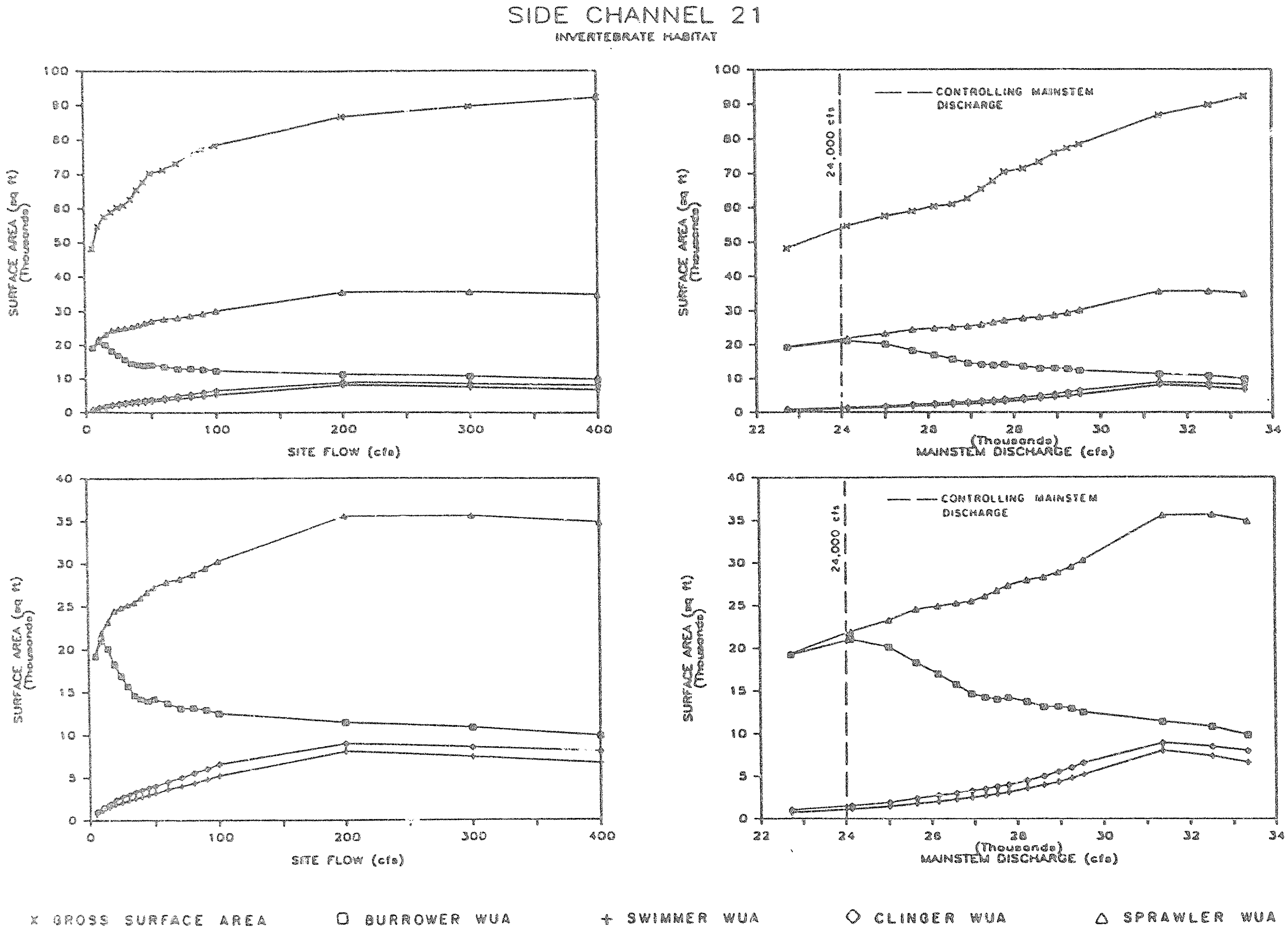

Figure 25 Projections of gross surface area and WUA of burrower, swimmer, clinger, and sprawler invertebrate habitat as a function of site flow and mainstem discharge for the Side Channel 21 modelling site.

Typically, projections of gross surface area at each of the study sites increase over the range of site flows and mainstem discharges modelled. The most rapid increases in gross surface area generally occur at the lower site flows prior to each site becoming breached and subsequently controlled by mainstem discharge. Subsequent to the site flows becoming controlled by mainstem discharge, the increases in gross surface area begin to level off.

The projections of WUA of swimmer, clinger, and sprawler habitat at each study site generally followed similar trends as the projections of gross surface area with the exception that WUA projections peaked or leveled off at some site flow/mainstem discharge. In contrast, the projections of burrower WUA typically decreased over the range of site flows/-mainstem discharges modelled. Typically, the projection of WUA of each of these behavioral groups were less than 30% of the projected gross surface area.

The WUA for swimmer, clinger, and sprawler habitat in Slough 9 peaked at a mainstem discharge between 28,000 and 30,000 cfs (Figure 22). The maximum WUA for sprawler habitat, however, was approximately double the maximum WUA of either swimmer or clinger habitat. In contrast, WUA of burrower habitat decreased over the entire range of mainstem discharges modelled. The initial and controlling breaching discharges for Slough 9 are 16,000 and 19,000 cfs, respectively.

The WUA of swimmer, clinger, and sprawler habitat did not peak at any of the mainstem discharges modelled in either Side Channel 10 or Upper Side

Channel 11 (Figures 23 and 24). The WUA for these behavioral groups increased with increasing mainstem discharge. In contrast, burrower WUA remained relatively constant in Side Channel 10 and declined in Upper Side Channel 11. The controlling mainstem breaching discharge at Gold Creek for Side Channel 10 and Upper Side Channel 11 are 19,000 cfs and 16,000 cfs, respectively.

The amount of WUA of swimmer, clinger, and sprawler habitat in upper Side Channel 21 peaked at an approximate mainstem discharge of 31,800 cfs. The maximum amount of WUA for sprawler habitat, however, was approximately triple the amount of WUA of either clinger or sprawler habitat. Burrower WUA peaked at 21,000 square feet at an approximate mainstem discharge of 24,000 cfs. The controlling mainstem breaching discharge at upper Side Channel 21 is 24,000 cfs.

3.3 Invertebrate Larval Development

The results of the examination of wing pads from individuals from five families of Plecoptera and four families of Ephemeroptera are shown in Table 9. These data reveal that high proportions of Capniidae and Taeniopterygidae were in late instar larval stages in late April and mid May. Nemouridae was probably in the adult and egg stages during this time period. Proportionately high numbers of early and middle instar individuals of these stonefly families were present during June through early October.

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Table 9. Percentage of early, middle, and late instar insects and the total number of individuals examined ( ), middle Susitna River, Alaska, Summer 1984. Individuals examined from April, May, September, and October samples are from synoptic surveys.

Family/Date	April 25-26	May 15	June 7 - July 14	August 9 - September 9	October 10-11
Nemouridae	(1)	(0)	(22)	(27)	(0)
Early	100	--	95	74	--
Middle	--	--	--	26	--
Late	--	--	5	--	--
Capniidae	(41)	(3)	(5)	(237)	(31)
Early	--	--	60	99	58
Middle	5	--	--	1	42
Late	95	100	40	--	--
Taeniopterygidae	(142)	(5)	(2)	(111)	(831)
Early	--	--	100	100	99
Middle	81	20	--	--	1
Late	19	80	--	--	--
Chloroperlidae	(9)	(1)	(71)	(35)	(0)
Early	11	--	41	74	--
Middle	78	100	49	9	--
Late	11	--	10	17	--
Perlodidae	(30)	(0)	(74)	(24)	(3)
Early	30	--	49	100	33
Middle	70	--	46	--	67
Late	--	--	5	--	--
Baetidae	(123)	(1)	(399)	(19)	(4)
Early	13	--	21	63	100
Middle	87	100	71	32	--
Late	--	--	8	5	--
Heptageniidae	(10)	(0)	(168)	(63)	(8)
Early	--	--	74	51	50
Middle	100	--	16	40	38
Late	--	--	10	9	12
Ephemerellidae	(22)	(0)	(89)	(31)	(1)
Early	--	--	96	84	100
Middle	100	--	4	16	--
Late	--	--	--	--	--
Siphlonuridae	(2)	(226)	(17)	(3)	(0)
Early	--	13	41	100	--
Middle	100	87	59	--	--
Late	--	--	--	--	--

During late April and middle May, Chloroperlidae and Perlodidae had a proportionately high number of middle instar individuals present. All three instar groups were present among the Chloroperlidae from June through early September. Over half the individuals in Perlodidae were middle and late instar individuals in June through mid July. In August and early September, all the individuals in Perlodidae were early instar.

High proportions of middle instar individuals were present among the Ephemeroptera in late April and mid May. There were no late instar individuals identified among the four families of Ephemeroptera for these two time periods. From June through mid July, high proportions of middle instar Baetidae and early instar Heptageniidae and Ephemerellidae were recorded. Through August and early September Ephemeropteran families had individuals which were mostly early instars.

3.4 Juvenile Chinook Salmon Diet

Seventy two juvenile chinook salmon ranging in total length from 38 mm to 85 mm (1.49 in. - 3.35 in.) with a mean total length of 53 mm (2.09 in.) were collected for stomach content analysis. The fish were captured under both turbid and non-turbid water conditions over all substrate types. Mean water velocities and water depths under these conditions ranged from approximately 0.0 ft/sec to 1.5 ft/sec and 0.2 ft to 2.0 feet, respectively. The majority of fish were captured at the head of pools or runs adjacent to faster water velocities.

The juvenile chinook salmon stomachs examined contained twelve orders of invertebrates consisting of eleven insect orders and one non-insect order (Appendix Table E-1). The eleven insect orders were identified to fifteen families. The majority of juvenile chinook salmon stomachs examined contained food items. Only two of the stomachs examined were empty. Figure 26 shows the percent contribution of the total numbers of seven different invertebrate taxonomical groups. Figure 27 shows the percent contribution of sixteen benthic invertebrate families grouped into the four behavioral types used in WUA calculations.

3.5 Turbidity at Study Sites and Mainstem Susitna River

Water samples were collected for measurement of turbidity at Slough 9, Side Channel 10, Upper Side Channel 11, and upper Side Channel 21 from June 7 to September 9, 1984. Turbidity measurements of water from the main channel of the Susitna River were taken monthly at Gold Creek by the U.S. Geological Survey, Water Resources Section from May 31 to September 28, 1984. Appendix F-1 shows the turbidity values obtained for each of these locations during the invertebrate sampling period.

Turbidity values ranged from one to 344 NTU (Nephelometric Turbidity Units) at IFG-4 sites and from 28 NTU to 320 NTU at head sites. Side channel and side slough head sites generally had higher turbidity values than IFG-4 sites. The IFG-4 sampling site in Upper Side Channel 11 had the highest turbidity values. Turbidity values at the IFG-4 transect site in upper Side Channel 21 were relatively low by comparison.

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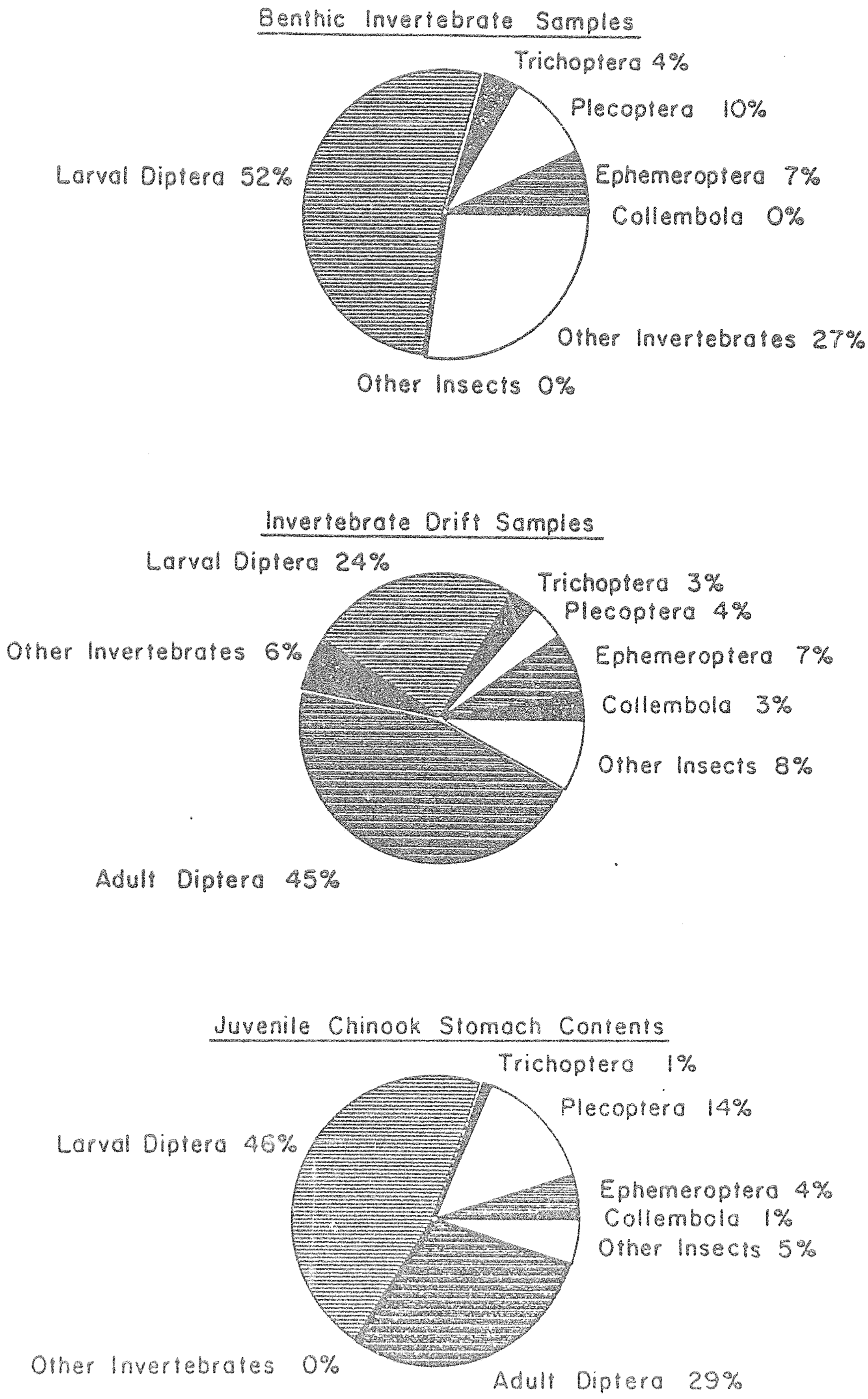

Figure 26 Percent composition of invertebrates in benthic, drift, and juvenile chinook stomach content samples taken at FAS sites, middle Susitna River, Alaska, 1984.

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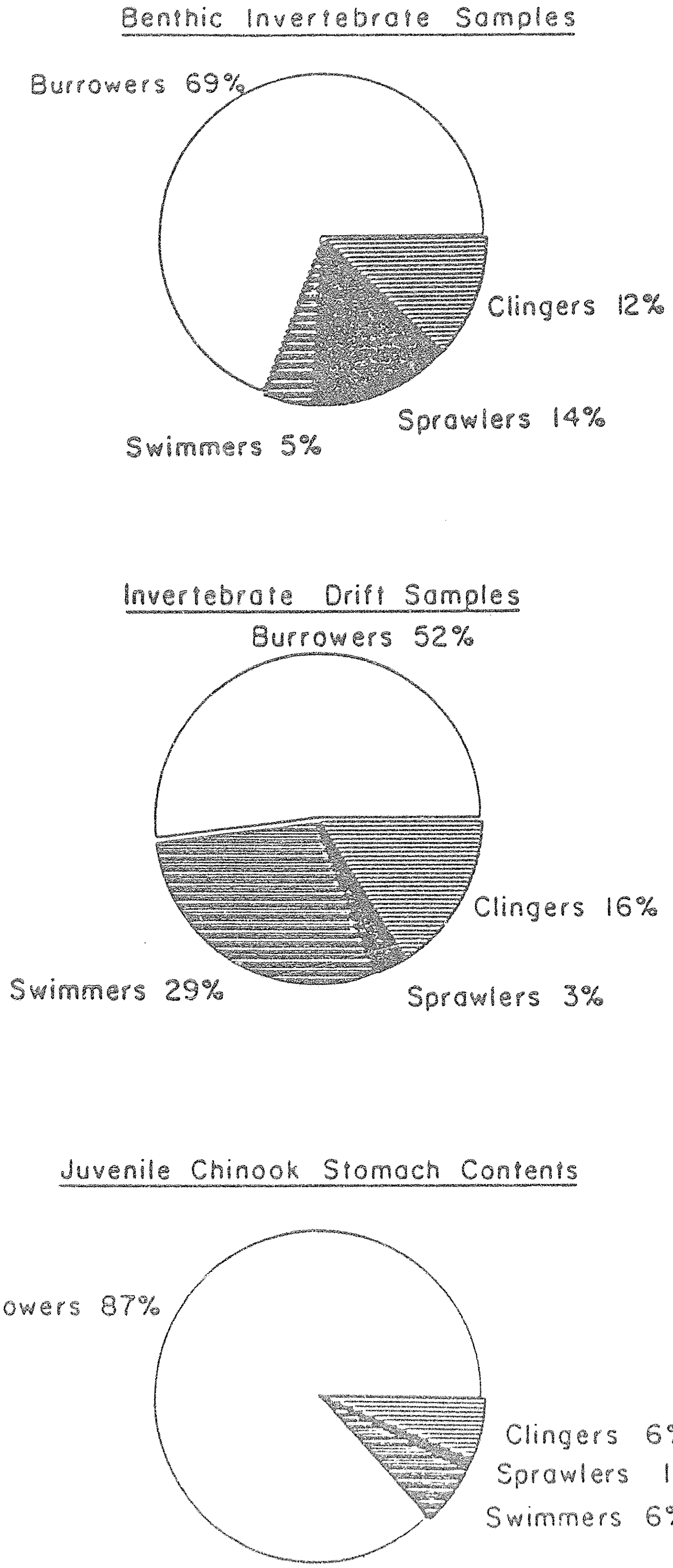

Figure 27 Percent composition of aquatic insect behaviroal groups in benthic drift, and juvenile chinook stomach content samples taken at FAS sites, middle Susitna River, Alaska, 1984.

The breached or unbreached condition of Slough 9, Side Channel 10, Upper Side Channel 11, and upper Side Channel 21 at the time of water samples were collected for turbidity measurement is also shown in Appendix F-1. Slough 9 and Upper Side Channel 11 were almost always breached during water sampling. Side Channel 10 and Upper Side Channel 21 were frequently unbreached.

4.0 DISCUSSION

4.1 Available Food Sources for Juvenile Chinook Salmon in Side Channels and Side Sloughs

Scatter plots of log transformed invertebrate drift data (Figures 7 and 8) indicate that, under breached conditions in side channels and side sloughs, behaviorally drifting invertebrates (e.g., invertebrates drifting in response to changes in light conditions) at IFG-4 sites were similar at the family level to those at head sites and that the density of drifting invertebrates at IFG-4 sites was only slightly less than that at head sites. The data also reveal that at or near breaching discharges, fewer drifting organisms were observed at the IFG-4 sites than at head sites, whereas during unbreached conditions, IFG-4 sites had more drifting invertebrates than expected (Table 10). Based on this, it is concluded that the invertebrate drift measured at IFG-4 sites located in middle Susitna River side channels and side sloughs is usually governed by the breaching flows of the mainstem. These flows presumably transport drifting invertebrates from the mainstem into the side channels and side sloughs where they become available as potential food for juvenile salmonids.

In terms of availability, these drifting invertebrates may be of greater importance to the feeding juvenile salmonids when their rate of drift (i.e., the number of drifting invertebrates passing a point per unit of time) is increased. This generally occurred when sample sites were

Table 10. Standardized densities (no/1000ft^3) of drifting invertebrates (Invert) and adult aquatic insects (Adult) at head and IFG-4 sites, middle Susitna River, 1984.

Date	Upper Side Channel 11				Side Channel 21				Slough 9				Side Channel 10			
	HEAD		IFG-4		HEAD		IFG-4		HEAD		IFG-4		HEAD		IFG-4	
	Invert	Adult	Invert	Adult	Invert	Adult	Invert	Adult	Invert	Adult	Invert	Adult	Invert	Adult	Invert	Adult
June 7-8	143	23	47	22	-	-	-	-	-	-	-	-	-	-	-	-
June 9-10[a]	-	-	-	-	185	315	1	3	-	-	-	-	-	-	-	-
June 11-12	-	-	-	-	-	-	-	-	32	23	13	8	-	-	-	-
June 13-14[b]	-	-	-	-	-	-	-	-	-	-	-	-	153	20	110	18
July 7-8	42	26	30	44	-	-	-	-	-	-	-	-	-	-	-	-
July 9-10[a]	-	-	-	-	16	39	6	3	-	-	-	-	-	-	-	-
July 11-12	-	-	-	-	-	-	-	-	41	9	52	23	-	-	-	-
July 13-14[a]	-	-	-	-	-	-	-	-	-	-	-	-	22	6	7	4
August 9-10	65	83	43	46	-	-	-	-	-	-	-	-	-	-	-	-
August 11-12[c]	-	-	-	-	0	0	53	204	-	-	-	-	-	-	-	-
August 13-14	-	-	-	-	-	-	-	-	53	60	65	31	-	-	-	-
August 15-16[c]	-	-	-	-	-	-	-	-	-	-	-	-	0	0	13	26

[a] at breaching point
[b] sampled one day at head site
[c] unbreached

breached or at breaching and was generally the result of increased water velocity from either large volumes of water inundating sample sites or from small volumes flowing rapidly over the the various study site substrates. This increased drift rate, which results during mainstem flows that just breach side channels or side sloughs, may be more beneficial to feeding fish than the drift which occurs at other times, since water in the study sites under these conditions is less turbid enabling fish to more easily see their prey.

The standardized drift data also showed that Ephemeroptera, especially of the family Baetidae, and Plecoptera, were numerically important drift components during mid June and mid August, respectively. Chironomid midges were the most consistently numerous family of invertebrates present in the drift from June through August. There is some evidence that this pattern in the drift, especially for Ephemeroptera, is related to the presence of proportionately large numbers of near emerging adults. Perry and Huston (1983) found that the drift rates of invertebrates in the Kootenai River below Libby Dam, Montana were higher during months when common species were near emergence. Hynes (1970), after reviewing the literature, stated that distinct downstream movement of some species of Simuliidae, Ephemeroptera, and Plecoptera shortly before pupation or the emergence of adults was a widespread phenomenon. Examination of wing pad development among families of Ephemeroptera in this study showed that this group had proportionately more middle and late instar individuals present during June and early July than during August. Ephemeropterans reached their highest densities in the drift and benthos within this same period.

The relatively high densities of Plecoptera in the drift in early-August may be a result of the higher numbers of early instar individuals in the benthos. Early instar Plecoptera were common in the drift during this time. Waters (1972), in reviewing the literature, found that some species of insects have been observed to have their greatest drift rate during early life cycle stages.

Besides behavioral drift from the mainstem, there is another possible kind of drift that could occur in side channels and side sloughs which would make invertebrates available as food. This drift is termed catastrophic drift (Waters 1972). Catastrophic drift can occur under two circumstances: 1) when there is physical disturbance of the bottom fauna, usually by a flood event (Anderson and Lehmkuhl 1968, Scullion and Sinton 1983); or 2) under conditions of receding water as a result of reductions in flow (Minshall and Winger 1968, White et al. 1981). In upper Side Channel 21, there is the possibility that conditions are ideal for drift of this nature to occur as a result of the first circumstance. In Slough 9, Side Channel 10, and Upper Side Channel 11 catastrophic drift could possibly occur as a result of the second circumstance. An increase in the amount of potential fish food organisms made available through catastrophic drift of the first circumstance however is probably not of significance in side channels and side sloughs of the middle Susitna River under current conditions. Any catastrophic drift which does occur is probably masked by the volume of behaviorally drifting invertebrates immigrating from the mainstem. In Slough 9, Side Channel 10, and Upper Side Channel 11 it is likely that major catastrophic drift occurs but probably is limited to a few occurrences during the entire open water season and then possibly only in August or September during receding flows.

4.2 Effects of Flow on the Distribution and Abundance of Benthic Invertebrates in Side Channels and Side Sloughs

Categorizing important fish food organisms into behavioral groups proved to be a valuable tool in projecting the habitat preferences and weighted usable habitat area when the mean density of these organisms was less than 500 individuals per square yard. By grouping organisms on a behavioral basis, it was possible to evaluate group preferences for specific velocities and substrate types which otherwise would be undetectable if organisms were treated on a taxonomic basis.

4.2.1 Habitat Suitability

Four behavioral groups of benthic invertebrates were identified which reflected basic habitat preferences: burrower, swimmer, clinger, and sprawler. In general, burrowers were reflective of slower deeper waters, such as pools, and swimmers, clingers, and sprawlers were reflective of faster shallower waters, such as riffles and runs. Pool-like habitats are typical of the backwater zones at the mouths of side channels and side sloughs whereas, riffle and run habitats are more typical of the head and middle portions.

The relationship between behavioral type and habitat type are likely the result of morphological and physiological adaptations of benthic organisms to their environment. For example, swimmers and clingers (which include baetid and heptageniid mayflies), are laterally compressed and dorso-ventrally flattened respectively and usually have higher oxygen requirements than other insects (e.g. Chironomidae) and therefore would more likely be found in faster flowing water (Hynes 1970). Burrowers on the other hand are cylindrical in shape and are adapted for digging in fine mineral or organic substrates (e.g. silt and sand). This group would more likely be found in slower moving waters such as pools.

The numerical productivity and community structure of invertebrates in riffle, run, and pool habitats of side channels and side sloughs of the middle Susitna River in presented in Table 11. In general, riffle and run habitats had a more diverse and evenly distributed assemblages of taxa than pools. Numerically, pool habitats appeared to be the more productive habitat during late summer. Production based on this measure, however, is not conclusive and riffles and runs are probably more important on a biomass scale. Hynes (1970) states that in general riffles are more productive than pools, in part because of the diverse number of microhabitats which could be occupied by organisms of various sizes. The diversity, eveness, and mean number of taxa calculated for riffles and runs appears to substantiate Hynes' conclusion. The diversity, eveness, and number of taxa in riffles and runs were consistently higher than in pools, probably because of the limited number of microniches available to invertebrates in this habitat type.

Table 11. Diversity ± S.E., eveness (Poole 1974), density, and number of taxa of benthic invertebrate communities from riffle, run, and pool habitats in side channels and side sloughs of the middle Susitna River, Alaska, 1984. Density and number of taxa are reported as the number per square yard ±98% confidence interval.

	Diversity (H'± S.E.)	Eveness (J')	Density (no./yd²)	No. Taxa	No. Samples
			Early-Mid Summer[a]		
Side Sloughs[b]					
Riffle[c]	2.43 ± 0.06	0.59	434.3 ± 393.1	5.9 ± 2.5	15
Run[d]	2.60 ± 0.09	0.64	151.2 ± 90.7	4.1 ± 1.8	23
Pool[e]	--	--	--	--	--
Side Channels[f]					
Riffle	2.91 ± 0.09	0.72	95.8 ± 44.5	4.0 ± 1.3	24
Run	2.64 ± 0.13	0.72	46.2 ± 24.4	2.7 ± 0.8	26
Pool	--	--	--	--	--
			Late Summer[g]		
Side Sloughs					
Riffle	1.90 ± 0.10	0.48	317.5 ± 331.0	4.0 ± 2.4	9
Run	1.64 ± 0.06	0.39	163.0 ± 76.4	2.7 ± 0.5	44
Pool	0.72 ± 0.15	0.25	195.7 ± 383.0	2.7 ± 3.3	6
Side Channels					
Riffle	2.55 ± 0.09	0.62	165.5 ± 79.8	4.6 ± 1.4	19
Run	1.70 ± 0.09	0.40	153.7 ± 87.4	3.0 ± 1.0	31
Pool	0.69 ± 0.11	0.22	286.4 ± 270.5	3.0 ± 2.1	7

[a] Samples taken 6/24/84 through 7/10/84.

[b] Samples taken at Slough [illegible] and Side Channel 21 transects.

[c] Samples taken at transects having an average depth ≤ 0.33 feet and an average current velocity ≥ 0.33 feet per second.

[d] Samples taken at transects having an average depth between 0.34 feet and 0.99 feet and an average current < 0.33 feet per second.

[e] Samples taken at transects having an average depth ≥ 1.00 feet and an average current velocity < 0.33 feet per second.

[f] Samples taken at Side Channel 10 and Upper Side Channel 11 transects.

[g] Samples taken 8/23/84 through 9/7/84.

4.2.2 Weighted Usable Area

Projections of weighted usable area (WUA) for the four behavioral groups is a measure of the amount of riffle-like and pool-like habitat made available to colonizing organisms at various site flows and mainstem discharges. At all four study locations, burrower WUA generally decreased with increasing site flows and mainstem discharge at Upper Side Channel 11 and upper Side Channel 21 were the only two locations which had an increase in the amount of burrower WUA between initial and controlling discharges. These changes in WUA are probably the result of changes in the area of backwater zone at each study site. Apparently, the hydraulic conditions of these zones begin to simulate those of a deep run at mainstem discharges above those which initiate controlling flow through side channels and side sloughs.

The amount of WUA for swimmer, clinger, and sprawler behavioral groups peaked at a mainstem discharge between 28,000 cfs and 31,200 cfs in Slough 9 and upper Side Channel 21. The high amount of sprawler habitat at these two sites and at Side Channel 10 and Upper Side Channel 11 is probably a reflection of this behavioral groups use of a wide range of velocities and substrates during the course of its life history. Sprawlers were comprised primarily of stoneflies from the families Capniidae and Nemouridae.

The habitat used by swimmer and clinger behavioral groups were less varied than that utilized by sprawlers. The suitability indices for these two groups showed a marked preference for velocities between 1.8 ft/sec and 2.2 ft/sec and substrates comprised primarily of rubble. This preference resulted in a distinct increase in WUA for mainstem discharges up to 31,200 cfs at which point WUA began to decline.

Projections of WUA for swimmers and clingers did not show a peak for Side Channel 10 and Upper Side Channel 11. This was probably the result of the limitations of the hydraulic model for these two study locations which do not permit predictions of WUA at mainstem discharges beyond 25,300 cfs and side channel flows beyond 100 cfs in Side Channel 10 and 250 cfs in Upper Side Channel 11. The mainstem discharge at which WUA for swimmers and clingers reaches a maximum in these two side channels is not known. However, the greatest WUA projected was at a mainstem discharge between 25,200 cfs and 25,500 cfs.

4.3 Utilization of Available Food by Juvenile Chinook Salmon in Side Channels and Side Sloughs

The 1984 FAS and previous Susitna River studies (ADF&G 1978, ADF&G 1983a) have shown that juvenile chinook salmon rearing in the sloughs and side channels of the middle Susitna River feed on a wide variety of aquatic and terrestrial invertebrates (Appendix Table B1). Of the invertebrates utilized, chironomid adults and larvae (burrowers) were numerically dominant in all previous Susitna River diet studies of juvenile chinook salmon. Loftus and Lenon (1977) determined that chironomidae were the most important family of food organisms for chinook salmon smolts in the Salcha River, Alaska. Similar results have been obtained by other researchers (Becker 1973, Dauble et al. 1980, Burger et al. 1982).

Although the family Chironomidae was found in this study to be the most numerically dominant taxa in the diet of Susitna River juvenile chinook salmon, numerical abundance alone does not necessarily correspond directly to relative importance (Lagler 1956). The majority of chironomids fed on by juvenile chinook salmon in this study were small (1-5 mm in length) and at least one order of magnitude less in volume than middle instar ephemeropterans and plecopterans (swimmers, clingers, and sprawlers). Due to this fact, it is felt that other aquatic insect taxa, primarily plecopterans and ephemeropterans, are more important in the diet of juvenile chinook salmon than numerical abundance indicates. Plecopterans and ephemeropterans were the most important invertebrates in the diet of juvenile chinook salmon next to chironomids in this and the previous ADF&G (1983) Susitna River diet studies and in Loftus and Lenon's (1977) Salcha River Study.

Everest and Chapman (1972), Becker (1973), and Loftus and Lennon (1977) have determined juvenile chinook salmon feed primarily on aquatic invertebrate drift and floating adult insects. Their findings correspond well with the results of this study which show a closer relationship between drift catch (includes floating insects) and juvenile chinook stomach contents than between stomach contents and benthic catch (Figure 26, Appendix Table A-1). For example, invertebrates from the adult Diptera category (primarily chironomids) and Other Insects category (primarily homopterans) made up 29% and 5% respectively of the juvenile chinook salmon diet and were available only as drift. In contrast, organisms occurring in the benthos but not selected as food included the Oligochaeta. Though this group comprised 27% of the Other Invertebrates category which in turn made up 27% of the benthic catch, none of these organisms were found in juvenile chinook salmon diet. This compares with the previous ADF&G (1983) diet study which reported few oligochaetes in the stomachs of juvenile chinook salmon. Finally, benthic invertebrates that were not readily found in the drift, did not appear to a significant extent in the juvenile chinook salmon diet. The major invertebrate groups (e.g., Chironomidae, Ephemeroptera, and Plecoptera) which have been reported as being good drifters (Hynes 1970) were, however, consumed by juvenile chinook salmon.

The availability of different aquatic insect groups during the growing season of juvenile chinook salmon may be an important factor in the rearing capacity of Susitna River slough and side channel habitats. As discussed in Section 4.1, middle and late instar ephemeropterans (swimmers and clingers) and plecopterans (clingers and sprawlers) are available in significant numbers as drift in June. Large numbers of early instar plecopterans show up in the drift in August. Adult and larval chironomids are available as drift from June through August, with the proportion of adult chironomids increasing as the summer progressed. The results of the FAS juvenile chinook salmon food utilization study generally followed these trends. Middle and late instar plecopterans and ephemeropterans were consumed primarily in June, early instar plecopterans were important in August, and chironomid adults and larvae were consumed during the entire open water season. Larvae from Chironimidae were consumed in early summer while higher proportions of adults were consumed during the latter part of summer (Figure 28).

4.4 Conclusions and Future Research

Four major conclusions can be drawn from the results of this study. First, the diet composition of juvenile chinook salmon is closely correlated with invertebrate drift composition and, to a lesser extent, to benthos composition, with midges from the family Chironomidae (Diptera) being the chief food organism of juvenile chinook salmon.

Secondly, the occurrence of drift under breached conditions in side channels and side sloughs of the middle Susitna River appeared to be governed by mainstem flows which transport drifting invertebrates into the side channels and side sloughs. Under breached conditions, the drift occurring in the side channels and side sloughs was negligible when compared to the drift under breached conditions when total drift is considered. The drift in both cases was dominated by midges from the family Chironomidae (Diptera), mayflies (Ephemeroptera) from the family Baetidae, and stoneflies (Plecoptera).

Thirdly, it was determined that categorizing invertebrate taxa by behavioral type (i.e. by burrower, swimmers, clingers and sprawlers) was

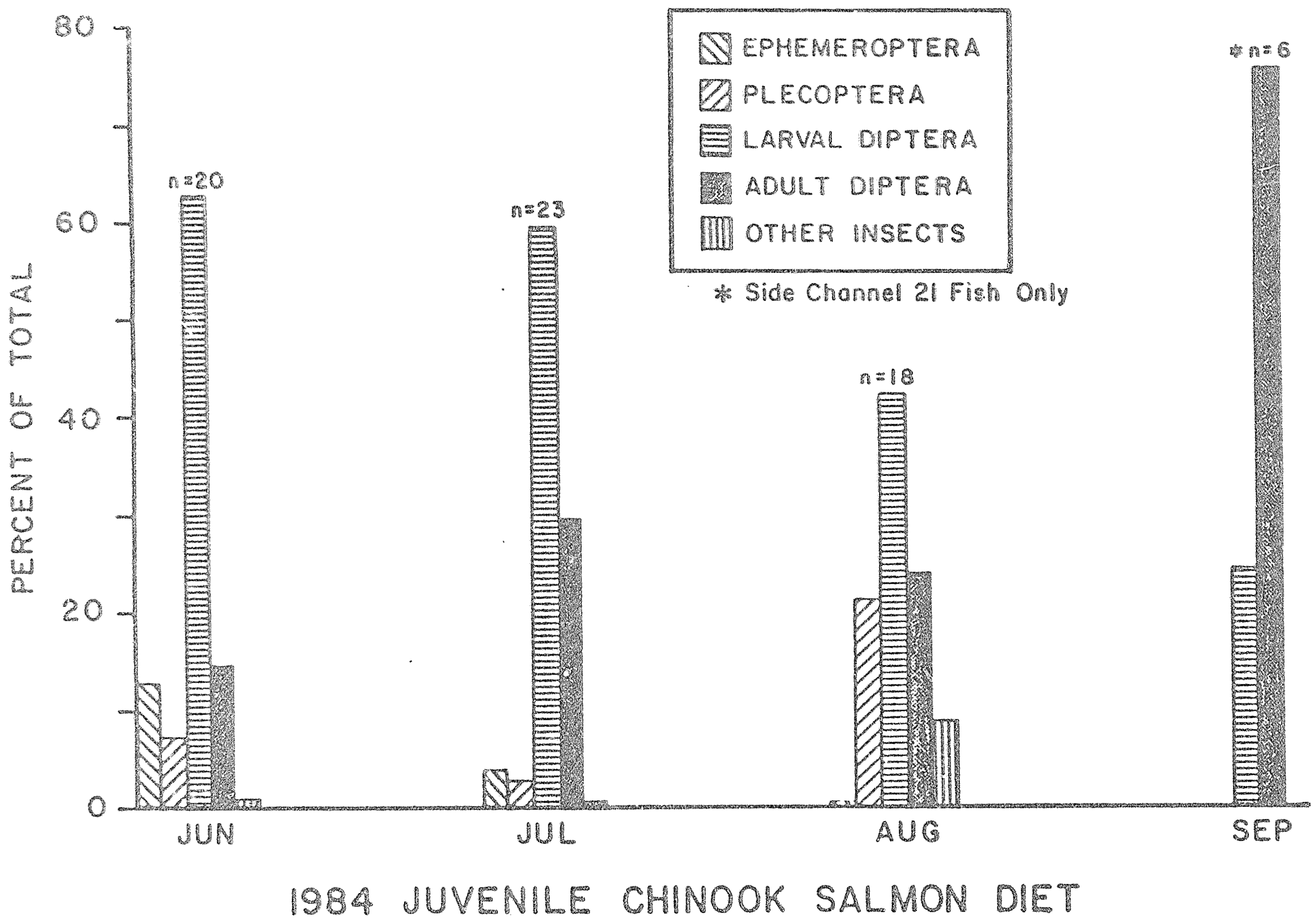

Figure 28. Percent of total numbers of aquatic and terrestrial insect groups in juvenile chinook salmon stomachs from FAS sites, June through September 1984, middle Susitna River, Alaska.

a valuable means for projecting benthic invertebrate WUA when the density of a majority of species averages less than ten individuals per 1.08 ft^2. It was found that water depth did not appear to be an important factor governing the overall distribution of any of the behavioral groups, but that water velocity and substrate type appeared to affect the distribution of most behavioral groups. Water velocities less than 0.4 ft/sec and substrate types comprised mostly of silt and sand (less than one eighth inch diameter) correlated well with high numbers of burrowers whereas rubble (three inches to five inches in diameter) substrates with components of large gravel (one inch to three inches diameter) or cobble (five inches to ten inches diameter) correlated with high numbers of swimmers, clingers, and sprawlers. Water velocities between 1.6 ft/sec and 2.6 ft/sec correlated well with high numbers of swimmers and clingers. Sprawlers did not appear to utilize any particular velocity over another.

Lastly, it can be concluded that WUA at each of the study sites for each of the behavioral groups clearly was a function of site flows and mainstem discharge. The minimum controlling mainstem discharge for a side channel or side slough generally produced the highest WUA for burrowers. A controlling mainstem discharge of 25,000 cfs generally produced the maximum WUA for swimmers, clingers, and sprawlers in Side Channel 10 and Upper Side Channel 11. The maximum WUA for swimmers, clingers, and sprawlers in Slough 9 and Side Channel 21 above A5 was produced at a controlling mainstem discharge of 29,000 cfs and 31,000 cfs, respectively.

In light of the above conclusions, naturally fluctuating flows of the mainstem Susitna River appear to increase total drift in side channels and side sloughs and subsequently the drift food supply for juvenile chinook salmon living in these turbid water mainstem affected habitats. Such periodic fluctuations also maintain drift for the continuous recolonization of mainstem affected habitats by invertebrates.

From the above discussion, the natural question arises: how are the invertebrates which are transported into side channel and side sloughs, influenced by mainstem discharge fluctuations when domiciled in the mainstem Susitna River itself? Answers to this and other questions can only come with further study of the density responses of invertebrates domiciled along mainstem shorelines to varying frequencies of watering and dewatering as a result of naturally fluctuating discharges.

5.0 CONTRIBUTORS

Project Leader	
Aquatic Habitat and instream Flow Project Leader	Doug Vincent-Lang
Principal Investigators	Tim Hansen J. Craig Richards
Editors	Douglas Vincent-Lang Joseph Sautner
Statistical and Data Analysis	Allen Bingham Paul Suchanek Andrew Hoffman Tim Quane Tommy Withrow Teri Keklak Alice Freeman Katrin Zosel
Graphics	Carol Hepler Roxann Peterson
Typing	Skeers Word Processing Anneliese Kohut Bobbie Sue Greene

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7.0 LITERATURE CITED

Alaska Department of Fish and Game. 1977. Preauthorization assessment of the proposed Susitna Hydroelectric Projects: preliminary investigations of water quality and aquatic species composition. Alaska Department of Fish and Game. Anchorage, Alaska.

______. 1978. Preliminary environmental assessment of hydroelectric development on the Susitna River. Alaska Department of Fish and Game. Anchorage, Alaska.

______. 1981. Willow and Deception Creeks instream flow demonstration study. Volume I. Anchorage, Alaska.

______. 1983a. Susitna Hydro aquatic studies phase II basic data report. Volume 3 (1 of 2). Resident and juvenile anadromous fish studies on the Susitna River below Devil Canyon, 1982. Alaska Department of Fish and Game Susitna Hydro Aquatic Studies. Anchorage, Alaska.

______. 1983b. Susitna Hydro aquatic studies phase II basic data report. Volume 4 (1 of 3: Parts I and II). Aquatic habitat and instream flow studies, 1982. Alaska Department of Fish and Game Susitna Hydro Aquatic Studies.

______. 1984. Susitna Hydro aquatic studies (May 1983 - June 1984). procedures manual (1 of 2). Alaska Department of Fish and Game Susitna Hydro Aquatic Studies. Anchorage, Alaska.

Anderson, J.W. 1982. Water velocity as a regulator of zoobenthic distributions in a stream riffle. New Mexico State University, Las Cruces. Unpublished Masters Thesis. 75pp.

Anderson, N.H. and D.M. Lehmkuhl. 1968. Catastrophic drift of insects in a woodland stream. Ecology 49:(2)198-206.

Arctic Environmental Information and Data Center. 1980. Environmental studies of the proposed Terror Lake Hydroelectric project, Kodiak Island, Alaska. Instream Flow Studies. University of Alaska, Anchorage, 197p.

Banks, R.L., J.W. Mullan, R.W. Wiley, and D.J. Duffek. 1974. The Fontennelle Green River trout fisheries considerations in its enhancement and perpetuation, including test flow studies of 1973. USFWS, Salt Lake City, Utah. 74pp.

Baumann, R.W., A.R. [illegible]fin, and R.F. Surdick. 1977. The stoneflies (Plecoptera) of the Rocky Mountains. American Entomological Society, Philadelphia. Memoirs number 31. 208p.

Baxter, R.M. 1977. Environmental effects of dams and impoundments. Annual Review of Ecology and Systematics. 8:255-283.

Becker, C.D. 1973. Food and growth parameters of juvenile chinook salmon, Oncorhynchus tshyawytscha in Central Columbia River. NOAA Fish. Bull. 71(2):387-400.

Belsley, D.A., E. Kuh, and R.E. Welsch. 1980. Regression diagnostics: identifying influential data and sources of collinearity. John Wiley and Sons, New York.

Bjornn, T.C., M.A. Brusuen, M.P. Molnau and J.H. Milligan, 1977. Transport of granitic sediment in streams and its effects on insects and fish. University of Idaho, Moscow. Project B-036-IDA USDI. 43 pp.

Borror, D.J., D.M. DeLong, and C.A. Triplehorn. 1981. An introduction to the study of insects. Saunders College Publishing, Philadelphia. 827p.

Bovee, K.D. and T. Cochnaur. 1977. Development and evaluation of weighted criteria, probability-of-use curves for instream flow assessments: Fisheries. Instream Flow Information Paper No. 3. FWS/OBS-77/63. December 1977.

Bovee, K.D. and R. Milhous. 1978. Hydraulic simulation in instream flow studies: theory and techniques. Instream Flow Information Paper No. 5. FWS/OBS-78/33. August 1978.

Burger, C.V., D.B. Wangaard, R.L. Wilmot, and A.N. Palmisano. 1982. Salmon investigations in the Kenai River, Alaska, 1979-1981. U.S. Fish and Wildlife Service, National Fishery Research Center, Alaska Field Station. Anchorage, Alaska. 181pp.

Cummins, K.W. 1975. Macroinvertebrates. p 170-198 in: River Ecology. B.A. Whitton (editor). Studies in Ecology, Volume 2. University of California Press, Berkeley. 725pp.

Dauble, D.D., R.H. Gray, and F.S. Page. 1980. Importance of insects and zooplankton in the diet of 0-age chinook salmon Oncorhynchus tshawytscha in the central Columbia River. Northwest Science. 54(4):253-258.

Draper, N.R. and H. SMith. 1981. Applied regression analysis. Second edition. John Wiley and Sons, New York.

Edmunds, Jr., G.F., S.L. Jensen, and L. Berner. 1976. The Mayflies of North and Central American. University of Minnesota Press, Minneapolis. 330p.

Everest, F.H. and D.W. Chapman. 1972. Habitat selection and spatial interaction by juvenile chinook salmon and steelhead trout in two Idaho streams. J. Fish. Res. Bd. Canada 29:91-100.

Giger, R.D. 1973. Streamflow requirements for salmonids. Oregon Wildlife Commission Lab Final Report. Project AFS-62-1. 117pp.

Gore, J.A. 1978. A technique for predicting instream flow requirements of benthic macroinvertebrates. Freshwater Biology 8:141-151.

Harris, T.L. and T.M. Lawrence. 1978. Environmental requirements and pollution tolerance of Trichoptera. U.S. Environmental Protection Agency, Cincinnati, Ohio. EPA-600/4-78-063. 310p.

Hoaglin, D.C., F. Mosteller, and J.W. Tulsey. 1983. Understanding robust and exploratory data analysis. John Wiley and Sons, New York.

Hubbard, M.D. and W.L. Peters. 1978. Environmental requirements and pollution tolerance of Ephemeroptera. U.S. Environmental Protection Agency, Cincinnat, Ohio. EPA-600/4-78-061.

Hynes, H.B. 1970. The Ecology of Running Waters. University of Toronto Press. Toronta, Canada. 555pp.

Johansen, O.A. and L.C. Thomsen. 1934. Aquatic Diptera. Entomological Reprint Specialists, Los Angeles. 425p.

Judy, R.D. and J.A. Gore. 1979. A predictive model of benthic invertebrate densities for use in instream flow studies. USFWS Instream Flow Group, Fort Collins, Colorado.

Kennedy, H.D. 1967. Seasonal abundance of aquatic invertebrates and their utilization by hatchery-reared rainbow trout. Technical Paper 12. U.S. Bureau of Sports Fisheries and Wildlife, Washington, D.C. 41 p.

Kimble, L.A. and T.A. Wesche. 1975. Relationships between selected physical parameters and benthic community structure in a small mountain stream. Water Resources Series No. 55, University of Wyoming, Laramie. 64pp.

Lagler, K.F. 1956. Freshwater Fishery Biology, 2nd ed. Wm. C. Brown Co. Publishers, Dubuque. 421pp.

Loftus, W.F. and H.L. Lenon. 1977. Food habits of the salmon smolts, Oncorhynchus tshawytscha and O. keta, from the Salcha River, Alaska. Trans. Am. Fish. Soc. 106(3):235-240.

Merritt, R.W. and K.W. Cummins (editors) 1978. An introduction to the aquatic insects. Kendall/Hunt Publishing Company, Dubuque. 441p.

Minshall, G.W. and P.V. Winger. 1968. The effect of reduction in stream flow on vertebrate drift. Ecology 49(3):580-582.

Milhous, R.T., D.L. Wegner, and T. Waddle. 1981. User's guide to the physical habitat simulation system. Instream Flow Information Paper No. 11. Report FWS/OBS 81/43. USFWS Instream Flow Service Group, Washington DC.

Newell, R.L. 1976. Yellowstone River Study - Final Report. Montana Department of Fish and Game and Intake Water Company. 97pp.

Ott, A.G. and K.E. Tarbox. 1977. Instream flow, applicability of existing methodologies for Alaska waters. Prepared for the ADF&G and DNR. Woodward Clyde Consultants, Anchorage, Alaska. 70pp.

Pearson, L.S., K.R. Conover, and R.E. Sams. 1970. Factors affecting the natural rearing of juvenile coho salmon during the summer low flow season. Oregon Fish. Comm., Portland, Oregon. Unpublished paper. 64pp.

Pennak, R.W. 1978. Freshwater invertebrates of the United States, 2nd Edition. John Wiley and Sons, New York. 802p.

Poole, R.W. 1974. An introduction to quantitative ecology. McGraw-Hill Book Company, Incorporated, New York. 532 pp.

Quane, T., P. Morrow, and T. Wighrow. 1984a. Stage and discharge investigations. Chapger 1 in 1984 Report No. 3: Aquatic Habitat and Instream Flow Investigations (May - October 1983). Estes, C.C. and D.S. Vincent-Lang, eds. Alaska Department of Fish and Game Susitna Hydro Aquatic Studies. Anchorage, Alaska.

______, I. Queral, T. Keklak, and D. Seagren. 1984b. Channel geometry investigations of the Susitna River basin. Chapter 2 in 1984 Report No. 3: Aquatic Habitat and Instream Flow Investigations (May - October 1983). Estes, C.C. and D.S. Vincent-Lang, eds. Alaska Department of Fish and Game Susitna Hydro Aquatic Studies. Anchorage, Alaska.

R&M Consultants, Incorporated. 1984. Susitna hydroelectric project water balance studies of middle Susitna sloughs. R&M Consultants Incorporated, Anchorage. Draft Report.

Schmidt, D.C., S.S. Hale, P. Suchanek, and D.L. Crawford, editors. 1984. Resident and juvenile anadromous fish investigations (May - October 1983). Alaska Department of Fish and Game Susitna Hydro Aquatic Studies. Report No. 2. Prepared for Alaska Power Authority. Anchorage, Alaska.

Scullion, J. and A. Sunton. 1983. Effects of artificial freshets on substratum composition, benthic invertebrate fauna and invertebrate drift in two impounded rivers in mid-Wales. Hydrobiologia 107:261-269.

Steel, R.G. and J.H. Torrie. 1960. Principles and Procedures of Statistics. McGraw-Hill Book Company, Incorporated, New York.

Stalnaker, C.B. and J.L. Arnette. 1976. Methodologies for the determination of stream resource flow requirements: an assessment. USFWS/OBS and Utah State University, Logan, Utah. 199pp.

Surdick, R.F. and A.R. Gaufin. 1978. Environmental requirements and pollution tolerances of Plecoptera. U.S. Environmental Protection Agency, Cincinnati, Ohio. EPA-600/4-78-062. 417p.

Ulfstrand, S. 1967. Microdistribution of benthic species (Ephemeroptera, Pelcoptera, Trichoptera, Diptera: Similiidae) in lapland streams. Oikos 18:293-310. Copenhagen.

Usinger, R.L. (editor). 1956. Aquatic insects of California University of California Press, Berkeley. 508p.

Vincent-Lang, D., A. Hoffmann, A.E. Bingham, C. Estes, D. Hilliard, C. Steward, E. Woody Trihey, and S. Crumley. 1984. An evaluation of chum and sockeye salmon spawning habitat in sloughs and side channels of the middle Susitna River. Chapter 7 in 1984 Report No. 3: Aquatic Habitat and Instream Flow Investigations (May - October 1983). Estes, C.C. and D.S. Vincent-lang, eds. Alaska Department of Fish and Game Susitna Hydro Aquatic Studies. Anchorage, Alaska.

Waters, T.F. 1972. The Drift of Stream Insects. Annual Review of Entomology. 17:253-272.

White, R.G., J.H. Milligan, A.E. Bingham, R.A. Ruediozer, T.S. Vogel, and D.H. Bennett. 1981. Effects of reduced stream discharge on fish and aquatic macroinvertebrate populations. Project B-045-IDA. U.S. Department of the Interior. Office of Water Research and Technology. 283pp.

Wiggins, G.B. 1977. Larvae of the North American caddisfly genera (Trichoptera). University of Toronto Press, Toronto. 401p.

8.0 APPENDICES

APPENDIX A

Study Site Hydrographs, Rating Curves

and Discharge Data

APPENDIX A

Appendix A contains a hydrograph for each of the FAS sampling sites and the mainstem Susitna River at Gold Creek for the 1984 open water season (Appendix Figures A-1 and A-2). Also included are the rating curves (Appendix Figures A-3 through A-6) and the discharge data (Appendix Table A-1) used to generate the hydrographs. A narrative of the step-wise procedure used to develop the hydrographs is also presented.

Hydrograph Development

Discharge was measured twice at Slough 9 and once each at Side Channel 10, Upper Side Channel 11, and upper Side Channel 21 according to procedures outlined in ADF&G (1984). These discharges were taken at study sites to combine with 1982 and 1983 ADF&G discharge data for developing rating curves for describing the relationship between mainstem discharge and side channel or side slough flow.

Rating curves were developed for defining the relationship between mainstem discharge and side channel or side slough flow at all four study sites according to procedures described in ADF&G (1984). These rating curves were used to construct hydrographs for side channel or side slough flows for the period of June 1 through September 30, 1984. Flows above the recommended predictive range of a site respective rating curve were estimated using the rating curve equation. The highest flow measured below controlling breaching mainstem discharge was used to state the upper limit of base flow in a side channel or side slough. These flows are published in Quane et al. (1984) and R&M Consultants (1984).

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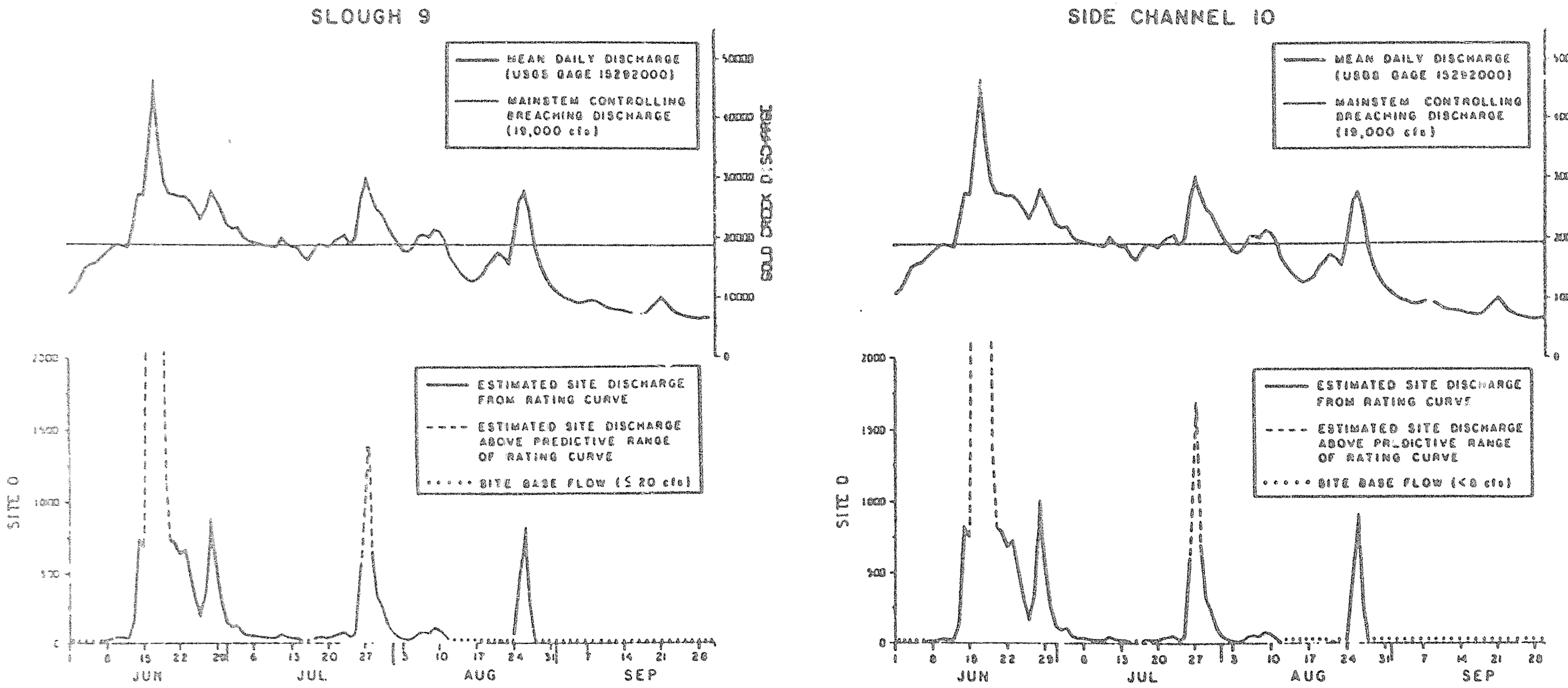

Figure A-1 Hydrograph (discharge versus time) for June - September 1984 for the Susitna River at Gold Creek (RM 136.5), Slough 9 (RM 128.3), and Side Channel 10 (RM 133.8).

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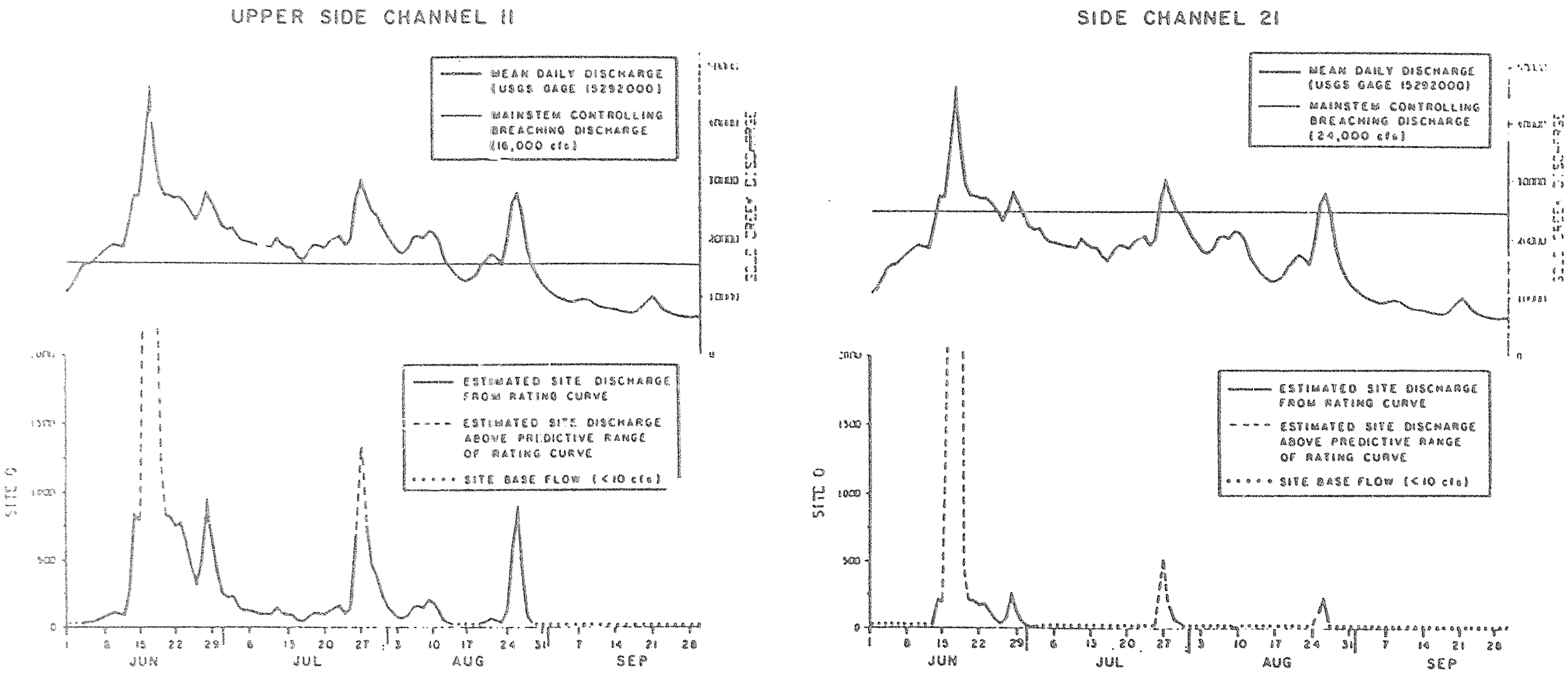

Figure A-2 Hydrograph (discharge versus time) for June - September 1984 for the Susitna River at Gold Creek (RM 136.5), Upper Side Channel 11 (RM 163.0), and Side Channel 21 above over flow channel A5 (RM 141.8).

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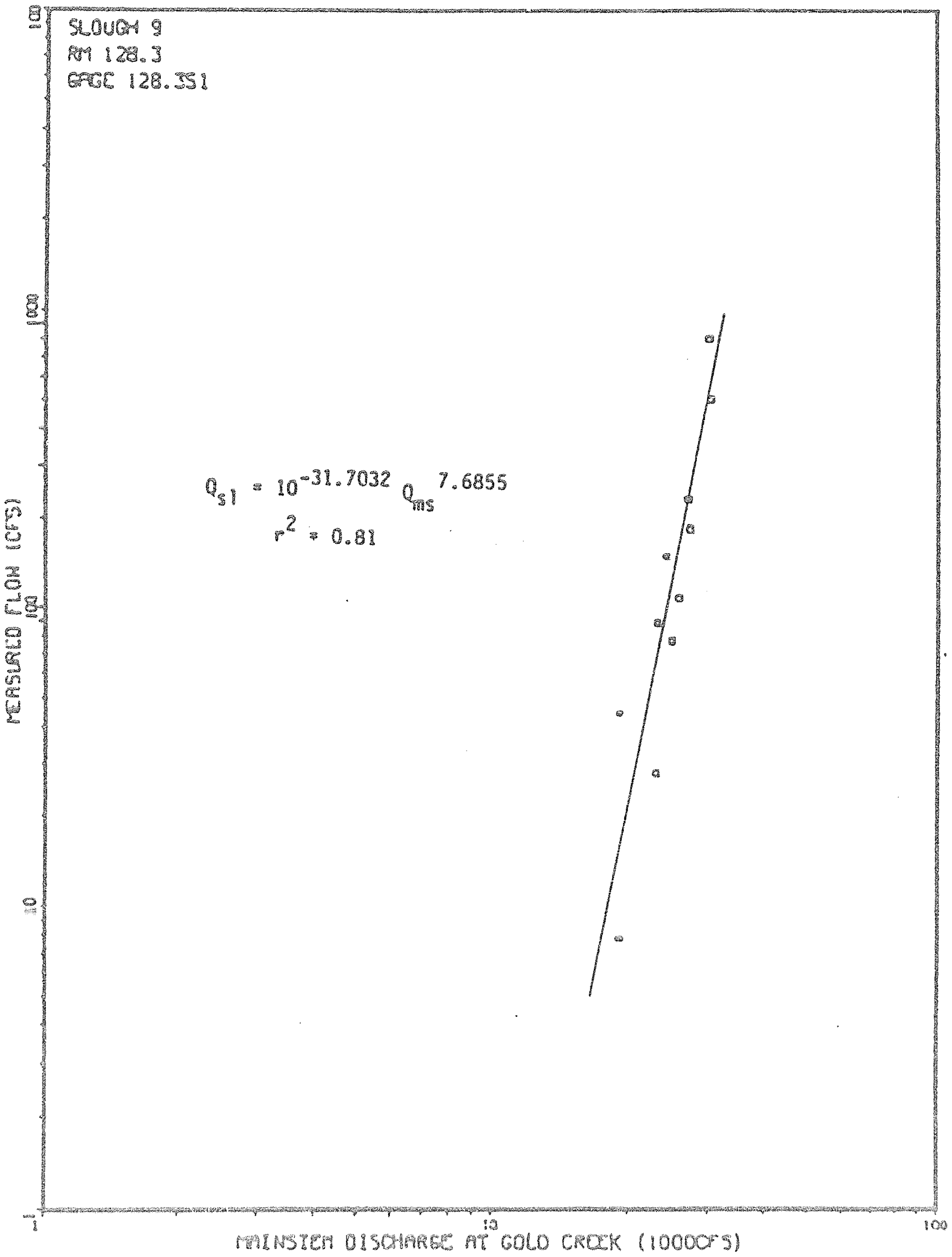

Figure A-3 Rating curve for predicting flow at Slough 9 at any mainstem discharge between 19,000 cfs and 35,000 cfs at Gold Creek.

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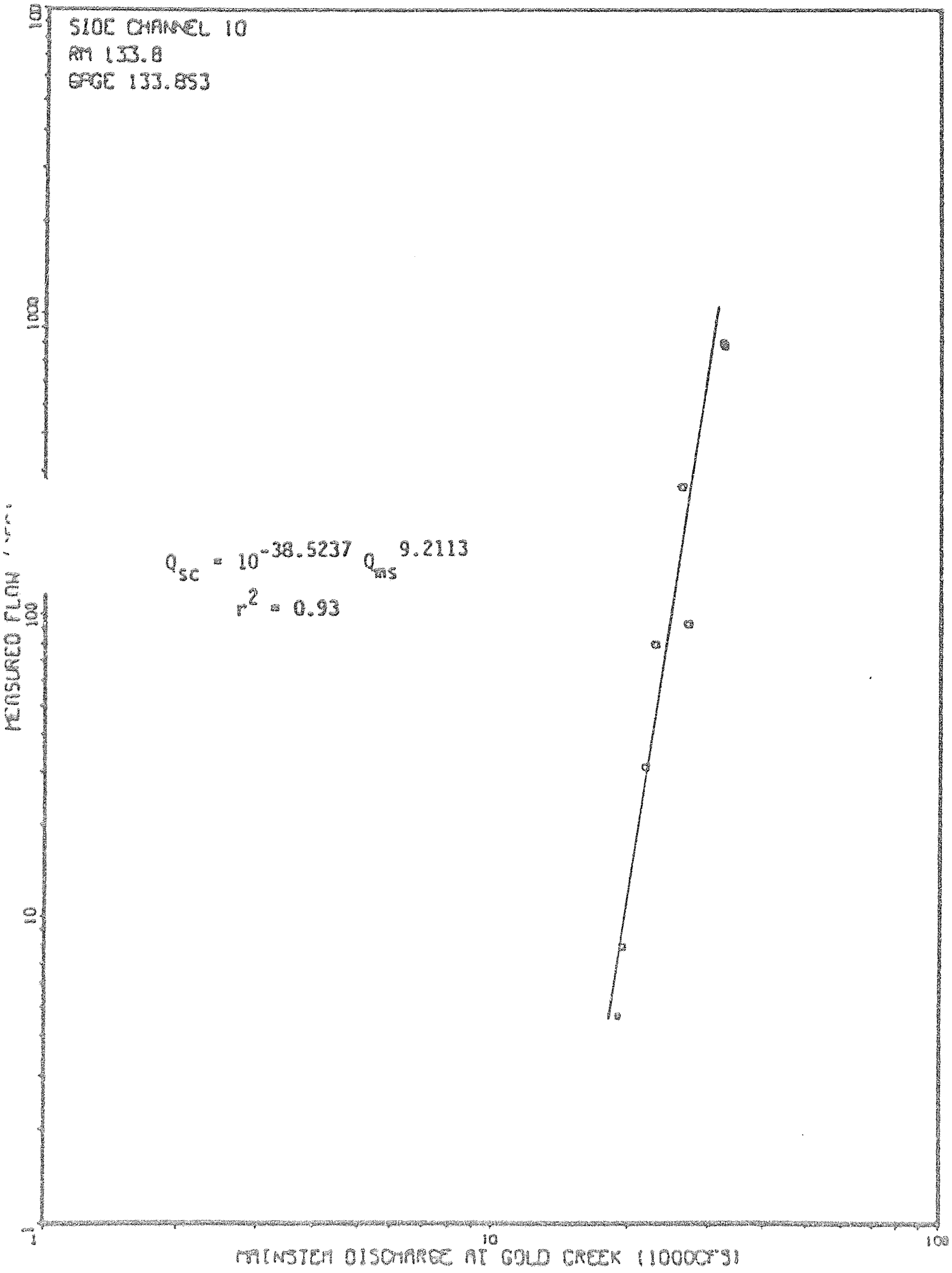

Figure A-4 Rating curve for predicting flow at Side Channel 10 at any mainstem discharge between 19,000 cfs and 35,000 cfs at Gold Creek.

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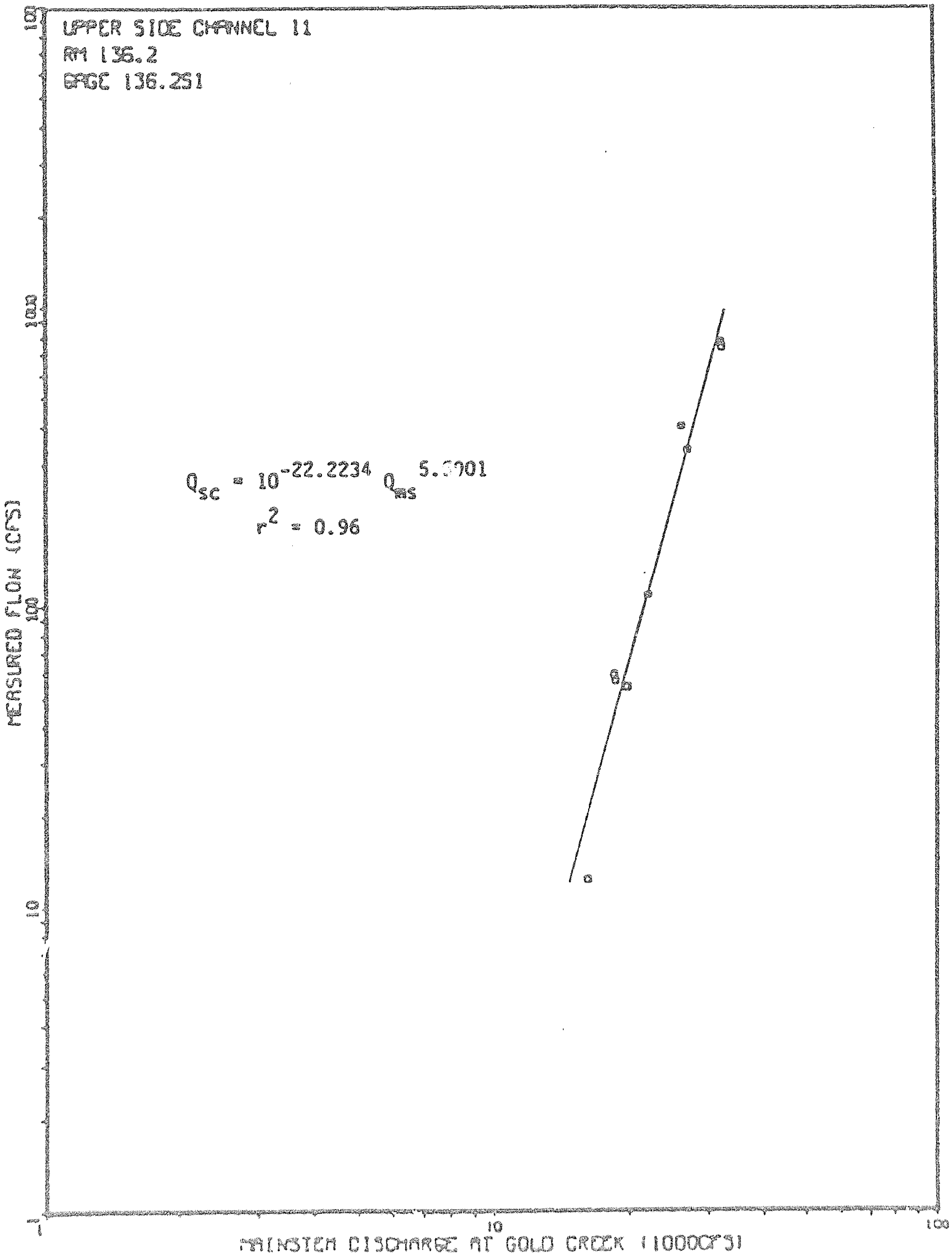

Figure A-5 Rating curve for predicting flow at upper Side Channel 11 at any mainstem discharge between 13,000 cfs and 35,000 cfs at Gold Creek.

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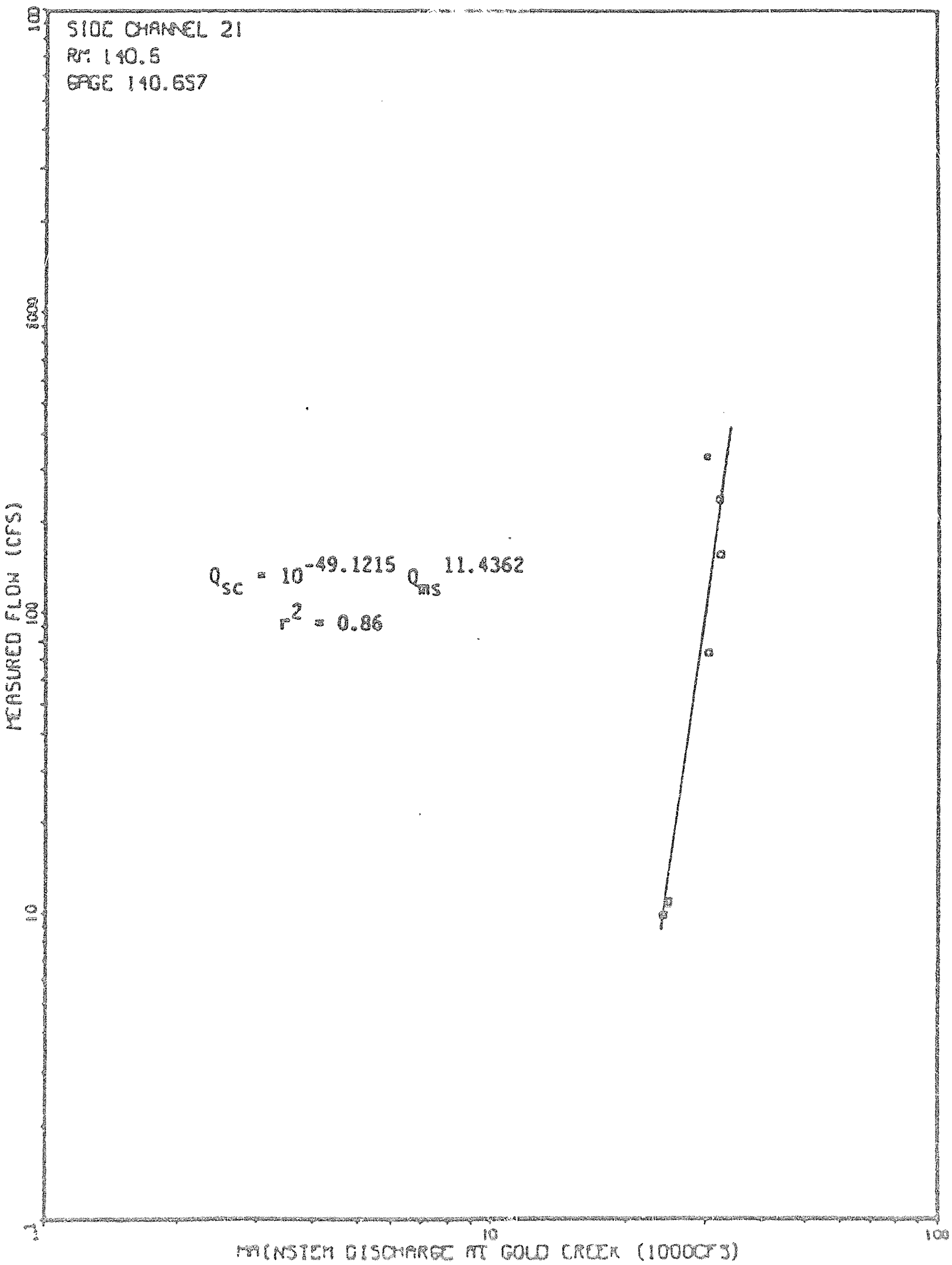

Figure A-6 Rating curve for predicting flow at Side Channel 21 above Channel A5 at any mainstem discharge between 20,000 cfs and 35,000 cfs at Gold Creek.

Appendix Table A-1. Side slough and side channel water surface elevation and flow measurements, and the corresponding mean daily Susitna River discharges at Gold Creek (USGS 15292000) used to construct rating curves for the four FAS sites.

	Date	Time	WSEL (ft)	Stream Flow (cfs)	Mainstem Discharge (cfs)
Side Slough 9 (Gage 128.3S1)	830730	0930	593.37	7.8	19,100
	840812	1455	593.84	44.4	19,000
	820720	----[a]	593.92	28.0	22,900
	830607	1225	593.96	89.0	23,000
	830630	1030	594.00	77.4	24,700
	820920	1520	594.15	148.0	24,000
	820715	----[a]	594.10	108.0	25,600
	820623	----[a]	594.27	182.0	27,000
	820918	1305	594.42	232.0	26,800
	830809	1547	595.25	501.5	29,900
	840825	1300	595.87	800.0	29,800
Side Channel 10 (Gage 133.8S3)	840812	1645	654.64	4.7	19,000
	830726	1530	654.72	8.0	19,400
	830803	1745	655.15	31.6	21,600
	830724	1620	655.57	80.0	22,700
	830629	1630	655.84	93.9	26,800
	830808	1235	656.30	266.6	26,000
	830810	1120	658.26	781.3	31,900
	830826	1605	657.97	803.0	31,700
Upper Side Channel 11 (Gage 136.2S1)	840814	1130	681.01	12.3	16,100
	830712	1145	681.35	54.0	19,700
	830720	0945	681.34	56.6	18,600
	830727	1130	681.38	59.6	18,500
	830608	1550	681.63	110.0	22,000
	830629	1255	682.13	335.0	26,800
	830808	1400	682.24	403.0	26,000
	830810	1346	682.87	735.6	31,900
	830826	1745	682.93	777.5	31,700
Side Channel 21 (Gage 140.6S7)	820919	1220	744.59	10.0	24,100
	830630	1130	744.73	10.9	24,700
	830605	1500	745.33	74.0	30,000
	820917	1540	745.80	157.0	32,000
	840826	1015	746.13	240.0	31,700
	830809	1315	746.08	332.0	29,900

[a] No data

APPENDIX B

Benthic and Drift Invertebrate Data

APPENDIX B

BENTHIC AND DRIFT INVERTEBRATE DATA

Appendix B contains the invertebrate catch data for benthic and drift samples at the four FAS sites. Appendix Table B-1 lists the occurrence of invertebrate taxa in the three types of samples: benthic, drift, and juvenile chinook salmon stomach content. Appendix Tables B-2 through B-5 contain drift catch data for each site. Appendix Table B-6 lists drift densities and rates for eight invertebrate groups. Appendix Tables B-7 through B-10 list benthic catch data for each site.

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Appendix Table B-1. Occurrence of invertebrates by life stage (i=immature, p=pupa, a=adult) and sample type (B=Benthos, D=Drift, F=Fish Stomach) at four sample sites, middle Susitna River, Alaska, 1984.

	SLough 9 RM 128.3			Side Channel 10 RM 133.8			Upper Side Channel 11 RM 136.0			Side Channel RM 141.8		
INSECTA												
Protura								D				
Collembola[a]			F			F		D	F			
Isotomidae	B	D			D		B	D		B	D	
Poduridae		D						D			D	
Sminthuridae		D			D			D			D	
TOTAL Collembola	B	D	F		D	F	B	D	F	B	D	
Ephemeroptera[a]			i F					a D	i F			
Baetidae	i B	ia D	i F	i B	ia D	i F	i B	ia D	i F	i B	a D	i F
Ephemerellidae	i B	i D	i F	i B	ia D	i f	i B	i D	i F	i B	a D	i F
Heptageniidae	i B	i D	i F	i B	ia D	i F	i B	ia D	i F	i B	a D	i F
Siphlonuridae	i B			i B	i D		i B	i D	i F		i D	i F
TOTAL Ephemeroptera	i B	ia D	i F	i B	ia D	i F	i B	ia D	i F	i B	ia D	i F
Plecoptera[a]		i D	i F			i F		i D	i F	i B		i F
Capniidae	i B	i D		i B	i D		i B	ia D	a F	i B	a D	
Chloroperlidae	i B	i D		i B	i D	i F	i B	i D	i F	i B		i F
Nemouridae	i B	i D		i B	i D	i F	i B	ia D		i B		
Perlodidae	i B	i D	i F	i B	i D	i F	i B	i D	ia F	i B	a D	i F
Pteronarcidae								D				
Taeniopterygidae	i B	i D		i B	i D		i B					
TOTAL Plecoptera	i B	i D	i F	i B	i D	i F	i B	ia D	ia F	i B	ia D	i F
Psocoptera		a D			a D				a F			
Thysanoptera		D	F		D	F		D	F		D	F
Hemiptera		D			D			D	F		D	
Homoptera		D	F		D	F		D	F		D	F

Appendix Table B-1 (Continued).

	SLough 9 RM 128.3			Side Channel 10 RM 133.8			Upper Side Channel 11 RM 136.0			Side Channel RM 141.8		
Neuroptera								D			D	
Coleoptera[a]		ia D	a F		a D			ia D	a F		a D	
Dytiscidae								ia D		i B		
Hypdrophilidae								i D				
TOTAL Coleoptera		ia D	a F		a D			ia D	a F	i B	a D	
Trichoptera[a]		ia D	i F				i B	ipa D	ia F	i B	i D	
Glossosomatidae					p D			ia D				
Hydropsychidae		i D	i F		i D			i D	i F	i B		
Limnephilidae	i B	i D	i F	i B	i D	i F	i B	ip D		ip B	i D	ip F
Hydroptilidae										i B		
Rhyacophilidae	i B							i D				
TOTAL Trichoptera	i B	ia D	i F	i B	ip D	i F	i B	ipa D	ia F	ip B	i D	ip F
Lepidotera		a D			a D			ia D	i F		a D	i F
Diptera[a]	ip B	a D	ia F		a D	a F	i B	ipa D	ia F	ip B	a D	a F
Ceratopogonidae	i B	a D			ia D		i B	a D			a D	
Chironomidae	ip B	ipa D	ipa F	ip B	ipa D	ipa F	ip B	ipa D	ia F	ip B	ipa D	ipa F
Culicidae								a D				
Dixidae								i D				
Empididae	ip B	ia D	ip F	i B	ipa D	ia F	i B	ia D	pa F	i B	a D	a F
Muscidae								i D		i B	i D	i F
Psychodidae		i D	i F		pa D		ip B	pa D		i B		
Simuliidae	i B	ipa D	i F	i B	ipa D	a F	i B	ipa D		i B	pa D	
Stratiomyidae								i D				
Syrphidae								i D				
Tipulidae	ip B	ipa D		ip B	ip D		i B	ipa D		ip B	pa D	
TOTAL Diptera	ip B	ipa D	ipa F	ip B	ipa D	ipa F	ip B	ipa D	ipa F	ip B	ipa D	ipa F
Hymenoptera		a D	a F		a D	a F		a D	a F		a D	a F

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Appendix Table B-1 (Continued).

	Slough 9 RM 128.3	Side Channel 10 RM 133.8	Upper Side Channel 11 RM 136.0	Side Channel RM 141.8
TURBELLARIA			B	B
NEMATODA	B	B D	B D	B
OLIGOCHAETA	B D	B D	B D	B D
CRUSTACEA				
Amphipoda			D	
Cladocera	B D F		D	
Eucopepoda	B D	D	B D	B
Podocopa	D	B D	B D	D
TOTAL CRUSTACEA	B D F	B D	B D	B D
ARACHNIDA				
Acari	B D	B D	B D	B D
Araneae	D F	D F	D F	D F
TOTAL ARACHNIDA	B D F	B D F	B D F	B D F
CHILOPODA			D	
GASTROPODA			B D	
PELECYPODA			B	
HYDROZOA				D

[a] Identified to Order only.

Appendix Table B-2. Total numbers of invertebrate larvae and adults ( ) in drift samples collected at Slough 9, middle Susitna River, Alaska, 1984. Terrestrial insect groups and non-insect groups are not differentiated by larvae or adult.

	Head			IFG-4		
	June	July	August	June	July	August
Water Filtered (ft^3)	13,064	4,088	2,697	13,321	2,925	2,805
INSECTA						
Collembola						
Isotomidae	5	2		6	2	
Poduridae				4	1	1
Sminthuridae	4				1	
TOTAL Collembola	9	2		10	4	1
Ephemeroptera						
Baetidae	19 (5)	4 (1)		5	(1)	4
Ephemerellidae	1	9	2		11	2
Heptageniidae	3	7	4	4	4	
TOTAL Ephemeroptera	23 (5)	20 (1)	6	9	15 (1)	6
Plecoptera[a]		9			31	
Capniidae	1				(1)	3
Chloroperlidae	1	2		1		
Nemouridae	1					
Perlodidae	4	6	1	1		1
Taeniopterygidae			30			38
TOTAL Pelcoptera	7	17	31	2	31 (1)	42
Psocoptera			3			1
Thysanoptera	18		5	13	1	1
Hemiptera	2	2		7	2	
Homoptera		2	13	1	2	2
Coleoptera	8			15	3	1
Trichoptera[a]	1	22			24	
Hydropsychidae			7			1
Limnephilidae			20	1	1	44
TOTAL Trichoptera	1	22	27	1	25	45
Lepidoptera	1		1	1		
Diptera[a]	(4)		(3)	(2)	(1)	
Ceratopogonidae	(1)	1 (1)			1 (2)	
Chironomidae	212(268)	31 (32)	5(157)	81(105)	37 (55)	6 (86)
Empididae		(1)		1 (2)	(5)	(1)
Psychodidae						2
Simuliidae	92 (17)	10 (1)	4 (1)	4 (3)	(1)	(1)
Tipulidae	3 (1)	1		1		
TOTAL Diptera	307(291)	73 (35)	9(161)	87(112)	38 (64)	8 (88)

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Appendix Table B-2 (Continued).

Water Filtered (ft^3)	Head June 13,064	Head July 4,088	Head August 2,697	IFG-4 June 13,321	IFG-4 July 2,925	IFG-4 August 2,805
Hymenoptera	21		30	20	12	12
OLIGOCHAETA	8	5	1	2	1	4
CRUSTACEA						
Cladocera	1	5	5		6	54
Eucopepoda	11	11	8	3	8	1
Podocopa		2	1		2	
TOTAL CRUSTACEA	12	18	14	3	16	55
ARACHNIDA						
Acari	4	5	1	1	2	4
Araneae	2	1	1	1	1	
TOTAL ARACHNIDA	6	6	2	2	3	4
FISH						
Alevin	1	1			1	

[a] Identified to Order only.

Appendix Table B-3. Total numbers of invertebrate larvae and adults ( ) in drift samples collected at Side Channel 10, middle Susitna River, Alaska, 1984. Terrestrial insect groups and non-insect groups are not differentiated by larvae or adult.

	Head			IFG-4		
	June	July	August	June	July	August
Water Filtered (ft^3)	1,574	1,613	--	3,338	5,292	892
INSECTA						
Collembola						
Isotomidae	2			11		
Sminthuridae	1					
TOTAL Collembola	3			11		
Ephemeroptera						
Baetidae	12	4		14	3	(1)
Ephemerellidae	1	2			3 (3)	
Heptageniidae	8			5	1	
Siphlonuridae	2			6		
TOTAL Ephemeroptera	23	6		25	7 (3)	(1)
Plecoptera						
Capniidae				2		
Chloroperlidae	1	1		1	1	
Nemouridae	2			1		
Perlodidae	2	1		1		
Taeniopterygidae		1			1	
TOTAL Plecoptera	5	3		5	2	
Psocoptera					1	
Thysanoptera				3		
Hemiptera	1	1		1		
Homoptera	2			1		1
Coleoptera	1			5		
Trichoptera						
Glossosomatidae				1		
Hydropsychidae		6			8	
Limnephilidae	1					(1)
TOTAL Trichoptera	1	6		1	8	(1)
Lepidoptera	1			1		(1)
Diptera[a]		(2)				
Ceratopogonidae	1			3 (1)	(2)	(2)
Chironomidae	142 (28)	10 (6)		227 (51)	11 (8)	3 (18)
Empididae	1 (1)	(1)		5 (2)	(10)	
Psychodidae				2 (1)		
Simuliidae	27 (3)			46 (5)		
Tipulidae	1	1		2		
TOTAL Diptera	172 (32)	11 (9)		285 (60)	11 (20)	3 (20)

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Appendix Table B-3 (Continued).

	Head			IFG-4		
	June	July	August	June	July	August
Water Filtered (ft^3)	1,574	1,613	--	3,338	5,292	892
Hymenoptera	1	4		1	4	2
NEMATODA	2			2		
OLIGOCHAETA	20	1		19		1
CRUSTACEA						
Eucopepoda	3	2		3	2	
Podocopa	2					
TOTAL CRUSTACEA	5	2		3	2	
ARACHNIDA						
Acari	3	1		2		5
Araneae	1			1		
TOTAL ARACNIDA	4	1		3		5
FISH						
Alevin	1			1		

[a] Identified to Order only.

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Appendix Table B-4. Total numbers of invertebrate larvae and adults ( ) in drift samples collected at Upper Side Channel 11, middle Susitna River, Alaska, 1984. Terrestrial insect groups and non-insect groups are not differentiated by larvae or adult.

	Head			IFG-4		
Water Filtered (ft^3)	June 21,530	July 4,699	August 4,096	June 23,211	July 6,226	August 5,490
INSECTA						
Protura	2					
Collembola[a]						1
Isotomidae	204	2	2	76	4	
Poduridae	11			3	1	2
Sminthuridae	3			5		
TOTAL Collembola	220	2	2	84	5	3
Ephemeroptera[a]					(1)	
Baetidae	1,226	29 (1)	2	154	17 (1)	3
Ephemerellidae		6	7		5	3
Heptageniidae	79	12	17	11	12 (1)	10
Siphlonuridae	43			3		
TOTAL Ephemeroptera	1,348	47 (1)	26	168	34 (3)	16
Plecoptera[a]		1	48		3	45
Capniidae	1 (1)			1	2 (2)	
Chloroperlidae	64	7	6	12	2	1
Nemouridae	64 (11)		2	26 (2)	1	2
Perlodidae	6	7	8	3		
Pteronarcidae	2					
TOTAL Plecoptera	137 (12)	15	64	42 (2)	8 (2)	48
Psocoptera	5		2			
Thysanoptera	18	6	1	10	4	
Hemiptera	3	2		4	1	
Homoptera	8	5	14	7	3	15
Neuroptera					1	
Coleoptera[a]	24	2		9	4	
Dytiscidae	2	1		2		
Hydrophilidae					1	
TOTAL Coleoptera	26	3		11	5	
Trichoptera[a]	(1)		5	1		3
Glossosomatidae				1	(1)	
Hydropsychidae			5		1	
Limnephilidae	3		2			
Rhyacophilidae	12			6		
TOTAL Trichoptera	15 (1)		12	8	1 (1)	3
Lepidoptera	21			14		

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Appendix Table B-4 (Continued).

	Head			IFG-4		
	June	July	August	June	July	August
Water Filtered (ft^3)	21,530	4,699	4,096	23,211	6,226	5,490
Diptera[a]	21 (20)	(4)	(3)	13 (10)	1 (6)	(4)
Ceratopogonidae	17			1 (1)	(4)	
Chironomidae	883(322)	73(110)	113(239)	572(444)	68(237)	131(249)
Culicidae					(1)	
Empididae	17 (3)	4 (7)		20 (1)	(11)	1
Psychodidae	10			2 (1)		
Simuliida	90(128)	14	6	24 (59)	21 (5)	5
Tipulidae	63 (3)			26 (2)	1 (4)	
Dixidae	3			2		
Muscidae	1			1		
Stratiomyidae	1					
Syrphidae	2			2		
TOTAL Diptera	1,108(476)	91(121)	119(342)	663(518)	91(268)	137(253)
Hymenoptera	29	10	8	14	9	5
NEMATODA	1		1	2	1	1
OLIGOCHAETA	82		7	27	5	1
CRUSTACEA						
Cladocera		4	5		5	
Eucopepoda		4	3	7	5	2
Amphipoda	1			1		
TOTAL CRUSTACEA	1	8	8	8	10	2
ARACHNIDA						
Acari	23	6	1	18	5	2
Araneae	19	1		10	1	
TOTAL ARACHNIDA	42	7	1	28	6	2
CHILOPODA	3					
GASTROPODA	2		1	1		1
FISH						
Alevin		2			1	
Juvenile salmon	1					

[a] Identified to Order only

Appendix Table B-5. Total numbers of invertebrate larvae and adults ( ) in drift samples collected at upper Side Channel 21, middle Susitna River, Alaska, 1984. Terrestrial insect groups and non-insect groups are not differentiated by larvae or adult.

	Head			IFG-4		
	June	July	August	June	July	August
Water Filtered (ft³)	54	864	--	9,693	5,808	5,190
INSECTA						
Collembola						
Isotomidae	1	2				1
Poduridae		1			4	
Sminthuridae	1					1
TOTAL Collembola	2	3			4	2
Ephemeroptera						
Baetidae						(2)
Ephemerellidae		(1)				3
Heptageniidae		(1)				2
Siphlonuridae	1					
TOTAL Ephemeroptera	1	(2)				5 (2)
Plecoptera[a]						5
Capniidae				(1)		
Nemouridae						1 (1)
Perlodidae		(1)				
TOTAL Plecoptera		(1)		(1)		6 (1)
Psocoptera						5
Thysanoptera				1		7
Hemiptera		1				1
Homoptera					1	9
Neuroptera		1				
Coleoptera	2	1		1		2
Trichoptera						18
Limnephilidae					1	
Lepidoptera						4
Diptera[a]	(1)	(1)			(2)	(4)
Ceratopogonidae		(1)			(3)	11
Chironomidae	2 (5)	(8)		2 (23)	4 (10)	42(1047)
Empididae		(19)			(1)	(3)
Simuliidae	1 (11)			(1)		(3)
Tipulidae	1	(2)				
TOTAL Diptera	4 (17)	(31)		2 (24)	4 (16)	53(1057)

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Appendix Table B-5 (Continued).

	Head			IFG-4		
	June	July	August	June	July	August
Water Filtered (ft^3)	54	864	--	9,693	5,808	5,190
Hymenoptera	1	8		2	8	85
HYDROZOA						2
OLIGOCHAETA					1	36
CRUSTACEA						
Podocopa						1
ARACHNIDA						
Acari					15	37
Araneae					2	2
TOTAL ARACHNIDA					17	39

[a] Identified to Order only.

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Appendix Table B-6. Densities (no./yd³ of water) and rates (no./min.) of invertebrate drift during June, July, and August at slough and side channel head and IFG sites, middle Susitna River, Alaska, 1984.

		June 7-14		July 7-14		August 9-16	
		Density	Rate	Density	Rate	Density	Rate
Collembola	Sl.9 Head	0.02	0.15	0.01	0.06	0.00	0.00
	IFG	0.02	0.17	0.04	0.11	0.01	0.03
	S.C.10 Head	0.05	0.40	0.00	0.00	0.00	0.00
	IFG	0.09	0.73	0.00	0.00	0.00	0.00
	U.S.C. 11 Head	0.27	2.14	0.01	0.06	0.01	0.07
	IFG	0.10	0.93	0.02	0.16	0.01	0.10
	S.C. 21 Head	1.00	0.07	0.09	0.10	0.00	0.00
	IFG	0.00	0.00	0.02	0.06	0.01	0.03
Ephemeroptera	Sl. 9 Head	0.06	0.47	0.15	0.61	0.06	0.18
	IFG	0.02	0.15	0.15	0.42	0.06	0.18
	S.C.10 Head	0.39	3.07	0.10	0.10	0.00	0.00
	IFG	0.19	1.60	0.05	0.20	0.03	0.01
	U.S.C. 11 Head	1.69	13.23	0.28	1.50	0.14	0.87
	IFG	0.20	1.87	0.16	1.12	0.07	0.50
	S.C. 21 Head	0.50	0.03	0.06	0.07	0.00	0.00
	IFG	0.00	0.00	0.00	0.00	0.04	0.12
Plecoptera	Sl.9 Head	0.01	0.12	0.11	0.44	0.31	0.91
	IFG	0.01	0.03	0.30	0.84	0.40	1.24
	Sl 10 Head	0.09	0.67	0.05	0.05	0.00	0.00
	IFG	0.04	0.33	0.01	0.04	0.00	0.00
	U.S.C. 11 Head	0.19	1.46	0.09	0.47	0.34	2.13
	IFG	0.05	0.49	0.04	0.31	0.24	1.60
	S.C. 21 Head	0.00	0.00	0.03	0.03	0.00	0.00
	IFG	0.01	0.02	0.00	0.00	0.04	0.12
Trichoptera	Sl.9 Head	0.01	0.02	0.15	0.61	0.27	0.79
	IFG	0.01	0.02	0.23	0.66	0.43	1.32
	S.C.10 Head	0.02	0.13	0.10	0.10	0.00	0.00
	IFG	0.01	0.07	0.04	0.16	0.03	0.01
	U.S.C. 11 Head	0.02	0.16	0.00	0.00	0.06	0.40
	IFG	0.01	0.09	0.01	0.06	0.01	0.10
	S.C. 21 Head	0.00	0.00	0.00	0.00	0.00	0.00
	IFG	0.00	0.00	0.01	0.02	0.09	0.30
Diptera Larvae	Sl.9 Head	0.63	5.12	0.48	2.03	0.09	0.26
	IFG	0.18	1.45	0.35	1.00	0.08	0.24
	S.C.10 Head	2.95	22.93	0.18	0.18	0.00	0.00
	IFG	2.31	19.00	0.06	0.22	0.09	0.03
	U.S.C. 11 Head	1.39	10.86	0.52	2.84	0.63	3.97
	IFG	0.77	7.37	0.39	2.84	0.67	4.53
	S.C. 21 Head	2.00	0.13	0.00	0.00	0.00	0.00
	IFG	0.01	0.03	0.02	0.06	0.28	0.90
Diptera Adults	Sl.9 Head	0.60	4.85	0.22	0.94	1.61	4.74
	IFG	0.23	1.87	0.59	1.68	0.85	2.59
	S.C.10 Head	0.55	4.27	0.15	0.15	0.00	0.00
	IFG	0.49	4.00	0.10	0.40	0.61	0.22
	U.S.C. 11 Head	0.60	4.67	0.70	3.78	1.28	8.07
	IFG	0.60	5.76	1.16	8.38	1.25	8.47
	S.C. 21 Head	8.50	0.57	0.97	1.03	0.00	0.00
	IFG	0.07	0.43	0.10	0.25	5.501	7.62

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Appendix Table B-6 Continued.

		June 7-14		July 7-14		August 9-16	
		Density	Rate	Density	Rate	Density	Rate
Other Insects	S1.9 Head	0.10	0.83	0.03	0.11	0.52	1.53
	IFG	0.12	0.95	0.18	0.53	0.15	0.47
	S.C.10 Head	0.10	0.80	0.08	0.08	0.00	0.00
	IFG	0.10	0.80	0.03	0.10	0.09	0.03
	U.S.C. 11 Head	0.14	1.10	0.15	0.81	0.14	0.87
	IFG	0.07	0.67	0.11	0.78	0.10	0.67
	S.C. 21 Head	1.50	0.10	0.34	0.37	0.00	0.00
	IFG	0.01	0.07	0.05	0.14	0.58	1.85
Other Invertebrates	S1.9 Head	0.05	0.43	0.19	0.81	0.17	0.50
	IFG	0.01	0.12	0.18	0.53	0.61	1.85
	S.C.10 Head	0.53	4.13	0.07	0.07	0.00	0.00
	IFG	0.22	1.80	0.01	0.04	0.18	0.07
	U.S.C. 11 Head	0.16	1.28	0.09	0.47	0.10	0.60
	IFG	0.08	0.74	0.10	0.69	0.03	0.23
	S.C. 21 Head	0.00	0.00	0.00	0.00	0.00	0.00
	IFG	0.00	0.00	0.11	0.28	0.41	1.30
Total Invertebrates	S1. 9 Head	1.49	11.98	1.34	5.64	3.03	8.91
	IFG	0.58	4.75	2.02	5.76	2.60	7.94
	S.C.10 Head	4.68	36.40	0.74	0.73	0.00	0.00
	IFG	3.44	28.33	0.29	1.16	1.06	0.39
	U.S.C. 11 Head	4.46	34.89	1.83	9.94	2.70	16.97
	IFG	1.88	17.91	1.98	14.28	2.39	16.20
	S.C. 21 Head	13.50	0.90	1.50	1.60	0.00	0.00
	IFG	0.90	0.55	0.31	0.80	6.94	22.23

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Appendix Table B-7. Total numbers of benthic invertebrates and the number of samples ( ) in which each taxa was found at Slough 9, middle Susitna River, Alaska, 1984.

	7/6/84 18 samples	9/9/84 24 samples
INSECTA		
Collembola		
Isotomidae	-	1 (1)
Ephemeroptera		
Baetidae	9 (5)	1 (1)
Ephemerellidae	27 (8)	1 (1)
Heptageniidae	11 (5)	-
Siphlonuridae	-	1 (1)
Total Ephemeroptera	47 (8)	3 (3)
Plecoptera		
Capniidae	-	50 (8)
Chloroperlidae	4 (2)	3 (3)
Nemouridae	-	2 (1)
Perlodidae	11 (6)	-
Taeniopterygidae	-	12 (3)
Total Plecoptera	15 (7)	67 (9)
Trichoptera		
Limnephilidae	-	11 (4)
Rhyacophilidae	-	2 (2)
Total Trichoptera	-	13 (5)
Diptera	2 (2)	-
Ceratopogonidae	1 (1)	-
Chironomidae	60 (13)	415 (19)
Empididae	4 (1)	-
Simuliidae	1 (1)	-
Tipulidae	-	4 (3)
Total Diptera	68 (13)	419 (20)
NEMATODA	1 (1)	1 (1)
OLIGOCHAETA	76 (9)	15 (7)
CRUSTACEA		
Cladocera	-	1 (1)
Eucopepoda	-	3 (3)
Total CRUSTACEA	-	4 (3)
ARACHNIDA		
Acari	1 (1)	-

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Appendix Table B-8. Total numbers of benthic invertebrates and the number of samples ( ) in which each taxa was found at Side Channel 10, Middle Susitna River, Alaska, 1984.

	6/26/84 32 samples	9/8/84 21 samples
INSECTA		
Ephemeroptera		
Baetidae	23 (9)	7 (3)
Ephemerellidae	1 (1)	-
Heptageniidae	24 (13)	1 (1)
Siphlonuridae	-	3 (2)
Total Ephemeroptera	48 (15)	11 (3)
Plecoptera		
Capniidae	-	145 (15)
Chloroperlidae	8 (6)	7 (6)
Nemouridae	-	1 (1)
Perlodidae	7 (6)	-
Taeniopterygidae	-	3 (2)
Total Plecoptera	15 (9)	156 (17)
Trichoptera		
Limnephilidae	-	10 (7)
Diptera	1 (1)	
Chironomidae	43 (16)	157 (18)
Empididae	-	9 (6)
Simuliidae	4 (4)	-
Tipulidae	-	7 (5)
Total Diptera	48 (16)	173 (21)
NEMATODA	1 (1)	3 (3)
OLIGOCHAETA	6 (3)	18 (9)
CRUSTACEA		
Podocopa	-	1 (1)
ARACHNIDA		
Acari	-	1 (1)

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Appendix Table B-9. Total numbers of benthic invertebrates and the number of samples ( ) in which each taxa was found at Upper Side Channel 11, middle Susitna River, Alaska, 1984.

	7/9/84 27 samples	8/23/84 36 samples
INSECTA		
Collembola		
Isotomidae	7 (2)	-
Ephemeroptera		
Baetidae	31 (9)	1 (1)
Ephemerellidae	23 (12)	7 (5)
Heptageniidae	24 (9)	1 (1)
Siphlonuridae	1 (1)	-
Total Ephemeroptera	79 (16)	9 (7)
Plecoptera		
Capniidae	-	31 (13)
Chloroperlidae	17 (10)	12 (8)
Nemouridae	1 (1)	17 (7)
Perlodidae	15 (9)	3 (3)
Taeniopterygidae	-	2 (2)
Total Plecoptera	33 (17)	65 (16)
Trichophtera	2 (2)	-
Limnephilidae	-	14 (11)
Total Trichophtera	2 (2)	14 (11)
Diptera	1 (1)	
Ceratopogonidae	-	2 (2)
Chironomidae	118 (22)	586 (28)
Empididae	-	2 (2)
Psychodidae	-	2 (2)
Simuliidae	1 (1)	-
Tipulidae	1 (1)	2 (2)
Total Diptera	121 (23)	594 (30)
TURBELLARIA	8 (6)	24 (5)
NEMATODA	1 (1)	4 (4)
OLIGOCHAETA	40 (9)	92 (20)
CRUSTACEA		
Eucopepoda	-	2 (2)
ARACHNIDA		
Acari	4 (4)	2 (2)
GASTROPODA	-	1 (1)
PELECYPODA	1 (1)	-

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Appendix Table B-10. Total numbers of benthic invertebrates and the number of samples ( ) in which each taxa was found at Side Channel 21, middle Susitna River, Alaska, 1984.

	6/24/84 20 samples	8/24/84 35 samples
INSECTA		
Collembola		
Isotomidae	-	5 (4)
Ephemeroptera		
Baetidae	64 (17)	-
Ephemerellidae	2 (2)	2 (1)
Heptageniidae	45 (10)	1 (1)
Total Ephemeroptera	111 (17)	3 (2)
Plecoptera	1 (1)	
Capniidae	-	6 (5)
Chloroperlidae	16 (10)	1 (1)
Nemouridae	5 (4)	4 (2)
Perlodidae	21 (10)	3 (3)
Total Plecoptera	43 (13)	14 (8)
Coleoptera		
Dytiscidae	2 (2)	-
Trichoptera		1 (1)
Hydropshchidae	3 (1)	-
Hydroptilidae	1 (1)	-
Limnephilidae	49 (8)	62 (18)
Total Trichoptera	53 (8)	63 (19)
Diptera	7 (4)	1 (1)
Chironomidae	244 (18)	448 (33)
Empididae	5 (4)	5 (5)
Muscidae	-	1 (1)
Psychodidae	-	2 (2)
Simuliidae	2 (2)	-
Tipulidae	8 (4)	4 (2)
Total Diptera	259 (18)	460 (33)
TURBELLARIA	49 (7)	8 (3)
NEMATODA	1 (1)	-
OLIGOCHAETA	451 (17)	286 (26)
CRUSTACEA		
Eucopepoda	1 (1)	1 (1)
ARACHNIDA		
Acari	7 (4)	3 (2)

APPENDIX C

Results of the Multiple Regression Analysis for Drift Data

APPENDIX C

Results of the Multiple Regression Analysis for Drift Data

Appendix C presents the results of the analysis of variance for calculating the F values in the two multiple regression analyses. Also shown are the results of the two sets of t tests run on the regression coefficients. A statement of the hypothesis being tested is also presented.

Hypothesis: The numbers of drifting invertebrate at IFG-4 sites was not dependent (related) upon the numbers of drifting invertebrates at head sites, the volume of water filtered at head sites, or the volume of water filtered at IFG-4 sites.

1) H_0: $\beta_1 = \beta_2 = \beta_3 = 0$

H_A: $\beta_2 \neq \beta_2 \neq \beta_3 \neq 0$

Table C-1. Analysis of Variance.

Source of Variation	D.F.	Sum of squares	Mean sum of squares	F value
Regression	3	222.203	74.068	170.741
Error	132	57.262	0.434	
Total	135	279.465		

The critical value of F at 3 and 132 d.f. and $\alpha = 0.05$ is $\cong$ 2.68. Since the calculated F is 170.741 we reject the null hypothesis (H_0) and accept the alternate hypothesis (H_A).

2) H_0: $\beta_1 = 0$, $\beta_2 = 0$, $\beta_3 = 0$

H_A: $\beta_1 \neq 0$, $\beta_2 \neq 0$, $\beta_3 \neq 0$

Table C-2. Results of Student's t-test.

Variable	Coefficient estimate	Standard error of estimate	t value
x_1	$\beta_1 = 0.808$	0.093	18.90
x_2	$\beta_2 = 0.095$	0.058	1.65
x_3	$\beta_3 = -0.345$	0.085	-4.05

The critical value of t at 132 d.f and $\alpha = 0.05$ is $\cong 1.98$.

Since the calculated t value for β_2 does not exceed the critical value (ignore signs) we fail to reject the null hypothesis (H_0) of no difference from zero for the relationship with volume of water filtered at the head site. Accordingly, a new model was evaluated which did not utilize x_2. The new model was:

$$Y = \beta_0 + \beta_1 x_1 + \beta_3 x_3 + \varepsilon$$

where the symbols are as defined in Section 2.3.1.

The new hypotheses tested:

1) H_0: $\beta_1 = \beta_3 = 0$
   H_A: $\beta_1 \neq \beta_3 \neq 0$

Table C-3. Analysis of Variance for new hypothesis.

Source of Variation	D.F.	Sum of squares	Mean sum of squares	F value
Regression	2	221.017	110.508	251.464
Error	133	58.448	0.439	
Total	135	279.465		

The critical value of F at 2 and 133 d.f. and $\alpha = 0.05$ is $\cong 3.07$. Since the calculated F is 251.464 we reject the null hypothesis (H_0) and accept the alternate hypothesis (H_A).

2) H_0: $\beta_1 = 0, \beta_3 = 0$

H_A: $\beta_1 \neq 0, \beta_3 \neq 0$

Table C-4. Results of Student's t-test for new hypothesis

Variable	Coefficient estimate	Standard error of estimate	t value
x_1	$\beta_1 = 0.841$	0.038	22.06
x_2	$\beta_3 = -0.310$	0.083	-3.73

The critical value of t at 133 d.f. and $\propto = 0.05$ is $\cong 1.98$. Since the calculated t values for the two regressin coefficients exceeds the critical value (ignore signs) we reject the null hypotheses (H_0) of no difference from zero. The final linear model with estimates of coefficients is:

$$Y = 2.684 + 0.841x_1 - 0.310x_3 + \varepsilon$$

Note, that extensive residual analysis as outlined by Draper and Smith (1981) and Hoaglin et al. (1983) was completed on this final model. This analysis indicated that residuals were approximately normally distributed, residuals were not related to either estimated vlaues of Y or original values of x_1 or x_3; and that no one point or groups of points unduly affected the relationship (i.e., had outstanding values of leverage [Belsley et al. (1980)]. Accordingly, the model described above is deemed "valid".

APPENDIX D

Formulae for Calculating the Shannon-Weaver

Diversity Index and Eveness Index

APPENDIX D

FORMULAE

Appendix D contains the formula for calculating the Shannon-Weaver diversity index and eveness index (Poole 1974) used to describe the benthic invertebrate communities in riffles, run, and pool habitats in side channels and side sloughs.

1) Shannon-Weaver index (H')

$$H' = -\sum_{i=1}^{s} P_i \log_2 P_i$$

where s = number of species
P_i = proportion of the total number of individuals consisting of the ith species (i.e., Family, Order)

2) variance of Shannon-Weaver index (var (H'))

$$\text{var}(H') = \frac{\sum_{i=1}^{s} P_i \log_2^2 P_i - \left(\sum_{i=1}^{s} P_i \log_2 P_i\right)^2}{N}$$

where N = total number of individuals

3) standard error of H'

$$S.E. = \sqrt{\text{var}(H')}$$

4) eveness (J')

$$J' = \frac{H'}{\log_2 S}$$

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APPENDIX E

Juvenile Chinook Salmon Stomach Content Data

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Appendix Table E-1. Number and kind of invertebrate larvae and adults ( ) from the stomachs of juvenile chinook salmon caught by electrofishing and drift nets at invertebrate sampling sites, middle Susitna River, Alaska, 1984.

	Slough 9 (14 fish)	Side Channel 10 (14 fish)	Upper Side Channel 11 (19 fish)	Upper Side Channel 21 (20 fish)	Drift Net (5 fish)
INSECTA					
Collembola	1	7	3	-	-
Ephemeroptera					
Baetidae	9	10	26	4	5
Ephemerellidae	4	8	2	4	-
Heptageniidae	3	1	2	1	-
Siphlonuridae	-	-	4	1	-
TOTAL Ephemeroptera	17	26	35	10	5
Plecoptera	111	73	35	4	39
Capniidae	-	-	(1)	-	-
Chloroperlidae	-	2	2	1	-
Nemouridae	-	1	-	-	-
Perlodidae	2	5	18 (2)	5	-
TOTAL Plecoptera	113	81	55 (3)	10	39
Thysanoptera	5	1	3	-	1
Hemiptera	-	-	1	-	-
Homoptera	5	23	10	34	1
Coleoptera	(2)	(1)	-	-	-
Trichoptera			(2)		
Hydropsychidae	2	-	4	-	-
Limnephilidae	1	4	-	4	-
TOTAL Trichoptera	3	4	4	4	-
Lepidoptera	2	-	2	-	1
Diptera	4 (2)	1 (4)	3 (15)	(6)	1 (2)
Chironomidae	101 (85)	374(107)	44 (35)	404(259)	23 (52)
Empididae	2 (7)	1 (10)	3 (30)	(15)	-
Miscidae	-	-	-	18	-
Psychodidae	3	-	-	-	-
Simuliidae	2	(1)	-	-	-
TOTAL Diptera	112 (94)	376(121)	50 (80)	422(281)	24 (54)
Hymenoptera	(2)	(5)	(2)	(2)	(2)
CRUSTACEA					
Cladocera		-	-	-	-
ARACHNIDA					
Araneae	1	2	-	1	1

APPENDIX F

Water Turbidity Data

Appendix Table F-1. Turbidity values in nephelometric turbidity units (NTU) from five locations, middle Susitna River, Alaska, 1984.

Location	Date	Time	IFG-4 (NTU)	Head (NTU)	Mainstem (NTU)	Mainstem Discharge (cfs) at Gold Creek	Breached (Yes/No)
Slough 9 (River Mile 128.3)	840611	2100	27	38	--[a]	21500	Y
	840612	2200	22	36	--[a]	21300	Y
	840706	1530	124	--[a]	--[a]	22300	Y
	840711	2130	152	160	--[a]	23100	Y
	840712	2130	130	156	--[a]	21900	Y
	840813	2030	100	152	--[a]	17600	Y
	840814	2000	70	130	--[a]	16100	Y
	840909	1150	1	--[a]	--[a]	10600	N
Side Channel 10 (River Mile 133.8)	840613	2130	24	56	--[a]	25900	Y
	840614	2100	120	--[a]	--[a]	31500	Y
	840626	1520	136	--[a]	--[a]	26600	Y
	840713	2100	138	138	--[a]	21200	Y
	840714	2130	77	86	--[a]	21200	Y
	840815	2000	2	--[a]	--[a]	15100	N
	840816	2000	1	--[a]	--[a]	14500	N
	840908	1110	1	--[a]	--[a]	10900	N
Upper Side Channel 11 (River Mile 136.0)	840607	2235	46	--[a]	--[a]	19300	Y
	840608	2200	44	48	--[a]	20300	Y
	840707	2100	138	140	--[a]	21900	Y
	840708	2100	142	162	--[a]	21500	Y
	840709	1122	140	--[a]	--[a]	21400	Y
	840809	2030	344	320	--[a]	24500	Y
	840810	2015	248	304	--[a]	24000	Y
	840823	1202	108	--[a]	--[a]	17900	Y
Side Channel 21 (River Mile 141.8)	840609	2100	1	--[a]	--[a]	21100	N
	840610	2130	2	28	--[a]	21900	Y[b]
	840624	1140	152	--[a]	--[a]	30000	Y
	840709	2100	2	--[a]	--[a]	21400	N
	840710	2130	8	188	--[a]	21200	Y[b]
	840811	2000	15	--[a]	--[a]	22500	N
	840812	2000	2	--[a]	--[a]	19000	N
	840824	1215	66	--[a]	--[a]	22700	Y
Mainstem at Gold Creek (River Mile 136.6)	840531	0840	--[a]	--[a]	10[c]	12600	--[a]
	840627	1300	--[a]	--[a]	110[c]	28700	--[a]
	840725	1230	--[a]	--[a]	70[c]	22800	--[a]
	840823	1345	--[a]	--[a]	130[c]	17900	--[a]
	840928	1300	--[a]	--[a]	8[c]	7320	--[a]

[a] No data

[b] At point of breaching.

[c] U.S.G.S (1985) Provisional Water Resources Data, Alaska, Water Year 1984 (in press).