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JUVENILE SALMON SEASONAL ABUNDANCE AND HABITAT PREFERENCE IN SELECTED REACHES OF THE KENAI RIVER, ALASKA, 1987-1988[1]

By

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ABSTRACT

Juvenile fish were captured by beach seine in the Kenai River delta between July and October 1987. Eighteen species of fish were captured, indicating that the delta has a higher species diversity than other mainstem or tributary reaches within the drainage. Species diversity decreased with distance inland. Catch proportions of juvenile salmon were highest at sample locations in the upper delta, and declined throughout the sample period. Catch proportions of marine species were highest at sample locations in the lower delta, and increased throughout the sample period.

Juvenile salmon were captured by minnow trap in the lower Kenai River during July through September 1987, and in the middle and upper river using a substrate sampler between November 1987 and April 1988. Summer catch rates and winter densities of juvenile salmon were evaluated by macrohabitat type, cover category, substrate category, velocity interval, and depth interval to estimate seasonal habitat preferences within each area.

The presence of instream and riparian cover had the greatest influence on juvenile chinook salmon *Oncorhynchus tshawytscha* and sockeye salmon *Oncorhynchus nerka* summer catch rates. In the presence of cover, variability in juvenile salmon catch rates was not explained by the availability of macrohabitat, velocity, or substrate, while depth had a marginal influence on chinook salmon catches. However, in the absence of cover, significant interactions occurred between salmon catch rates and sample site velocity and substrate size. Under both conditions of cover, macrohabitat type had little effect on catch rates. Coho salmon *Oncorhynchus kisutch* had significantly higher catch rates at sites that lacked cover. The lack of significant interactions between catch rates and habitat conditions at sites with cover suggests that cover availability was the most important habitat feature in our study. It further suggests that suitable summer rearing habitat for juvenile salmon is widely available along the margins of the Kenai River and that the extremes of depth, velocity and substrate size encountered in our study were well within the limits of suitability for rearing salmon.

Chinook salmon winter densities were significantly related to cover and sampling period. Our study failed to show significant interactions between density and depth, velocity, or macrohabitat conditions. We were able to define limits of use for depth, velocity, and substrate conditions but could not demonstrate statistically significant preferences within each parameter. These data again suggest that juvenile chinook salmon exploit a wide range of readily available habitat conditions in the mainstem Kenai River.

While mainstem habitat conditions do not appear to be limiting in the Kenai River, abrupt declines in the density of chinook salmon occurred following our November sampling period. We hypothesize that the majority of sub-yearling chinook salmon depart the mainstem Kenai River during an overwintering migration to Skilak Lake.

KEY WORDS: Kenai River, juvenile fish, habitat preference, macrohabitat, overwintering behavior, cover, substrate, substrate sampler, beach seine, minnow trap, chinook salmon.

INTRODUCTION

The Kenai River (Figure 1), located in Southcentral Alaska on the Kenai Peninsula, has developed into one of the most intensively used river systems in Alaska. Abundant Pacific salmon (*Oncorhynchus* spp.) runs, road accessibility, and the proximity of the Kenai River to major population centers have contributed to a dramatic increase in private, recreational, and commercial developments within, and adjacent to the Kenai River. During 1986, anglers expended over 330,000 angler-days of effort in the Kenai River making this the largest freshwater fishery in Alaska (Mills 1987).

Private, recreational, and commercial developments adjacent to, and within, the Kenai River represent the greatest threat to the long-term productivity of the drainage. The Alaska Department of Fish and Game (ADF&G) is responsible for addressing public concern about the biological impacts to the river resulting from increased development, as well as establishing a policy for discharging its permitting authority covering a wide variety of activities within the drainage.

Along the mainstem Kenai River below Skilak Lake, approximately 66% of the adjacent river land is in private ownership, 15% is owned by the cities of Soldotna and Kenai or the Kenai Peninsula Borough, 15% is in State ownership, and 4% is in Federal ownership (Alaska Department of Natural Resources 1986). Developments adjacent to the river include businesses, permanent and seasonal residences, and recreational facilities; while instream developments include boat docks, launching facilities, canals, boat basins, groins, and several types of revetments. Road construction, draining and filling of wetlands, and the removal of instream debris and riparian vegetation have accompanied the development of the Kenai River. Public concern that uncontrolled development of the Kenai River will increase rates of erosion and degrade habitats required to support fish resources prompted the formation of the Kenai River Special Management Area (KRSMA) by the Alaska State Legislature in 1984. The KRSMA encompasses all State owned lands along the river and is managed by the Alaska Department of Natural Resources (ADNR). As a result of KRSMA legislation, the recommendations of a special advisory board, and a series of public meetings held throughout the region, the ADNR adopted the <u>Kenai River Comprehensive Management Plan</u> in 1986. The plan addresses development concerns of private land owners and public agencies, and identifies goals and objectives for future use of the river. Implementation of the plan is contingent upon the cooperative efforts of agencies, local government, and private landowners. A major impediment to the entire planning process for the Kenai River has been a lack of fundamental resource information.

To address this, and related informational needs, the ADF&G has entered into a multi-year cooperative effort with the U.S. Soil Conservation Service, the U.S. Fish and Wildlife Service, ADNR, the U.S. Corps of Engineers, the Kenai Peninsula Borough, and the U.S. Geological Survey. The primary focus of the ADF&G effort has been to obtain low-level, color infrared photography of the river corridor and to initiate sampling for baseline habitat and biological data necessary to formulate development policies for the Kenai River (Estes and Kuntz 1986; Litchfield and Flagg 1986; Bendock and Bingham 1987). Burger et al. (1983) described juvenile salmon distribution, catch rates, and habitat

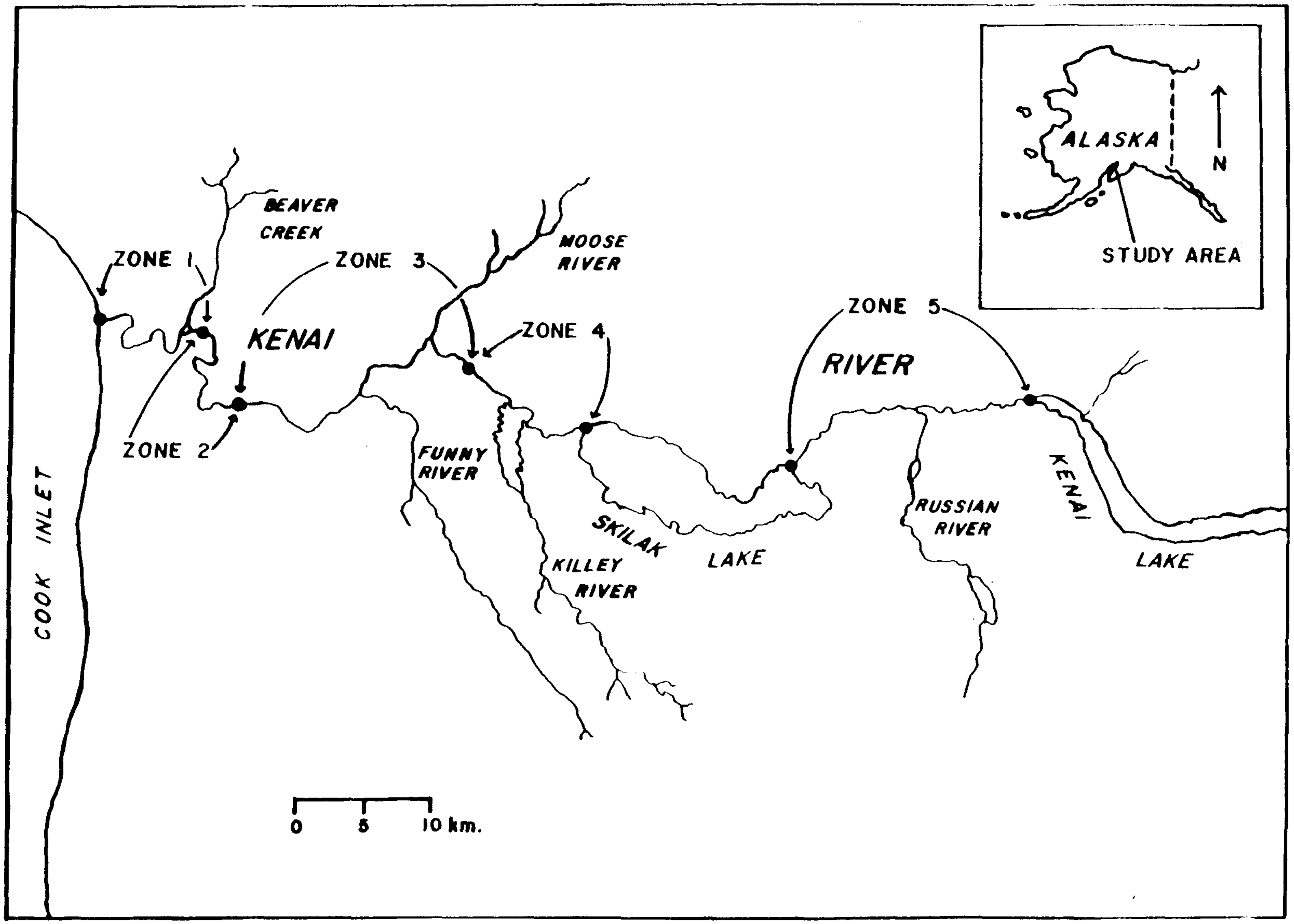

Figure 1. Map of the Kenai River showing five macrohabitat subdivisions between Cook Inlet and Kenai Lake.

utilization in the lower 45 miles of the Kenai River, while Elliott and Finn (1984) investigated juvenile fish use of several tributaries to the lower river.

The goal of this project is to obtain seasonal, baseline fisheries and habitat data for establishing a rationale and policy to address development activities within ADF&G jurisdiction in the Kenai River drainage. Bendock and Bingham (1987) evaluated the seasonal use of hand-held beach seines, baited minnow traps, and a modified substrate sampler for capturing juvenile salmonids in the Kenai River as well as methods of measuring habitat types and estimating cover, substrate, depth and velocity. Based on the findings of that investigation, this study attempts to describe the catch composition and distribution of juvenile fish in the Kenai River delta, evaluate juvenile salmon summer catch rates by macrohabitat type in the lower Kenai River and estimate the overwintering density of juvenile salmon by macrohabitat type and substrate composition in the middle and upper reaches of the Kenai River. Common names, scientific names, and abbreviations for species referenced in this report are shown in Appendix Table (1).

Specific objectives for the 1987 to 1988 field season were:

1. To estimate the proportional catch composition, general distribution, and diversity of juvenile fish in the Kenai River Delta during the 1 July through 30 September 1987 time period;

2. To classify and inventory the overall range of mainstem macrohabitats and to estimate the proportional composition of these macrohabitats between River Kilometers 18.5 and 35.4;

3. To estimate the proportions of selected cover and substrate categories occurring by macrohabitat type between River Kilometers 18.5 and 35.4;

4. To test the hypothesis that macrohabitat types and selected microhabitat variables affect juvenile salmon catch rates between River Kilometers 18.5 and 35.4 during the 1 July through 15 September 1987 time period;

5. To classify and inventory the overall range of mainstem macrohabitats and to estimate the proportional composition of these macrohabitats between River Kilometers 35.0 to 63.5 and 105.0 to 132.0 during the 1 November 1987 through 1 April 1988 time period;

6. To estimate the proportions of substrate categories occurring by macrohabitat type between River Kilometers 35.0 to 63.5 and 105.0 to 132.0; and

7. To test the hypothesis that macrohabitat types and selected microhabitat variables affect juvenile salmon overwintering densities between River Kilometers 35.0 to 63.5 and 105.0 to 132 during the November 1987 through April 1988 time period.

METHODS

This study includes three separate investigations in four river reaches during two time periods. Throughout this report, objective 1 will be referred to as the "Delta Study". Objectives 2 through 4 will be referred to as the "Summer Study" and objectives 5 through 7 will be referred to as the "Winter Study". All three studies were conducted independently, thus, the types and levels of analyses and procedures varied according to the objectives addressed.

Study Designs

Study designs varied with the different gear types that were deployed during separate phases of investigation. Specific procedures for obtaining habitat measurements associated with each gear are discussed under the appropriate headings.

Delta Study:

The proportional catch composition and general distribution of juvenile salmonid fish in the Kenai River delta (River Kilometers 0.0 to 18.5) was estimated using a systematic study design. The lower 18.5 river kilometers constitute a single, homogeneous macrohabitat reach of the Kenai River, thus, eight sample locations were systematically chosen between the upper and lower boundaries of the study reach (Figure 2). Each site was sampled on one day (usually Monday) each week during 6 July through 31 August, and 21 September through 5 October 1987 providing a total of 12 sampling occasions. Sampling was conducted using a 15 m x 1.8 m x 0.6 cm hand-held beach seine. A standard effort consisted of a single 30.5 m downstream haul that began and terminated along the shoreline. The width of each haul varied with the slope of the beach out to the 1.2 m depth contour which was the maximum fordable depth using chest-waders. A systematic grid procedure was used to determine locations for measuring depth, velocity, and substrate at each seine site. The length and width of each haul was stepped-off into thirds and a measurement was obtained at the eight grid intersections (Figure 3).

The following parameters were recorded at each seine haul site: date; site number; River Kilometer; effort; catch by species; macrohabitat type; cover; air temperature; water temperature; salinity; conductivity; turbidity; substrate type; depth; and velocity. All fish captured by beach seine were identified to species, counted and released at the sample site.

Summer Study:

Minnow traps measuring 48 x 20 x 0.6 cm and baited with brine-cured salmon roe were used to test the hypothesis that macrohabitat types and selected microhabitat variables affect juvenile salmon catch rates between River Kilometers 18.5 and 35.4. Sixteen sites were sampled during each of four sampling occasions: 28 to 31 July; 11 to 14 August; 25 to 28 August; and 8 to 11 September 1987, giving a total of 64 sample locations (Figure 4). Each sample site was a 61 m lineal reach of contiguous shoreline. Macrohabitat within the study reach was classified and inventoried (see macrohabitat

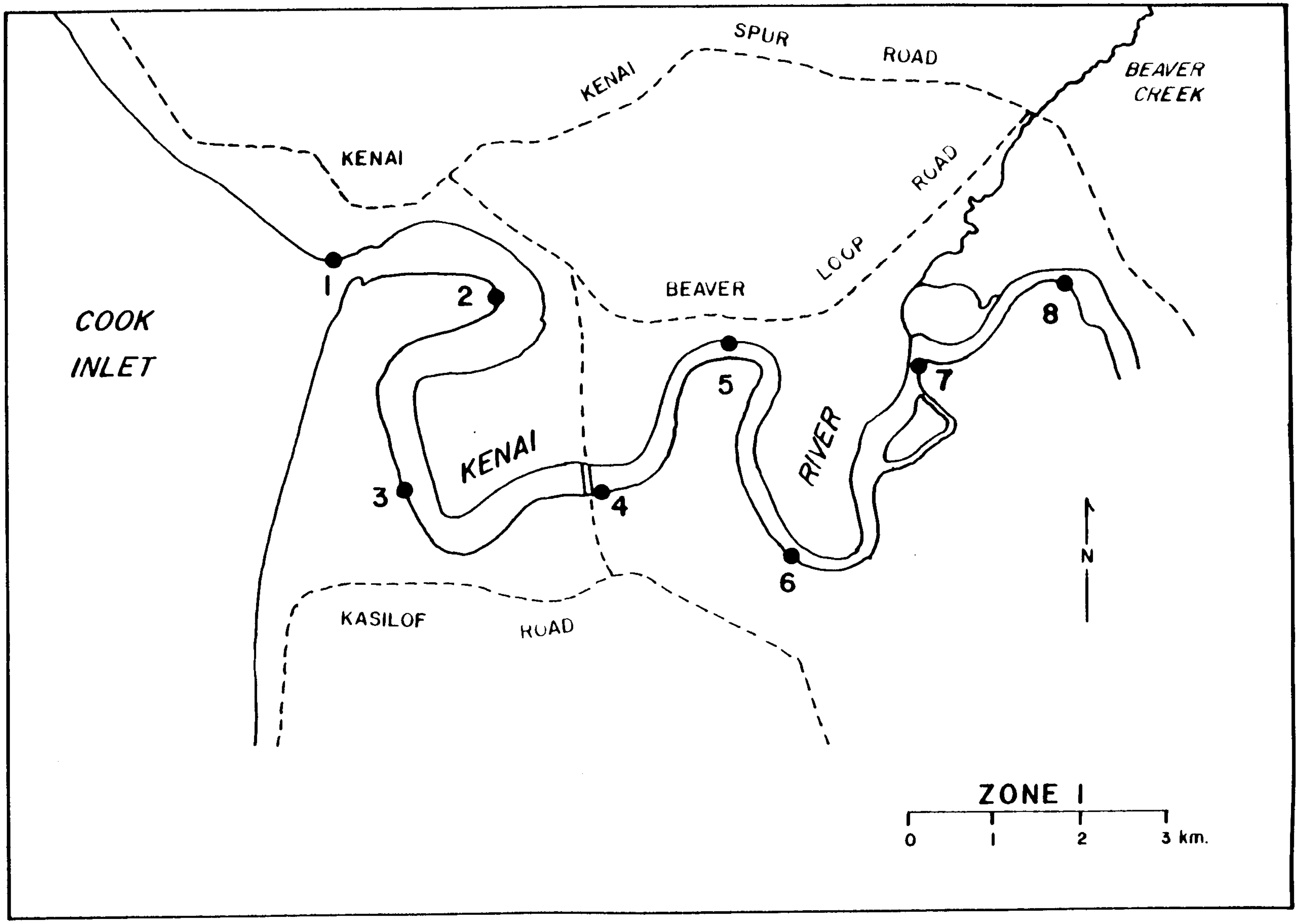

Figure 2. Map of the lower 18.5 kilometers of the Kenai River showing the locations of eight beach seine sample sites.

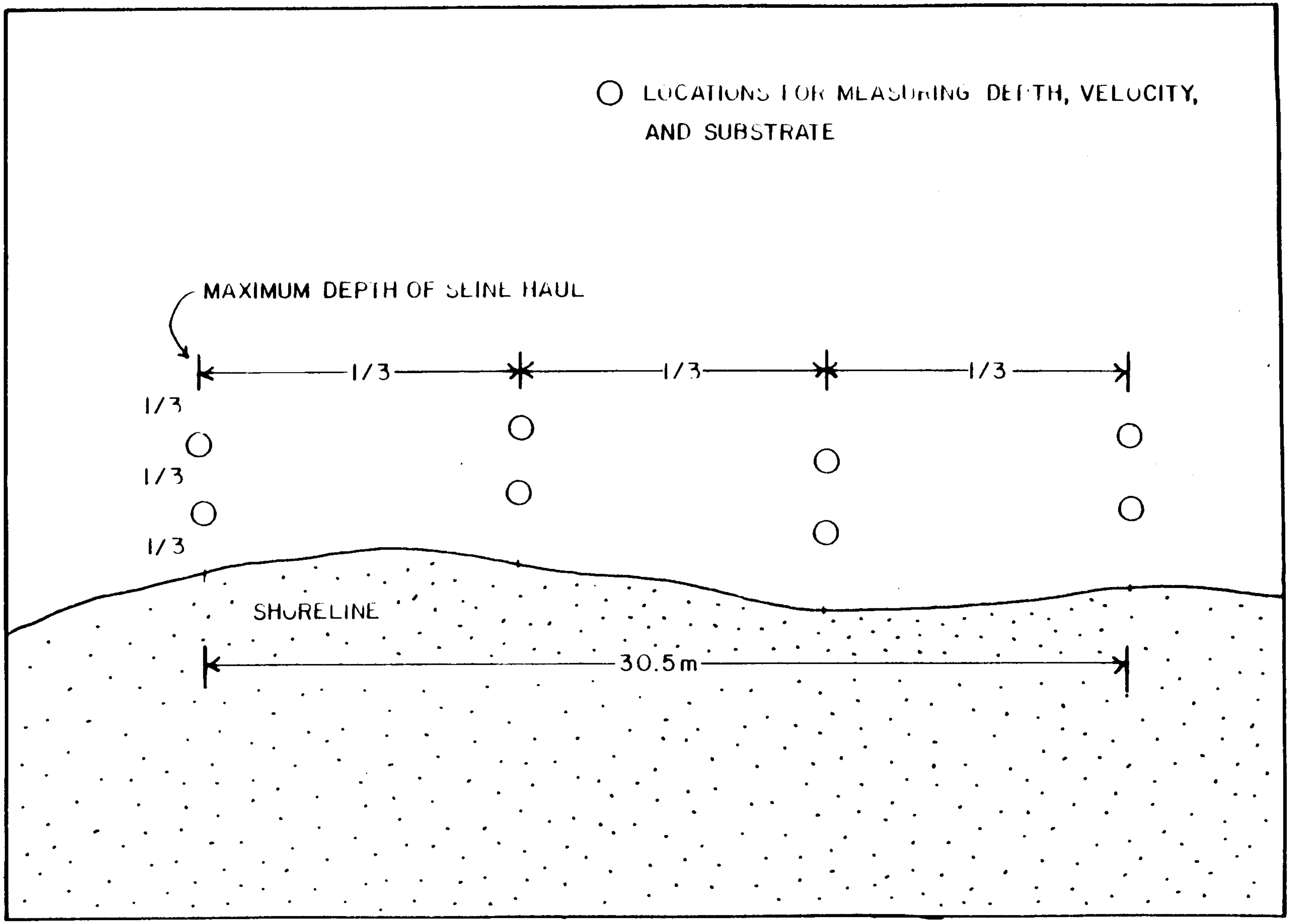

Figure 3. Schematic example of systematic procedure used to locate positions for measuring depth, velocity, and substrate conditions at beach seine sites in the Kenai River delta.

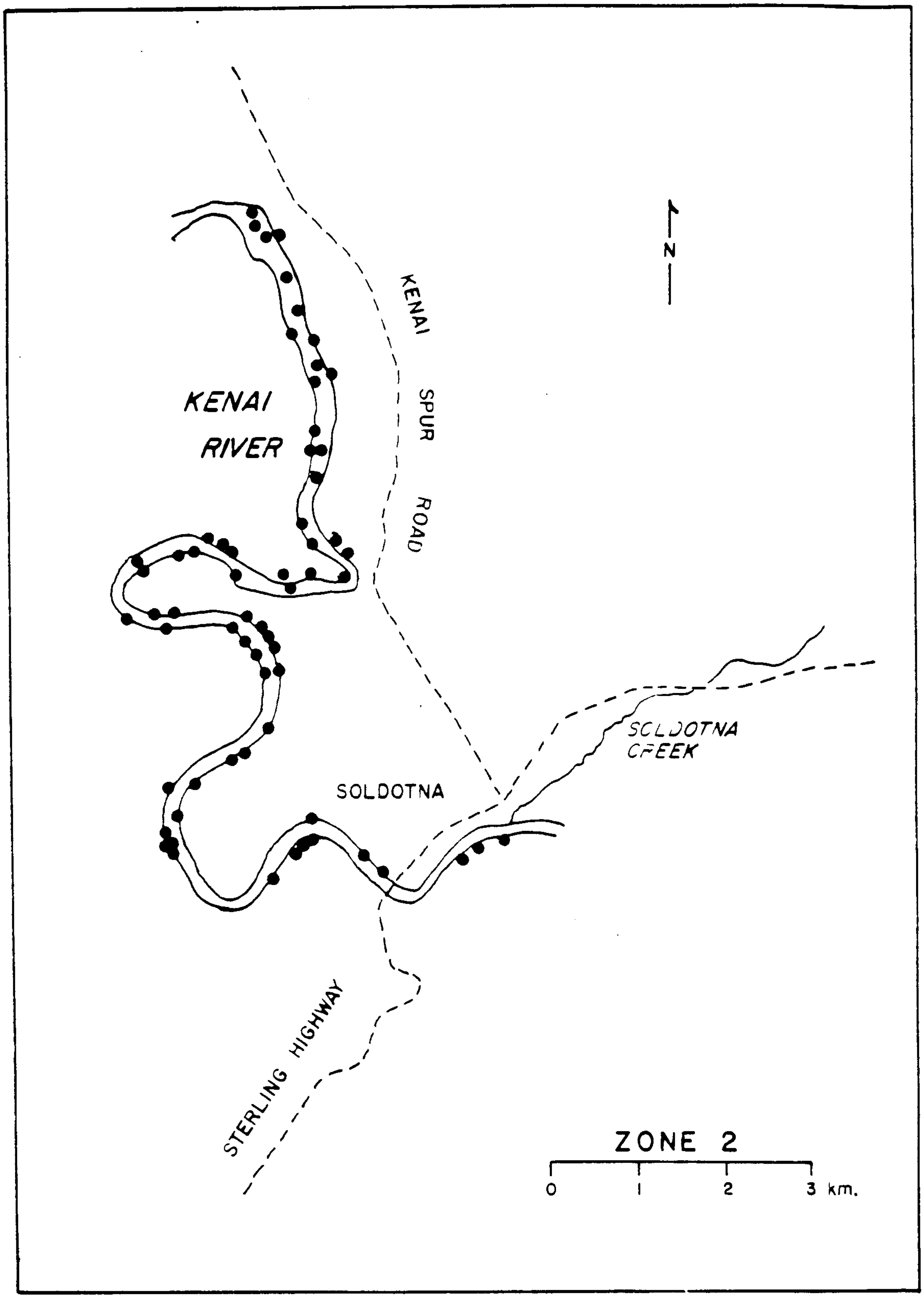

Figure 4. Map of the Kenai River showing the locations of sample sites between River Kilometers 18.5 and 35.4.

classification procedures below). Sample sites were selected randomly (without replacement) in proportion to macrohabitat availability. This approach represented a randomized complete block (unbalanced [i.e., cell sizes unequal]) sample design. The "blocks" are macrohabitats and sampling occasion (and macrohabitat within sampling occasion). Each 61 m sample site was selected following the above procedure and delineated on a 1 in to 400 ft scale map of the river which was then used to locate the sites in the field.

Twelve baited minnow traps were fished for 30 minutes at each site. When possible, traps were set adjacent to shore, at uniform intervals along the sample site reach. Since minnow traps attract fish from an undetermined area that is influenced by the bait, a random sampling procedure was used to determine locations for estimating substrate type, depth, and velocity, without regard to the specific locations of each trap. Eight stations were located along the 61 m shoreline by drawing eight numbers between 0 and 40 from a random numbers table (40 is used in this case because 40 steps using either the right or left foot is approximately 61 m). At each station, substrate type, depth, and velocity was estimated 2 ft and 4 ft from shore giving a total of 16 measurements of each parameter, at each site.

The following parameters were recorded at each minnow trap site: date; site number; river kilometer; effort; catch by species; macrohabitat type; air temperature; water temperature; salinity; conductivity; turbidity; cover type; substrate type; depth; and velocity. Catch and effort from all twelve traps at each site were combined. Fish caught by minnow trap were identified to species, counted, and released.

Winter Study:

A modified substrate sampler (Figure 5) was used to estimate the density of juvenile fish overwintering in the substrate of the Kenai River between River Kilometers 45.0 to 63.5 (zone 3) and 105.0 to 132.0 (zone 5). The substrate sampler consisted of a gasoline powered water pump that was used to agitate substrate confined under a $2m^2$ re-bar capture frame. Twenty-four sites were sampled in each zone during each of three sampling occasions: 7 to 19 November 1987 (period 1); 17 February to 22 March 1988 (period 2); and 31 March to 15 April 1988 (period 3) providing a total of 72 sample sites for each zone (Figures 6 and 7). Sample sites were 61 m lengths of contiguous shoreline and the substrate sampler was deployed at five stations within each site. Thus, 720 $2m^2$ sample stations (120/zone/period) were sampled throughout the winter study.

The random sampling procedures used in the summer study were also used to determine winter sample site locations and stations within each site. The following parameters were estimated at each winter site: date; site number; station number; river kilometer; macrohabitat type; air temperature; water temperature; conductivity; and turbidity. Substrate type, cover type, depth, and velocity were estimated at each sample station. Fish captured at each station were identified, counted, and released.

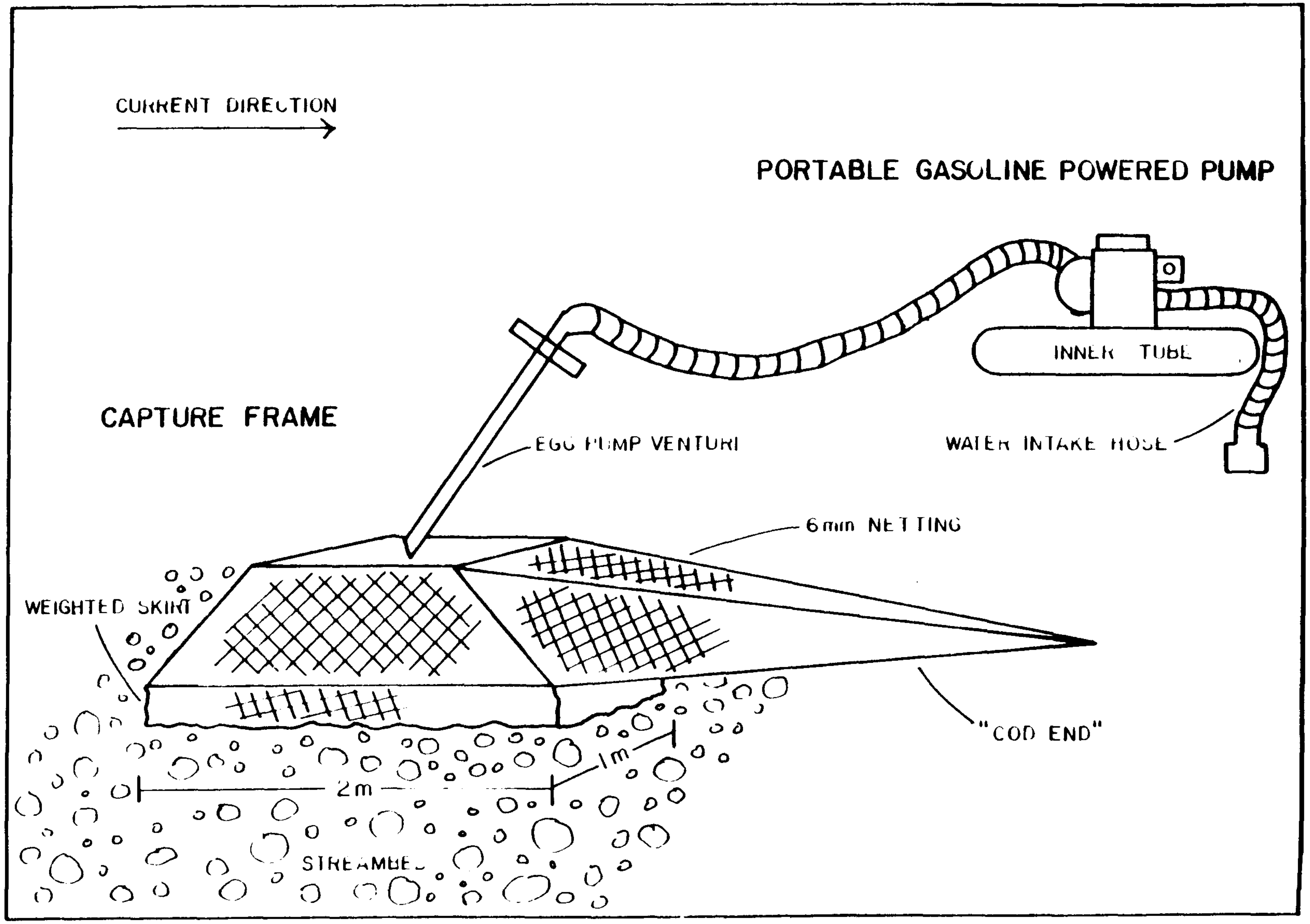

Figure 5. Substrate sampler apparatus used to capture juvenile fish overwintering within Kenai River substrates.

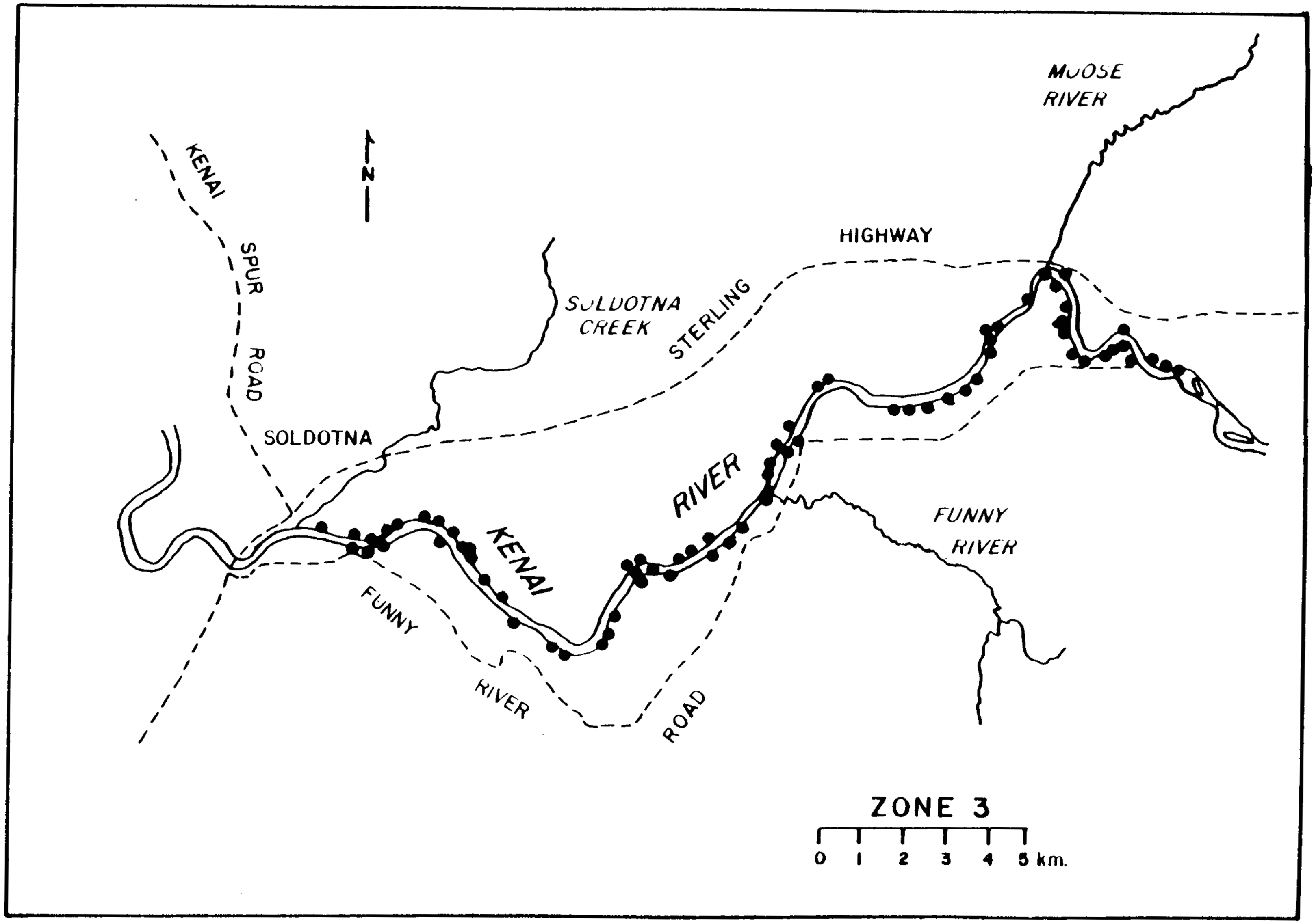

Figure 6. Map of the Kenai River showing the locations of winter sample sites between River Kilometers 45.0 and 63.5.

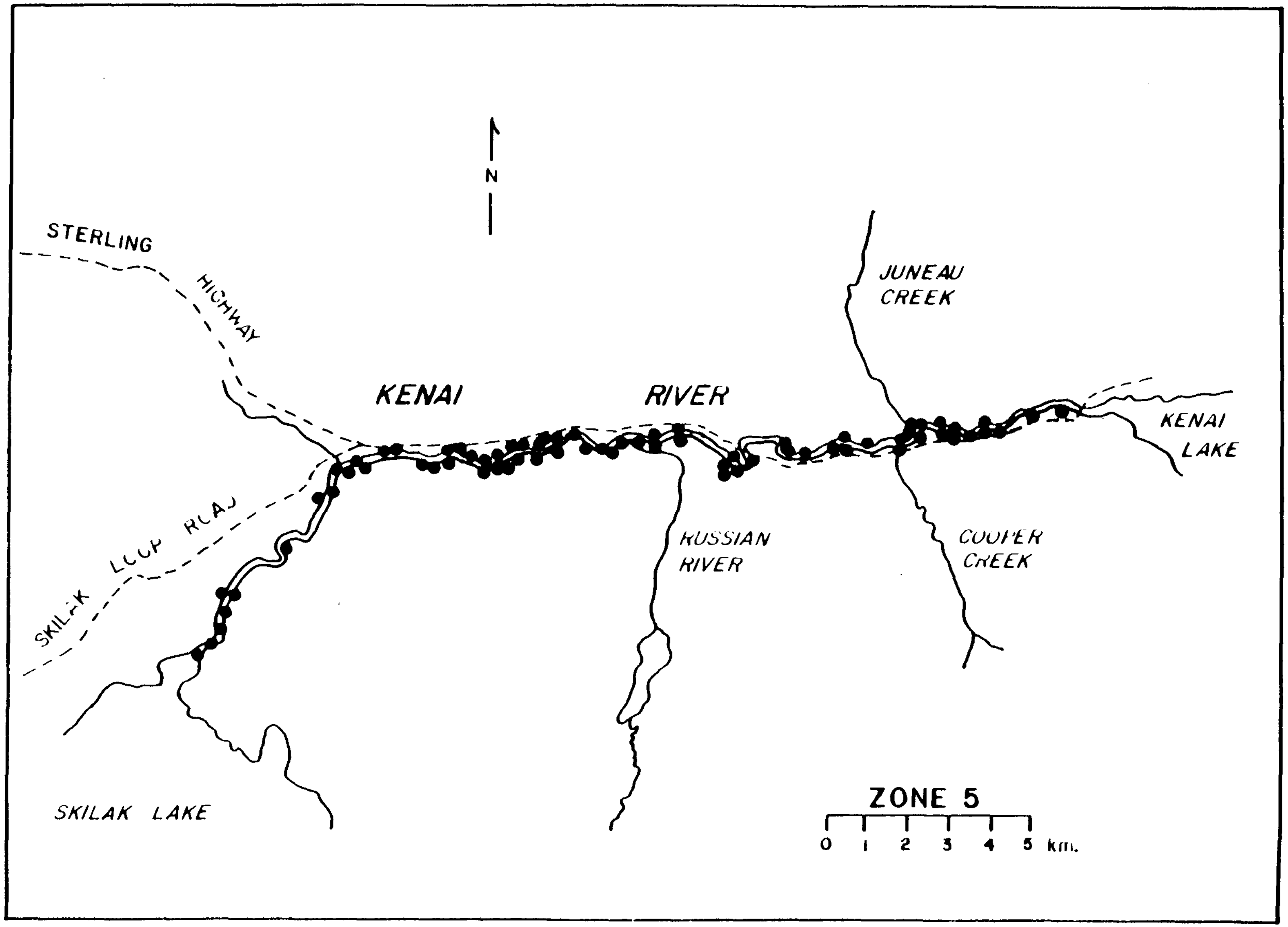

Figure 7. Map of the Kenai River showing the locations of winter sample sites between River Kilometers 105.0 and 132.0.

Macrohabitat Classification

A mainstem macrohabitat matrix (Appendix Table 2) was used to classify summer and winter sample site locations. The Kenai River was divided into five lineal reaches or zones based on physiographic and morphologic characteristics: 1) intertidal; 2) transition; 3) entrenched; 4) upper; and 5) interlake (Figure 1). Each zone was subdivided into four instream habitat categories: main channel; side channel; island; and tributary. Each habitat category was identified as being either modified by development that altered the hydraulic or morphologic characteristics of the natural stream bank, or unmodified. Figure 8 shows a schematic representation of the instream habitat categories. A three digit code identifying the macrohabitat reach, habitat category, and modification was assigned to each summer and winter sample site.

Macrohabitat Inventory

Maps of the study reaches were made using 1 in to 400 ft scale low level infrared aerial photographs of the Kenai River. High flow (July) photographs were used to map the summer study area, while low flow (April) photographs were used to map the winter study areas. The shoreline boundaries of each instream macrohabitat category were delineated on the maps. Habitat categories were then divided into 61 m increments, each numbered and representing a potential sample site. The number of 61 m increments, by category, was used to estimate the proportional composition of macrohabitats. Random number tables, developed for the sum of potential sites in each category, were used to select sample sites in proportion to macrohabitat availability.

Measurement Of Habitat Variables

The specific parameters estimated in various phases of the investigation are listed under study designs. Similar procedures were used to estimate habitat variables in all study phases.

Cover:

The cover at each site was visually characterized according to the following cover categories:

1. No object cover;

2. Emergent vegetation which consists of riparian grasses and small shrub vegetation that is normally inundated at medium to high flows;

3. Aquatic vegetation which consists of rooted submerged vegetation as well as mats of green and brown algae;

4. Deadfalls including spruce and deciduous trees which have fallen into the river, as well as root wads and stumps;

5. Overhanging riparian vegetation which typically consists of leaning spruce trees and shrub vegetation;

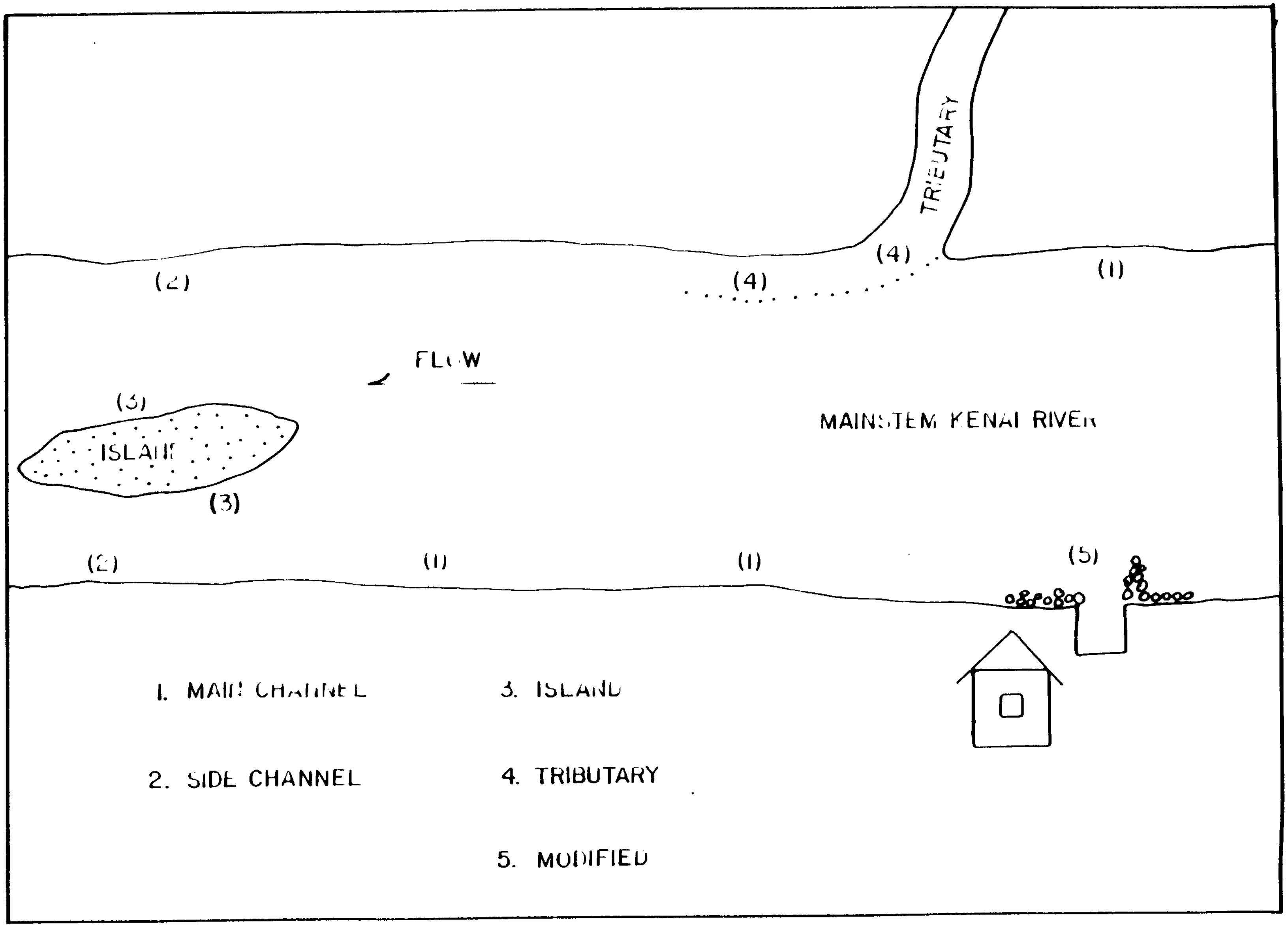

Figure 8. Schematic example of macrohabitat types used to classify mainstem Kenai River study locations.

6. Undercut banks which are typically vegetated banks that have undergone erosion resulting in a scalloped surface at the water's edge.

Cover at summer sample sites was visually estimated for the entire site and the estimated percent coverage for each type was recorded in order of predominance. At winter sample sites, a single cover type was visually estimated for each sample station.

Substrate:

The substrate at each sample station was visually classified based on the following size categories:

1. Silt/Sand - Grains less than 0.6 cm in diameter
2. Gravel - 0.6 cm to 7.6 cm
3. Rubble - 7.6 cm to 12.7 cm
4. Cobble - 12.7 cm to 25.4 cm
5. Boulder - Over 25.4 cm

The predominant substrate size category was recorded at each station.

Climatological and Hydrological Measurements:

Air temperature was measured at each site using a hand-held mercury thermometer and recorded in degrees Celsius. Measurements of water temperature, salinity, and conductivity were obtained using a Yellow Springs Instruments S.T.C. meter. A water sample was collected for turbidity at each sample site and stored in a clean nalgene bottle. Samples were later analyzed using a HF Instruments model DRT 100 turbidity meter. A Marsh McBirney model 201 portable water current meter was used to measure velocity at each station. A top setting rod was used to determine various depths of measurement and the water column depth at each station. In depths less than 0.76 m, the mean water column velocity was measured at a single point located 0.6 of the total depth from the surface. In depths of 0.76 m or greater, velocities at 0.2 and 0.8 of the total depth from the surface were measured and averaged to estimate mean water column velocity.

Data Analysis

Rudimentary data summaries, frequencies, and plots of catches by species and sampling location or occasion were produced by utilizing the database and reporting facilities of the REFLEX (Borland 1985) microcomputer program. Additional analyses were conducted using the Statistical Analysis System (SAS 1985a and b) program.

Observed frequencies of catch per unit effort in the substrate sampler program were used to estimate density (fish/m^2) since the apparatus sampled a fixed area ($2m^2$) during each effort. The underlying assumption is that the sampler exhumes and entraps all fish within each ($2m^2$) sample station. The estimation procedures are the same as for proportions (see below).

All statistical tests were conducted at the 90% (a = 0.10) significance level unless otherwise noted.

Proportion Estimates:

Observed frequencies of various categories in the sampling program were used to estimate proportions of each category. A simultaneous 90% confidence interval for multinomial proportions was calculated using the equation (Goodman 1965):

$$90\%\ CI = \hat{p}_i +/- [B(\hat{p}_i)(1-\hat{p}_i)/n]^{1/2} \qquad [1]$$

where:

$\hat{p}_i$ is the estimated substrate category proportion (n_i/n),

n_i is the number of samples in a particular substrate category,

n is the total number of samples,

B is a tabled chi-square statistic for $\alpha = 1-(0.10/k)$ and degrees of freedom = 1, and

k is the number of different substrate categories possible.

<u>Analysis Procedures for Comparison of Juvenile Salmon Catch versus Macrohabitat and Microhabitat Parameters for the Transition Zone Minnow Trapping</u>

Multivariate analyses of covariance (MANACOVA) were used for testing the hypothesis that cover, substrate, depth, and velocity affect the catches of the three species of juvenile salmon (chinook, coho, and sockeye). Standard MANACOVA procedures were followed to test the hypothesis (Morrison 1976). Prior to completing the MANACOVA, elementary exploratory data analysis (EDA) techniques were used to evaluate the sample data for agreement with the underlying assumptions of MANACOVA (Hoaglin et al. 1983, 1985). The initial steps of EDA indicated that the catch statistics for coho salmon and sockeye salmon needed to be transformed in order to stabilize the variances. Two standard transformations were evaluated. The $\log_e$ of the catches plus one transformation and the inverse hyperbolic sine (Arcsinh) transformation are often useful in stabilizing variances in instances of "contagion" (that is, when the animals come in groups or not at all [e.g., lots of zero catches]) (Zar 1974). The Arcsinh transformation performed successfully in reducing variance instability, and was selected for the MANACOVA. Chinook salmon catches were not transformed. All analyses were conducted utilizing the Statistical Analysis System (SAS 1985a, 1985b).

Given the limited total sample size (64 samples), we had to collapse the dimensionality of the macrohabitat and microhabitat variables as follows:

1. Macrohabitat codes (originally coded as 2.1.1, 2.2.1, etc.) were collapsed to either modified (i.e., 2.1.1 and 2.2.1) or unmodified (i.e., 2.1.2, 2.2.2, 2.3.2, 2.4.2).

2. Substrate readings (a total of 16 readings at each site coded 1 through 5 as noted above) were reduced to one value by utilizing the most frequently occurring value (i.e., the mode).

3. Cover type percentage coverage (originally the percentage areal coverage by each of the 6 types noted above) were categorized as the predominantly occurring cover as follows:

    a. If percentage coverage of cover type 1 (i.e., no object cover) was greater than or equal to 50% then the site was classified as predominantly having no object cover.

    b. Otherwise we compared the maximum percentage coverage of cover types 2 (emergent vegetation), 3 (aquatic vegetation), and 4 (deadfalls) with the maximum percentage coverage of cover types 5 (overhanging riparian vegetation) and 6 (undercut banks). If the maximal percentage coverage of types 2-4 was greater than the maximal percentage coverage for types 5-6 then the site was classified as predominantly having instream cover.

    c. Otherwise we classified the site as having riparian cover.

4. Depth readings (a total of 16 readings at each site in feet as noted above) were reduced to one value by taking the mean of the 16 readings.

5. Velocity readings (a total of 16 readings at each site in cm/s as noted above) were reduced to one value by taking the mean of the 16 readings.

RESULTS

Delta Study

The lower 18.5 km of the Kenai River (zone 1) are a single, homogeneous macrohabitat reach characterized by tidal fluctuations in water level, current velocity, and salinity. It has a single, meandering channel, low relative surface slope, and extensive floodplain. The predominate substrates are silt and sand. Shoreline developments include: commercial fish processing plants and canneries; commercial and municipal boat docking facilities; and private residences. Drift gill net boats, participating in Cook Inlet commercial fisheries moor in the lower Kenai River during July and August. Most commercial activity is restricted to the lower 6.5 km of the river.

Beach seining was conducted at eight locations during 12 occasions between 5 July and 5 October 1987 in the Kenai River delta.

Habitat Conditions:

All sample sites occurred in macrohabitat type 112 (zone 1, main channel, unmodified) and cover category 1. Water temperature was lowest (mean = 6.5 ^{o}C) during the 5 October sampling period and highest (mean = 14.8^{o}C) during the 24 August sampling period. Sample site salinity, conductivity, and turbidity decreased with distance upstream from Cook Inlet. Mean values and standard errors for selected habitat conditions by sample location are shown in Table 1.

Beach Seine Catch Composition And Proportions:

A total of 7,140 fish was captured in 96 beach seine hauls conducted in the Kenai River delta. The catch included 5 Families and 18 species of fresh-water, marine, or anadromous fish. Species in the Family *Salmonidae* accounted for 89% of the entire catch, while a single species, chinook salmon, accounted for 68% of the total catch. Figure 9 shows the species composition of combined (location and occasion) beach seine catches from the Kenai River delta. Slender eelblenny *Lumpenus fabricii* were previously unreported from the Kenai River.

Beach seine catch proportions were analyzed for significant differences by location and occasion. Due to small sample sizes associated with the catch of many species, analyses were conducted comparing catch proportions of the following species and categories of species: chinook salmon; coho salmon; sockeye salmon; other salmonids; and other species. Results indicated that among sample locations, between species, chinook salmon accounted for the largest catch proportions at sites 3, 5, 6, 7, and 8; while other species represented the largest proportions at sites 1 and 2. Sockeye salmon accounted for the largest catch proportion at site 4. Catch proportions of juvenile salmon and other salmonids tended to increase with distance above the river mouth, while catch proportions of other species declined. Among species, the highest proportion of chinook salmon was observed at site 7; coho salmon, site 1; sockeye salmon, site 4; other salmonids, site 8; and other species, site 2. Figure 10 shows the 90% confidence interval (CI) limits for proportions of species or categories captured by sample site location.

Among sample occasions between species, chinook salmon were caught in the highest proportions during the first 7 periods (5 July through 17 August). Other species accounted for the highest catch proportions during periods 9 through 12 (31 August through 5 October) and sockeye salmon represented the highest catch proportion during period 8 (24 August). Within species by occasion, the highest proportion of chinook salmon was caught during period 6; coho salmon, period 10; sockeye salmon, period 8; other salmonids, period 12; and other species, period 12. The catch proportions of juvenile chinook and sockeye salmon declined throughout the study period, while proportions of coho salmon and other species increased. Catch proportions of other salmonids were

Table 1. Mean values and standard errors for habitat conditions measured at eight Kenai River delta beach seine sample sites on 12 sampling occasions, 1987.

Site no.	Water Temperature (°C)		Salinity (0/00)		Conductivity (micro mho/cm)		Turbidity (ntu)		Depth (ft)		Velocity (cm/sec)	
	mean	SE	mean	SE	mean	SE	mean	SE	mean	SE	mean	SE
1	11.7	0.7	3.0	1.0	3845	1108.5	88	27.6	1.5	0.07	12.4	2.2
2	11.4	0.7	4.6	2.0	5590	2317.2	102	14.6	1.6	0.04	26.7	5.2
3	11.3	0.8	0.1	0.1	210	78.9	55	10.7	1.7	0.06	19.3	3.5
4	10.8	0.8	0	0	66	6.5	32	7.4	1.7	0.08	11.9	3.2
5	10.9	0.8	0	0	47	1.3	23	4.7	1.7	0.05	19.8	2.2
6	10.6	0.8	0	0	43	1.5	13	2.1	1.8	0.03	20.2	3.5
7	10.4	0.7	0	0	47	4.2	10	1.1	1.6	0.03	29.4	4.6
8	10.8	0.7	0	0	42	1.3	9	1.1	1.5	0.09	55.4	5.1
ALL	11.0	0.8	1.0	1.0	1236	1138.4	42	15.9	1.6	0.06	24.4	5.5

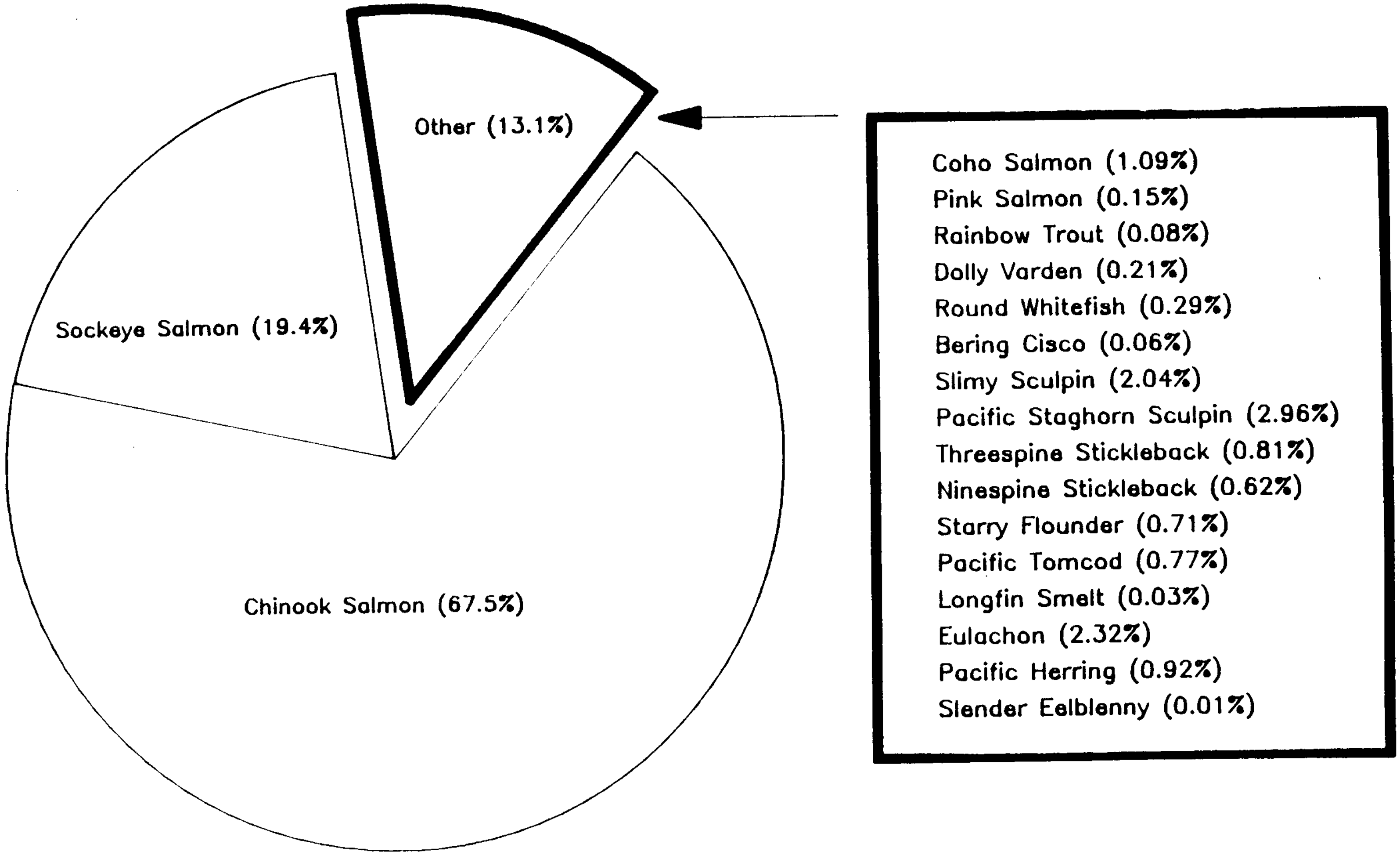

Figure 9. Percent catch composition of 96 beach seine hauls taken in the Kenai River delta, 1987.

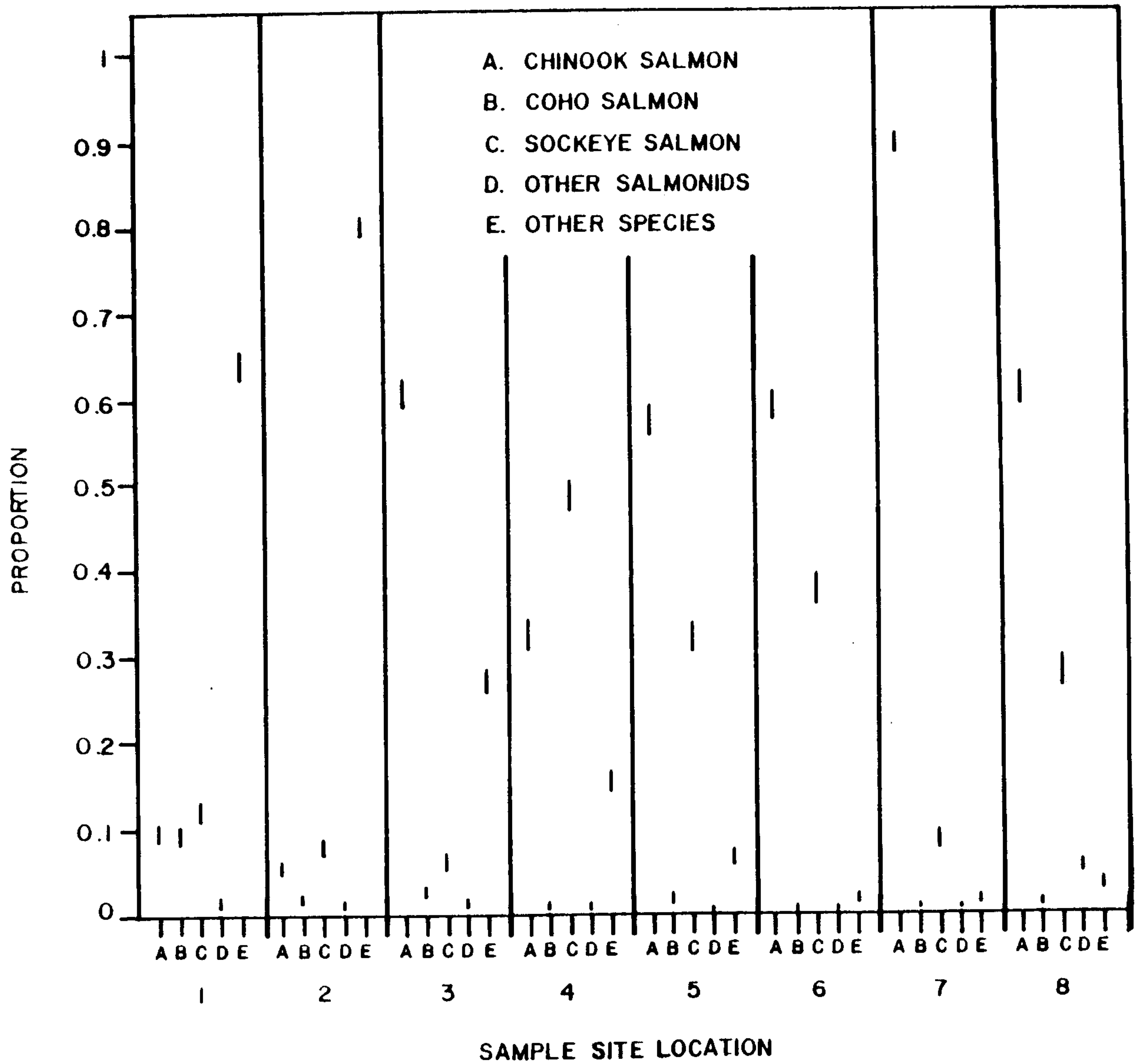

Figure 10. Ninety percent confidence interval limits for species proportions by sample site location in the Kenai River delta, 1987.

relatively low throughout the period of investigation. Figure 11 shows the 90% CI limits for proportions of species or categories captured by sampling occasion.

Summer Study

Sampling with baited minnow traps was conducted at 64 sites between River Miles 11.5 and 22 during the 28 July through 11 September 1987 time period. Macrohabitats within the study reach were inventoried and classified, and minnow trap catch rates were analyzed by macrohabitat types and microhabitat conditions.

Habitat Classification and Inventory:

Linear proportions of macrohabitat categories, and sample site distribution in zone 2 of the mainstem Kenai River during high flow (summer) conditions are shown in Table 2. Unmodified main channel habitat occurred in the highest proportion (42%), while unmodified tributary habitat occurred in the lowest proportion (3.3%). There were no modified tributary or modified island habitats within the study reach. Sample site locations were chosen in proportion to macrohabitat availability.

Seventy-six percent of all sample sites were associated with one or more of the six cover categories, while 24% of the sites had no object cover. Undercut banks occurred at a frequency of 37% followed by: emergent vegetation, 31%; no cover, 13%; overhanging riparian vegetation, 11%; deadfalls, 6%; and aquatic vegetation, 2%. The frequencies of cover categories occurring by macrohabitat type are shown in Figure 12. The most diverse combination of cover types occurred in side channel and island habitats. Tributary sites had the least diverse cover.

Substrate composition at all sites within zone 2 was predominantly gravel (51%) and silt/sand (40%). The frequencies of rubble and boulder categories were 9% and 0.1% respectively. There were no observations of cobble category substrate. The frequencies of estimated substrate coverage by macrohabitat types are shown in Figure 13.

Water temperature ranged from 8 ^{o}C to 15 ^{o}C (mean = 11.6 ^{o}C) among all sample locations and occasions. Turbidity ranged from 6 ntu to 16 ntu and averaged 9.0 ntu, while conductivity ranged from 40 micro mho/cm to 320 micro mho/cm and averaged 75.2 micro mho/cm. Sample station depths ranged from 0.3 ft to 5.2 ft and averaged 1.5 ft. Velocity ranged from 0 to 123 cm/sec and averaged 18.1 cm/sec. At all sample stations, velocity increased with distance from shore. Mean velocity estimated at stations 4 ft from shore was 74% higher (mean = 23.0 cm/sec) than measurements estimated at stations 2 ft from shore (mean = 13.2 cm/sec). Estimated mean velocities, depths, conductivities, and turbidities for all sample stations by macrohabitat type are shown in Figure 14.

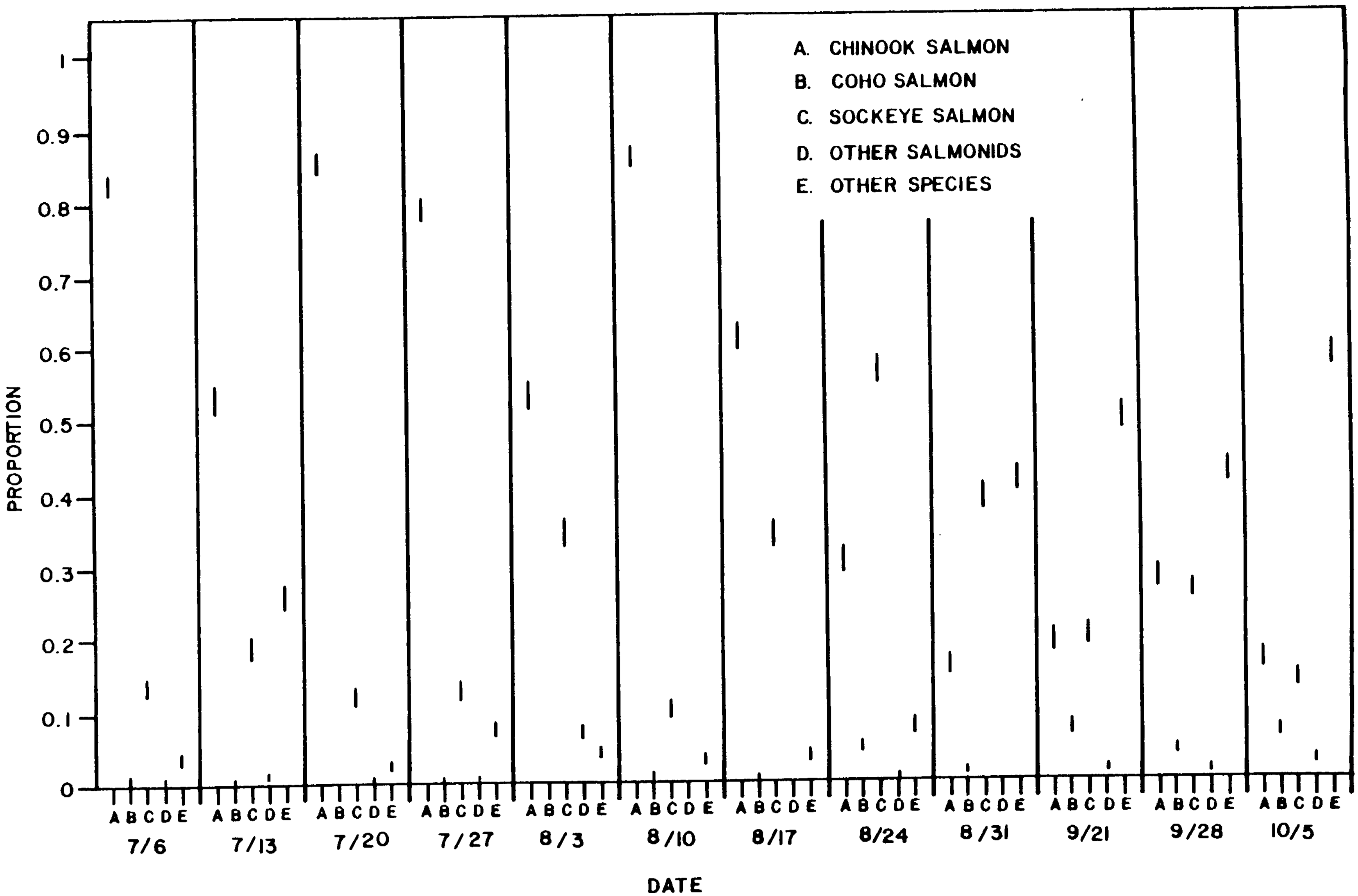

Figure 11. Ninety percent confidence interval limits for species proportions by sampling occasion in the Kenai River delta, 1987.

Table 2. Linear proportions of macrohabitat categories and sample site distribution in zone 2 of the mainstem Kenai River during high flow (summer) conditions, 1987.

Habitat Matrix Categories	Number of 200' Sample Site Increments	Proportion	90% CI Limits Lower	90% CI Limits Upper	No. of Sites Sampled
2. Transition Zone (18.5 to 35.0 km)	704	1.0			64
1. Main Channel					
1. Modified	33	0.0468	0.0270	0.0668	8
2. Unmodified	297	0.4218	0.3754	0.4684	20
2. Side Channel					
1. Modified	24	0.0341	0.0171	0.0512	8
2. Unmodified	148	0.2102	0.1719	0.2486	12
3. Island					
1. Modified	0	0	0.0	0.0	0
2. Unmodified	200	0.2841	0.2416	0.3265	12
4. Tributary					
1. Modified	0	0	0.0	0.0	0
2. Unmodified	2	0.0028	0.0	0.0079	4

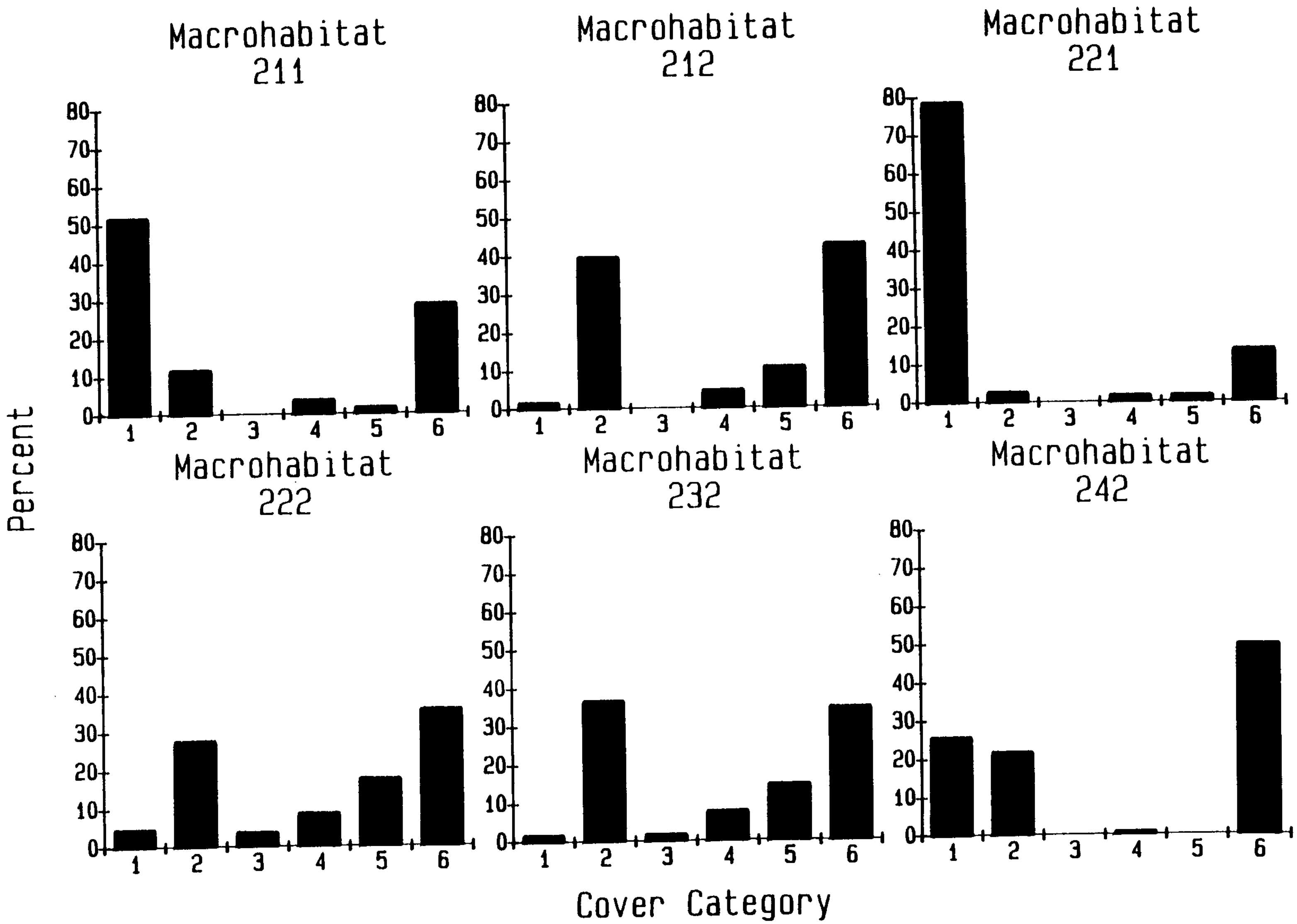

Figure 12. Frequencies of cover categories estimated by macrohabitat type in zone 2 of the mainstem Kenai River, 1987.

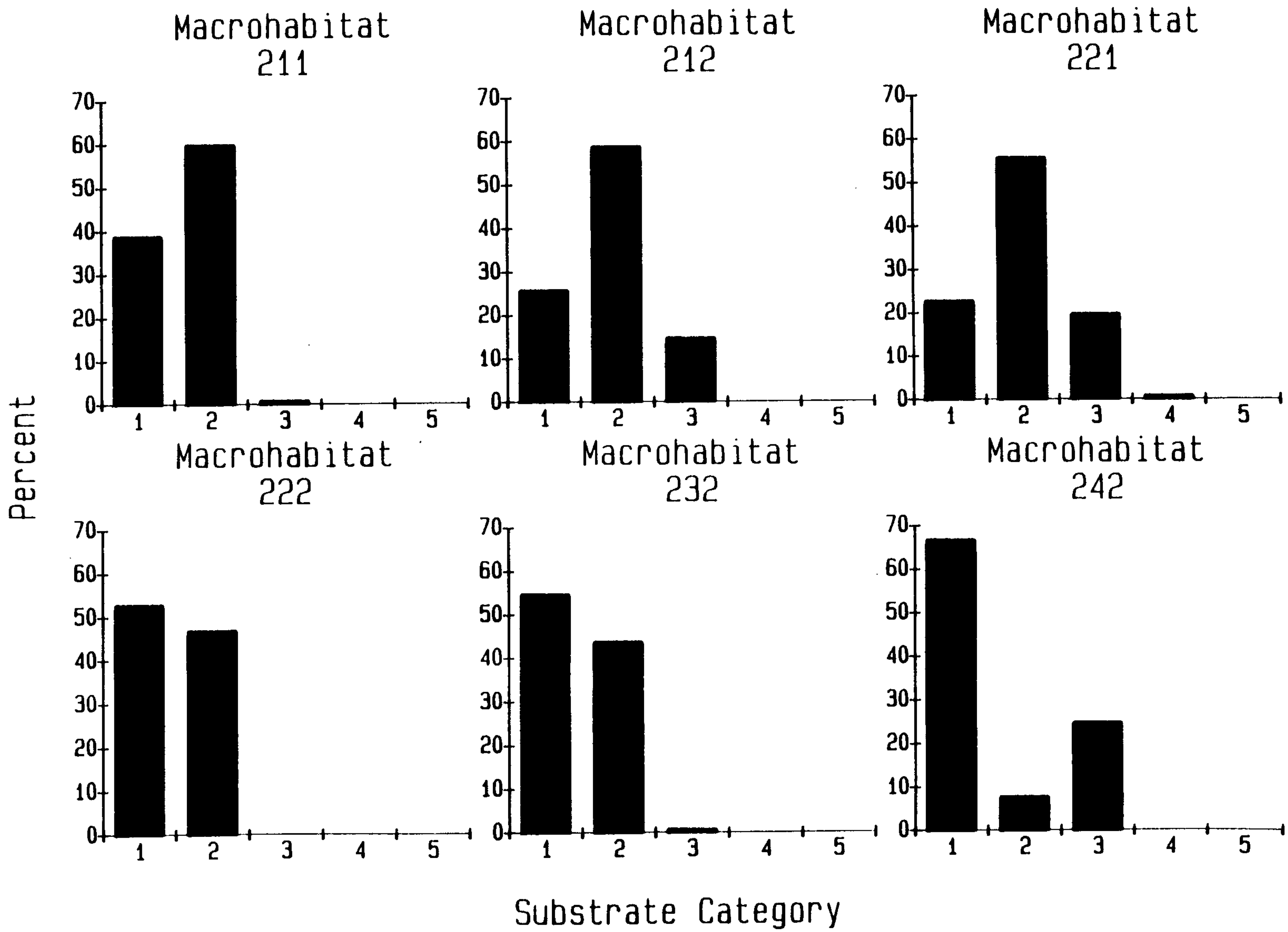

Figure 13. Frequencies of estimated substrate sizes by macrohabitat type in zone 2 of the mainstem Kenai River, 1987.

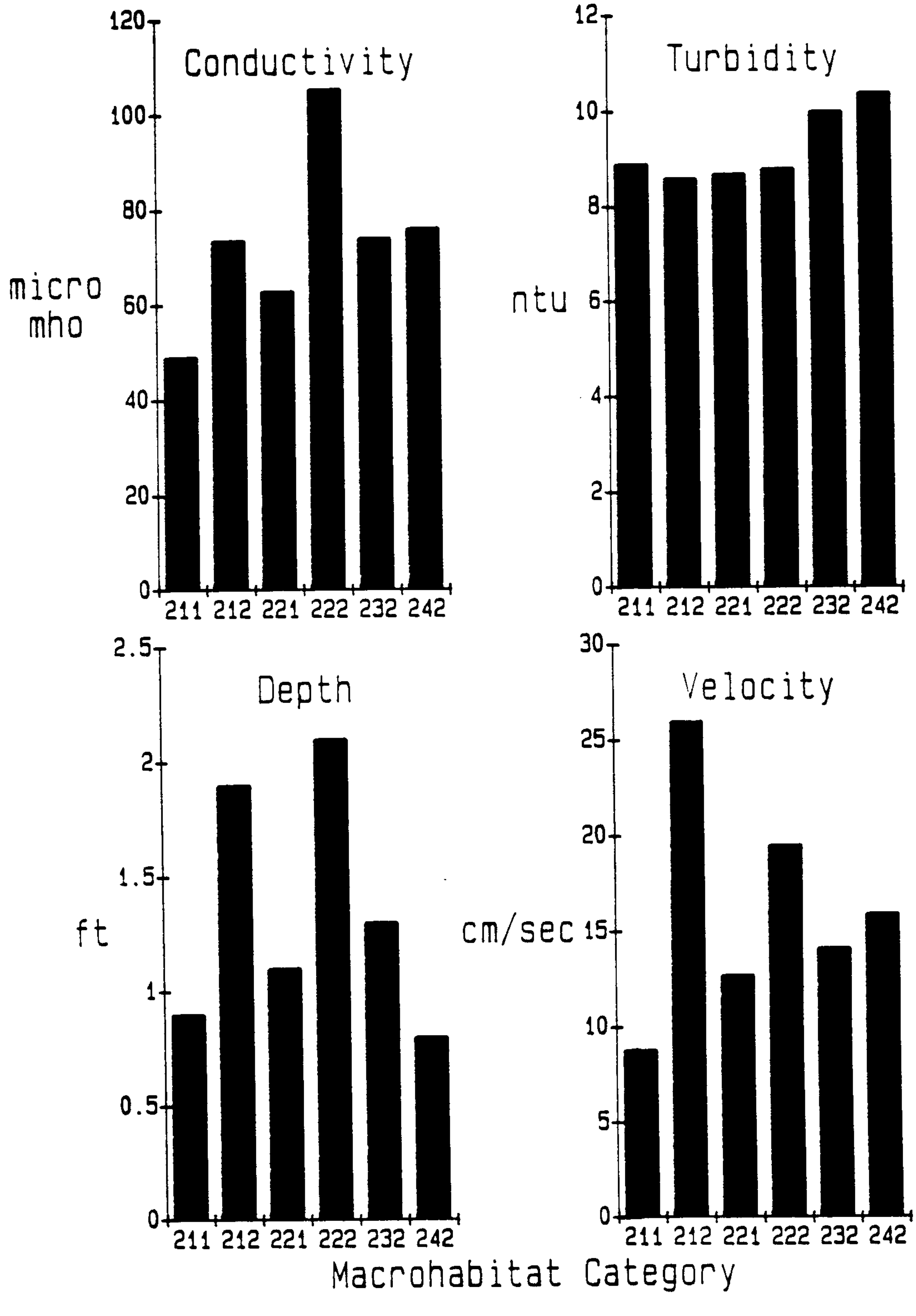

Figure 14. Estimated mean conductivity, turbidity, depth, and velocity values by macrohabitat type in zone 2 of the mainstem Kenai River, 1987.

Minnow Trap Catch Composition:

A total of 19,103 fish was captured in 22,800 trap-minutes of effort within the study reach. Seven species of fish were captured, and juvenile chinook salmon accounted for 88% of the total catch. The numbers, percent composition, and catch rates (fish/trap-minute) are shown in Table 3. Due to the low numbers of some species captured by minnow trap, further analyses only concerned the catch of chinook, coho, and sockeye salmon.

<u>Effects of Habitat Conditions on Summer Study Juvenile Salmon Catches</u>

Multivariate analyses of covariance of the minnow catch of juvenile chinook and the transformed (Arcsinh) minnow trap catches of juvenile coho and sockeye salmon as affected by macrohabitat type, cover, substrate, depth, and velocity were conducted. The general analyses (i.e., all species as dependent upon all explanatory parameters) indicated that a significant interaction effect (at a = 0.05) between cover type and substrate type and between cover type and mean velocity existed. Accordingly, analyses were carried out for each cover type separately. A total of 14 sites was categorized as having no object cover (Table 4). A total of 2,717 juvenile chinook salmon, 887 juvenile coho salmon, and 235 juvenile sockeye salmon were caught in these sites. The no object cover, juvenile salmon minnow trap catches and transformed catches were negatively and significantly (q = 0.0005) related to the level of velocity sampled. Juvenile coho and sockeye salmon transformed catches were most affected by velocity levels (with slopes = -0.2132 and -0.1776, q = 0.0007 and 0.0009, for coho and sockeye salmon, respectively). Juvenile chinook salmon transformed catches were moderately affected by velocity levels (with slope = -8.910, q = 0.0521). Substrate category significantly affected juvenile salmon catches (q = 0.0814), with the predominant effect associated with chinook salmon catches (q = 0.0355). Mean chinook catches were significantly greater in sites with predominantly gravel or rubble substrates versus sites with silt-sand substrates. The resultant univariate models (by species) with substrate type and mean velocity as explanatory variables had the following multiple correlation coefficients (R^2): chinook salmon catch R^2 = 0.5549, transformed coho salmon catch R^2 = 0.7041, and transformed sockeye salmon catch R^2 = 0.7371). Neither macrohabitat type or depth were significantly related to juvenile salmon minnow trap catches in the no cover sites.

A total of 30 sites was categorized as having predominantly instream cover (Table 4). A total of 7,888 juvenile chinook salmon, 504 juvenile coho salmon, and 75 juvenile sockeye salmon were caught in these sites. The instream cover, juvenile salmon minnow trap catches and transformed catches were apparently not related to macrohabitat type (modified or unmodified), substrate type, mean depth, or mean velocity.

Twenty sites were categorized as having predominantly riparian cover (Table 4). A total of 6,133 juvenile chinook salmon, 140 juvenile coho salmon, and 88 juvenile sockeye salmon were caught in these sites. The overall MANACOVA model was split into two separate models: one MANACOVA for chinook and coho salmon; and one ANACOVA for sockeye salmon. The overall model was split due to numerous significant (at a = 0.10) two-way interaction terms, and due to the apparent difference in response to habitat parameters

Table 3. Numbers, catch rates, and percent composition of species captured by minnow trap in zone 2 of the mainstem Kenai River, 1987.

Species	n	CPUE (fish/min.)	Percent Composition
Chinook Salmon	16,738	0.734	87.6
Sockeye Salmon	398	0.017	2.1
Coho Salmon	1,531	0.067	8.0
Rainbow Trout	26	0.001	0.1
Dolly Varden	33	0.001	0.2
Slimy Sculpin	42	0.002	0.2
Threespine Stickleback	335	0.015	1.8
ALL	19,103	0.838	100

Table 4. Minnow trap depth, velocity, and catch statistics of juvenile chinook, coho, and sockeye salmon by collapsed macrohabitat, and collapsed substrate categories for samples from the Kenai River Summer Study, 28 July to 11 September 1987.

Cover Category	Substrate Category	Number of Sites	Depth (ft) Mean	Depth (ft) S.E.	Velocity (cm/s) Mean	Velocity (cm/s) S.E.	Chinook Salmon Catch	Chinook Salmon Mean	Chinook Salmon S.E.	Coho Salmon Catch	Coho Salmon Arcsinh(Catch) Mean	Coho Salmon Arcsinh(Catch) S.E.	Sockeye Salmon Catch	Sockeye Salmon Arcsinh(Catch) Mean	Sockeye Salmon Arcsinh(Catch) S.E.
<u>MODIFIED MACROHABITATS</u>															
NO OBJECT	SILT-SAND	3	0.8	0.0	4.5	4.5	433	144.3	36.5	480	5.0	0.9	203	3.8	1.2
	GRAVEL	7	1.0	0.1	13.1	2.2	1,871	267.3	60.7	375	3.2	0.8	22	1.4	0.4
	RUBBLE	1	1.0	---	21.0	---	244	244.0	---	24	3.9	---	0	0.0	---
	SUBTOTAL	11	0.9	0.1	11.5	2.3	2,548	231.6	42.1	879	3.8	0.6	225	1.9	0.5
INSTREAM	SUBTOTAL	0	---	---	---	---	---	---	---	---	---	---	---	---	---
RIPARIAN	SILT-SAND	1	1.6	---	4.6	---	207	207.0	---	6	2.5	---	0	0.0	---
	GRAVEL	4	1.0	0.2	10.3	3.2	1,487	371.8	67.2	77	2.9	0.7	58	2.7	0.6
	RUBBLE	0	---	---	---	---	---	---	---	---	---	---	---	---	---
	SUBTOTAL	5	1.1	0.2	9.1	2.7	1,694	338.8	61.6	83	2.8	0.6	58	2.2	0.7
ALL COVER TYPES	SILT-SAND	4	1.0	0.2	4.5	3.2	640	160.0	30.2	486	4.4	0.9	203	2.9	1.3
	GRAVEL	11	1.0	0.1	12.1	1.8	3,358	305.3	46.4	452	3.1	0.5	80	1.9	0.4
	RUBBLE	1	1.0	---	21.0	---	244	244.0	---	24	3.9	---	0	0.0	---
TOTAL		16	1.0	0.1	10.8	1.8	4,242	265.1	35.9	962	3.5	0.4	283	2.0	0.4

-Continued-

Table 4. Minnow trap depth, velocity, and catch statistics of juvenile chinook, coho, and sockeye salmon by collapsed macrohabitat, and collapsed substrate categories for samples from the Kenai River Summer Study, 28 July to 11 September 1987 (Continued).

Cover Category	Substrate Category	Number of Sites	Depth (ft) Mean	Depth (ft) S.E.	Velocity (cm/s) Mean	Velocity (cm/s) S.E.	Chinook Salmon Catch	Chinook Salmon Mean	Chinook Salmon S.E.	Coho Salmon Catch	Coho Salmon Arcsinh(Catch) Mean	Coho Salmon Arcsinh(Catch) S.E.	Sockeye Salmon Catch	Sockeye Salmon Arcsinh(Catch) Mean	Sockeye Salmon Arcsinh(Catch) S.E.
<u>UNMODIFIED MACROHABITATS</u>															
NO OBJECT	SILT-SAND	3	0.7	0.1	19.0	4.3	169	56.3	33.7	8	1.6	0.4	10	1.0	1.0
	GRAVEL	0	---	---	---	---	---	---	---	---	---	---	---	---	---
	RUBBLE	0	---	---	---	---	---	---	---	---	---	---	---	---	---
	SUBTOTAL	3	0.7	0.1	19.0	4.3	169	56.3	33.7	8	1.6	0.4	10	1.0	1.0
INSTREAM	SILT-SAND	13	1.9	0.3	12.4	1.5	3,026	232.8	40.1	283	2.8	0.5	35	1.4	0.3
	GRAVEL	14	1.7	0.2	27.7	2.5	4,141	295.8	55.7	149	2.0	0.4	27	1.1	0.3
	RUBBLE	3	1.5	0.7	41.5	26.1	721	240.3	35.9	72	1.9	1.5	13	1.7	0.9
	SUBTOTAL	30	1.8	0.2	22.5	3.1	7,888	262.9	31.3	504	2.3	0.3	75	1.3	0.2
RIPARIAN	SILT-SAND	7	1.4	0.3	9.7	2.5	1,927	275.3	54.7	32	1.6	0.5	24	1.3	0.5
	GRAVEL	8	2.0	0.3	23.7	4.7	2,512	314.0	88.4	25	1.2	0.5	6	0.6	0.2
	RUBBLE	0	---	---	---	---	---	---	---	---	---	---	---	---	---
	SUBTOTAL	15	1.7	0.2	17.2	3.3	4,439	295.9	52.0	57	1.4	0.3	30	0.9	0.3
ALL COVER TYPES	SILT-SAND	23	1.6	0.2	12.4	1.3	5,122	222.7	31.0	323	2.3	0.3	69	1.3	0.2
	GRAVEL	22	1.8	0.2	26.2	2.3	6,653	302.4	46.6	174	1.7	0.3	33	0.9	0.2
	RUBBLE	3	1.5	0.7	41.5	26.1	721	240.3	35.9	72	1.9	1.5	13	1.7	0.9
TOTAL		48	1.7	0.1	20.6	2.2	12,496	260.3	26.4	569	2.0	0.2	115	1.1	0.1

-Continued-

Table 4. Minnow trap depth, velocity, and catch statistics of juvenile chinook, coho, and sockeye salmon by collapsed macrohabitat, and collapsed substrate categories for samples from the Kenai River Summer Study, 28 July to 11 September 1987 (Continued).

Cover Category	Substrate Category	Number of Sites	Depth (ft)		Velocity (cm/s)		Chinook Salmon			Coho Salmon			Sockeye Salmon		
											Arcsinh(Catch)			Arcsinh(Catch)	
			Mean	S.E.	Mean	S.E.	Catch	Mean	S.E.	Catch	Mean	S.E.	Catch	Mean	S.E.
ALL MACROHABITATS															
NO OBJECT	SILT-SAND	6	0.7	0.1	11.7	4.3	602	100.3	29.7	488	3.3	0.9	213	2.4	0.9
	GRAVEL	7	1.0	0.1	13.1	2.2	1,871	267.3	60.7	375	3.2	0.8	22	1.4	0.4
	RUBBLE	1	1.0	---	21.0	---	244	244.0	---	24	3.9	---	0	0.0	---
	SUBTOTAL	14	0.9	0.1	13.1	2.1	2,717	194.1	38.8	887	3.3	0.5	235	1.7	0.5
INSTREAM	SILT-SAND	13	1.9	0.3	12.4	1.5	3,026	232.8	40.1	283	2.8	0.5	35	1.4	0.3
	GRAVEL	14	1.7	0.2	27.7	2.5	4,141	295.8	55.7	149	2.0	0.4	27	1.1	0.3
	RUBBLE	3	1.5	0.7	41.5	26.1	721	240.3	35.9	72	1.9	1.5	13	1.7	0.9
	SUBTOTAL	30	1.8	0.2	22.5	3.1	7,888	262.9	31.3	504	2.3	0.3	75	1.3	0.2
RIPARIAN	SILT-SAND	8	1.5	0.2	9.0	2.3	2,134	266.8	48.1	38	1.7	0.5	24	1.1	0.4
	GRAVEL	12	1.6	0.2	19.2	3.7	3,999	333.3	61.6	102	1.7	0.4	64	1.3	0.4
	RUBBLE	0	---	---	---	---	---	---	---	---	---	---	---	---	---
	SUBTOTAL	20	1.6	0.2	15.2	2.6	6,133	306.6	41.4	140	1.7	0.3	88	1.2	0.3
ALL COVER TYPES	SILT-SAND	27	1.5	0.2	11.3	1.3	5,762	213.4	27.0	809	2.6	0.3	272	1.5	0.3
	GRAVEL	33	1.5	0.1	21.5	2.0	10,011	303.4	34.3	626	2.1	0.3	113	1.2	0.2
	RUBBLE	4	1.3	0.5	36.4	19.2	965	241.3	25.4	96	2.4	1.2	13	1.2	0.7
TOTAL		64	1.5	0.1	18.1	1.8	16,738	261.5	21.6	1,531	2.3	0.2	398	1.4	0.2

between the two species groups (i.e., chinook and coho salmon versus sockeye salmon). For the "non-sockeye model", mean depth significantly (q = 0.0285) affected the catch of juvenile chinook salmon and the transformed catch of juvenile coho salmon. The effect was predominantly exhibited for the juvenile chinook salmon catches (with slope = 119.9, q = 0.0286) as opposed to the juvenile coho salmon transformed catches (with slope = -0.2945, q = 0.4991). The resultant univariate models (by species) with mean depth as an explanatory variable had the following correlation coefficients (R^2): chinook salmon catch $R^2 = 0.2392$, and transformed coho salmon catch $R^2 = 0.0258$. Neither macrohabitat type, substrate type, or velocity were significantly related to juvenile chinook or coho salmon minnow trap catches in the riparian cover sites.

For the "sockeye only model", the riparian cover, juvenile sockeye salmon transformed catches were not significantly related to macrohabitat type (modified or unmodified), substrate type, mean depth, or mean velocity.

If we ignore all habitat parameters except cover, then a significant (q = 0.0037) effect of cover on juvenile salmon catches and transformed catches was observed. However, the effect was only significant at the univariate level for juvenile coho salmon transformed catches. The mean transformed juvenile coho catches in the no cover sites was significantly greater than the mean catches in the riparian sites. The means were compared using Tukey's studentized range test (also known as the Honestly Significant Difference or HSD test) (Miller 1981; SAS 1985b). There were no significant differences in mean transformed coho catches, but catches were highest in the no cover sites and smallest in the riparian sites.

<u>Winter Study</u>

Winter sampling occurred in macrohabitat zone 3 (35 to 63 km) and zone 5 (105 to 135 km) during November 1987, February to March 1988, and March to April 1988. Zone 3 is the longest macrohabitat reach within the study area. It has a single, sinuous, entrenched channel with relatively large substrate material and high surface slope. The interlake zone flows between Kenai and Skilak Lakes. It has the highest gradient and largest substrate of the five macrohabitat zones. Zone 5 remains ice-free throughout the winter due to the thermal influence of Kenai Lake, while zone 3 has a variable ice cover for 1 to 3 months of the winter.

Habitat Classification and Inventory:

Linear proportions of macrohabitat categories and sample site distribution for zones 3 and 5 during low flow (winter) conditions are shown in Table 5. There were no modified habitat types in either zone. Within each zone, main channel unmodified habitat (312 and 512) occurred in significantly higher proportions than other habitat types, while tributary habitats occurred in the lowest proportions. There was no significant difference in proportions of unmodified side channel and island habitats in both zones. Between zones 3 and 5, there was no significant difference in proportions of main channel habitat; however, zone 5 had significantly higher proportions of side channel, island, and tributary habitat.

Table 5. Linear proportions of macrohabitat categories and sample site distribution in zones 3 and 5 of the mainstem Kenai River during low flow (winter) conditions, 1987 to 1988.

Habitat Matrix Categories	Number of 200' Sample Site Increments	Proportion	90% CI Limits Lower	90% CI Limits Upper	No. of Sites Sampled
3. Entrenched Zone (35 to 63 km)	922	1.0			72
1. Main Channel					
1. Modified	0	0	0	0	0
2. Unmodified	881	0.9555	0.9386	0.9725	57
2. Side Channel					
1. Modified	0	0	0	0	0
2. Unmodified	18	0.0114	0.0081	0.0309	6
3. Island					
1. Modified	0	0	0	0	0
2. Unmodified	21	0.0123	0.0105	0.0350	6
4. Tributary					
1. Modified	0	0	0	0	0
2. Unmodified	2	0.0038	0	0.0060	3
5. Interlake Zone (105 to 132 km)	1095	1.0			72
1. Main Channel					
1. Modified	0	0	0	0	0
2. Unmodified	862	0.7872	0.7563	0.8181	48
2. Side Channel					
1. Modified	0	0	0	0	0
2. Unmodified	111	0.1014	0.0786	0.1242	9
3. Island					
1. Modified	0	0	0	0	0
2. Unmodified	112	0.1023	0.0794	0.1252	9
4. Tributary					
1. Modified	0	0	0	0	0
2. Unmodified	10	0.0091	0.0020	0.0163	6

Water temperature ranged from 0 to 5 °C and averaged 2.8 °C for all winter sample sites. Turbidity ranged from 0.4 to 10.0 NTU and averaged 3.8 NTU. Conductivity ranged from 30 to 335 micro mho/cm and averaged 50 micro mho/cm. Zone 5 had lower estimated mean water temperature, turbidity, and conductivity values than zone 3, while zone 3 had larger ranges for the above parameters. Table 6 shows the mean values for depth, velocity, water temperature, turbidity, and conductivity estimated by macrohabitat type at winter sample stations in zones 3 and 5.

Sample site depth ranged from 0.4 to 2.9 ft and averaged 1.3 ft. Mean sample site depth for zone 3 was higher than for zone 5 ($a = 0.05$). Sample site velocity ranged from 0 to 125 cm/sec and averaged 33.8 cm/sec. There was no significant difference between mean sample site velocities for zone 3 and 5.

Cover category 1 (no object cover) occurred at a frequency of 98% in both zones. Cover category 3 (submerged vegetation) occurred at frequencies of 2% in zone 3 and 1% in zone 5, while cover category 5 (overhanging vegetation) occurred at a frequency of 1% in zone 5.

Proportions of substrate categories were estimated for each zone (Figure 15) and for each macrohabitat type within zones. Rubble (type 3) and cobble (type 4) were the predominant substrate categories in both zones, while silt/sand (type 1) accounted for the smallest proportions. Zone 5 had significantly larger proportions of gravel and boulder categories. Zone 3 had a significantly larger proportion of cobble. There was no significant difference in proportions of silt/sand, or rubble categories between zones 3 and 5. The composition of substrate categories by macrohabitat types for zones 3 and 5 is shown in Figure 16. Main channel habitats in both zones had the most diverse substrate composition.

Catch Composition and Juvenile Fish Abundance:

A total of 989 juvenile fish representing nine species was captured during the winter sampling period (Table 7). All nine species were captured in zone 3, while six of the species were taken in zone 5. Species catch and diversity was highest during the November sampling period and lowest during the February to March period. Sculpins accounted for 68% of the total catch and chinook salmon represented 16%.

The density of all species (total density) for combined sampling locations and occasions ranged from 0 to 25.5 fish/m^2 and averaged 0.687 fish/m^2. The total density for zone 3 (0.707 fish/m^2) was higher than the total density for zone 5 (0.667 fish/m^2). Sculpin were the most abundant species in both zones with densities of 0.354 and 0.585 fish/m^2 for zones 3 and 5 respectively. The highest single species density at a sample station was for chinook salmon in zone 3 (14.5 fish/m^2), followed by coho salmon in zone 3 (13.0 fish/m^2).

Due to the low numbers of some species in the substrate sampler catch, further analyses were conducted using the following catch categories: 1) chinook salmon; 2) sculpins; and 3) other species. Since category 3 includes all species other than chinook salmon and sculpins, and sample sizes are limited,

Table 6. Values for depth, velocity, water temperature, turbidity, and conductivity estimated by macrohabitat type at winter sample sites in zones 3 and 5 of the mainstem Kenai River, 1987 to 1988.

Macro Habitat	n	Sample Depth (ft)				Velocity (cm/sec)				Water Temp. (C)				Turbidity (ntu)				Conductivity (micro mho)			
		min	max	mean	S.E.	min	max	mean	S.E.	min	max	mean	S.E.	min	max	mean	S.E.	min	max	mean	S.E.
Zone 3	360	0.5	2.9	1.3	0.023	0	108	31.6	1.015	0	5.0	2.9	0.072	2.3	10.0	4.2	0.081	30	335	56.6	3.249
312	285	0.5	2.9	1.4	0.026	0	108	30.5	1.110	1	5.0	3.0	0.079	2.3	7.1	4.2	0.085	30	335	53.5	3.689
322	30	0.6	2.0	1.1	0.060	0	74	34.0	3.991	1	5.0	2.9	0.276	2.7	10.0	4.6	0.482	35	250	75.0	14.544
332	30	0.5	1.7	1.0	0.060	0	67	36.5	3.668	2	5.0	3.0	0.208	2.7	5.8	4.0	0.233	35	160	67.5	8.143
342	15	0.6	2.5	1.4	0.165	1	70	38.0	5.650	0	4.0	1.7	0.454	2.8	5.0	3.8	0.243	35	80	58.3	4.920
Zone 5	360	0.4	2.5	1.2	0.021	0	125	36.0	1.417	1	4.5	2.7	0.050	0.4	5.6	3.4	0.057	35	108	43.5	0.696
512	240	0.5	2.5	1.2	0.002	0	125	36.3	1.715	1	4.5	2.7	0.058	1.4	5.6	3.6	0.068	35	108	44.7	1.032
522	45	0.4	2.5	1.3	0.072	0	90	31.3	3.737	1	4.0	2.7	0.155	1.9	4.9	3.6	0.144	35	45	39.9	0.359
532	45	0.4	2.2	1.1	0.058	0	95	45.2	3.836	2	4.0	2.6	0.122	2.4	4.0	3.2	0.084	40	40	40.0	0
542	30	0.6	2.4	1.5	0.092	0	112	26.3	5.512	1	4.0	2.3	0.225	0.4	3.7	2.2	0.211	40	50	45.3	0.692
All	720	0.4	2.9	1.3	0.016	0	125	33.8	0.873	0	5.0	2.8	0.044	0.4	10.0	3.8	0.052	30	335	50.1	1.678

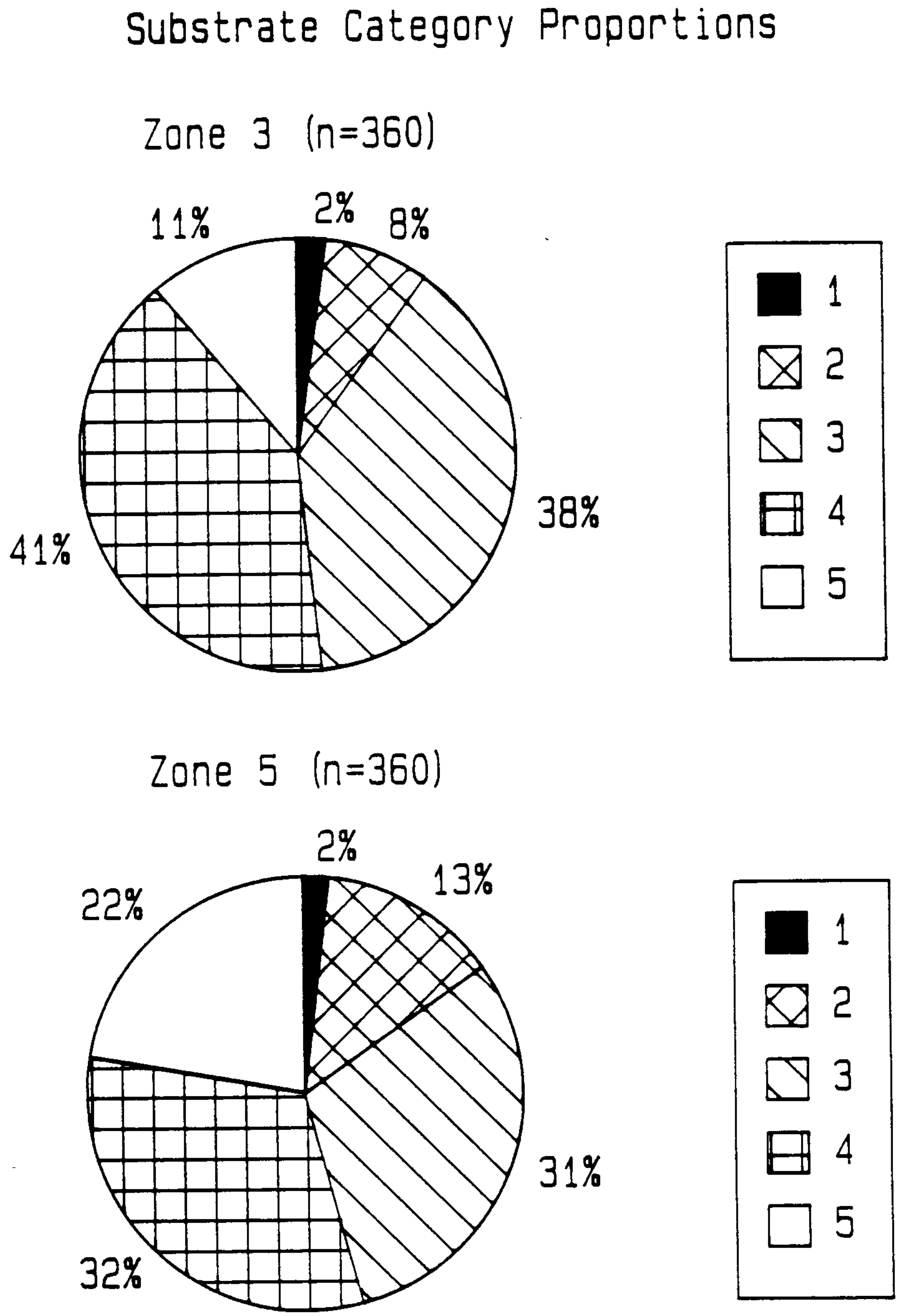

Figure 15. Estimated proportions of substrate size categories in zones 3 and 5 of the mainstem Kenai River, 1987 to 1988.

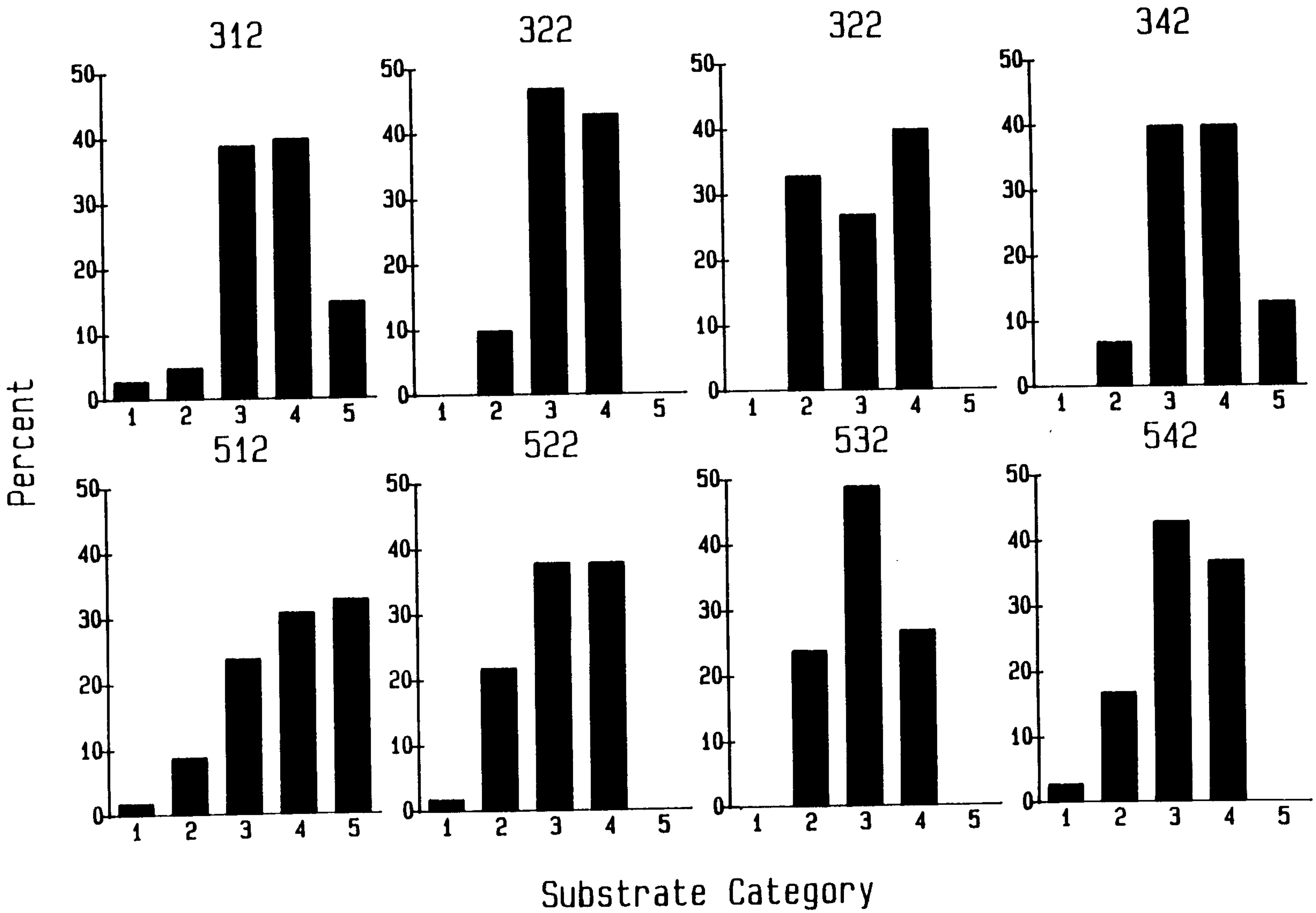

Figure 16. Percent composition of substrate categories by macrohabitat type in zones 3 and 5 of the mainstem Kenai River, 1987 to 1988.

Table 7. Numbers of fish caught in zones 3 and 5 of the mainstem Kenai River during three winter sampling events, 1987 to 1988.

Species	Sample Period						All
	November		Feb.- March		March - April		
	Zone 3	Zone 5	Zone 3	Zone 5	Zone 3	Zone 5	
Chinook Salmon	145	3	1	0	6	0	155
Sockeye Salmon	2	0	0	0	0	0	2
Coho Salmon	59	8	0	0	0	1	68
Rainbow Trout	6	6	0	1	1	4	18
Dolly Varden	8	4	0	0	0	2	14
Round Whitefish	1	0	0	0	0	0	1
Threespine stickleback	4	30	8	0	1	0	43
Slimy Sculpin	77	237	61	52	117	132	676
Arctic Lamprey	7	0	0	0	5	0	12
All	309	288	70	53	130	139	989

we do not wish to imply that a common preference is exhibited by all members of this category. We have included data for category 3 to show the range of winter conditions in which all species were captured. The overwintering densities of catch categories were analyzed by sample period, macrohabitat category, substrate category, depth interval, velocity interval and cover category.

The mean density of chinook salmon and other species declined abruptly following the November sample period, while sculpin densities remained relatively high throughout all three sample periods (Figure 17). Mean densities of chinook salmon were significantly higher in zone 3 than in zone 5 during the first and third periods. They were absent from the catch in zone 5 during the second and third periods.

All macrohabitat categories were utilized by overwintering juvenile fish (Figure 18). Side channel macrohabitat sites had the highest mean densities of chinook salmon and other species, while island macrohabitat sites had the highest mean density of sculpins in zone 3. In zone 5, island and tributary macrohabitat sites had the highest mean densities of sculpins and other species respectively.

Sculpins utilized the widest range of substrate size categories in both zones and had higher mean densities in rubble and cobble substrates (Figure 19). They were not found in silt/sand substrates. Chinook salmon utilized the most narrow range of substrate sizes. They were absent in categories 1 and 2, and had the highest mean density in category 4 (cobble). Other species occurred in all substrate categories with the highest mean densities in cobble for zone 3, and rubble for zone 5.

Mean densities were analyzed by 0.5 ft intervals of depth out to a maximum depth of 3.0 ft (Figure 20). Chinook salmon in zone 3 were not captured in depths less than 0.5 ft or greater than 2.5 ft. Densities tended to increase with depth between 0.5 and 2.0 ft. Sculpins were found in a similar range of depths for zone 3, but occupied all depth intervals in zone 5. Sculpin density tended to decrease as depth increased in both zones. Other species overwintered in depths between 0.5 ft and 2.5 ft in both zones.

Chinook salmon in zone 3 were found at sites with mean velocities between 0 and 100 cm/sec (Figure 21). The highest mean density of chinook salmon was in the 0 to 20 cm/sec velocity interval. Mean densities declined significantly in velocities above 20 cm/sec. Sculpin were found in velocities up to 100 cm/sec in zone 3 and 120 cm/sec in zone 5. Peak sculpin densities were found between 80 to 100 cm/sec in zone 3, and 40 to 60 cm/sec in zone 5. Other species had peak densities at 0 to 20 cm/sec in both zones.

Chinook salmon and other species densities in zone 5 were significantly higher in cover category 3 (aquatic vegetation) than in cover category 1 (no object cover), while sculpin densities were similar in both cover categories (Figure 22). There were no fish captured in cover category 3 in zone 5. Sculpins and other species in zone 5 had similar densities in cover category 1 and 5.

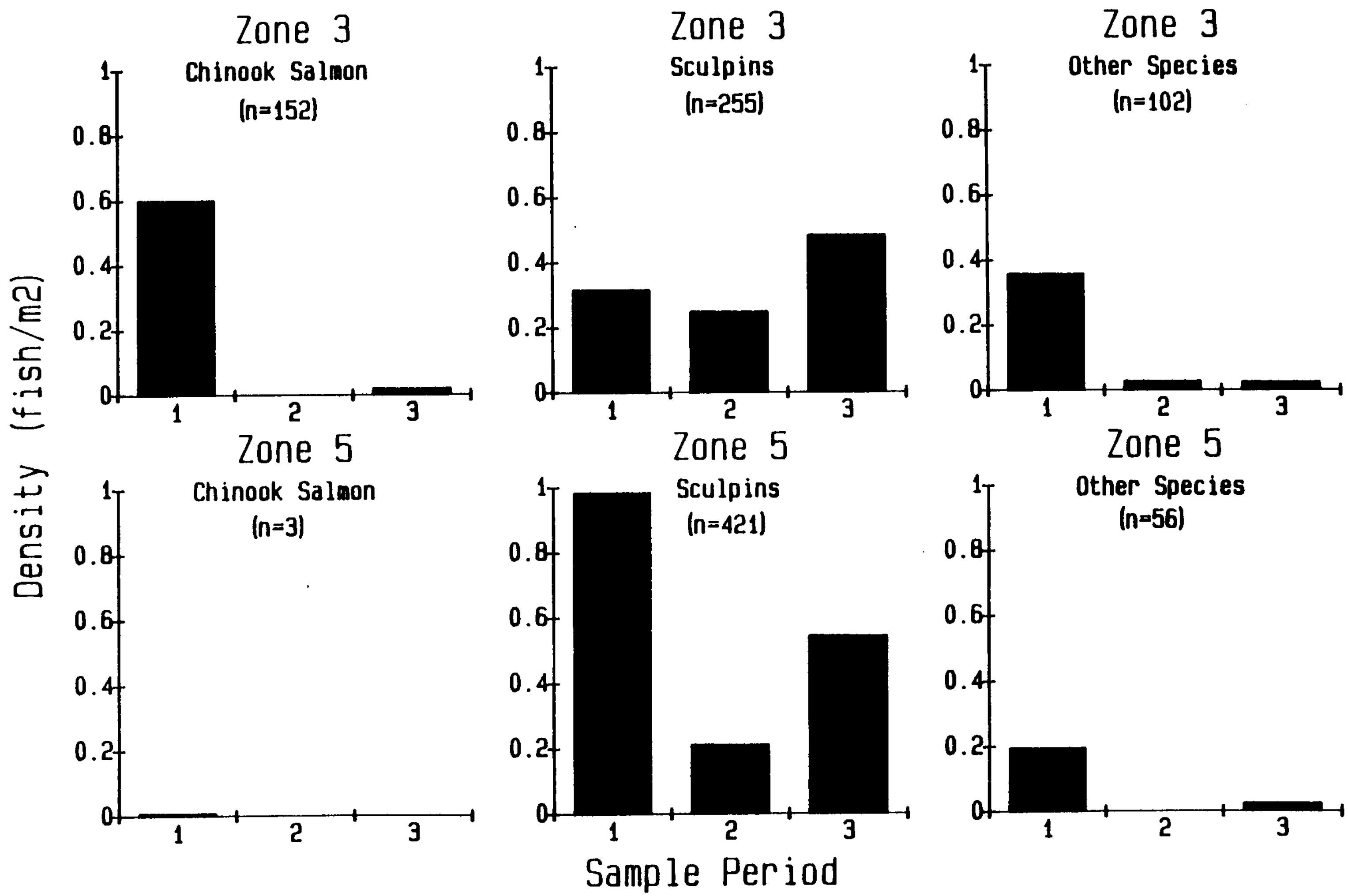

Figure 17. Winter densities of chinook salmon, sculpin, and other species captured in zones 3 and 5 of the mainstem Kenai River during three winter sample periods, 1987 to 1988.

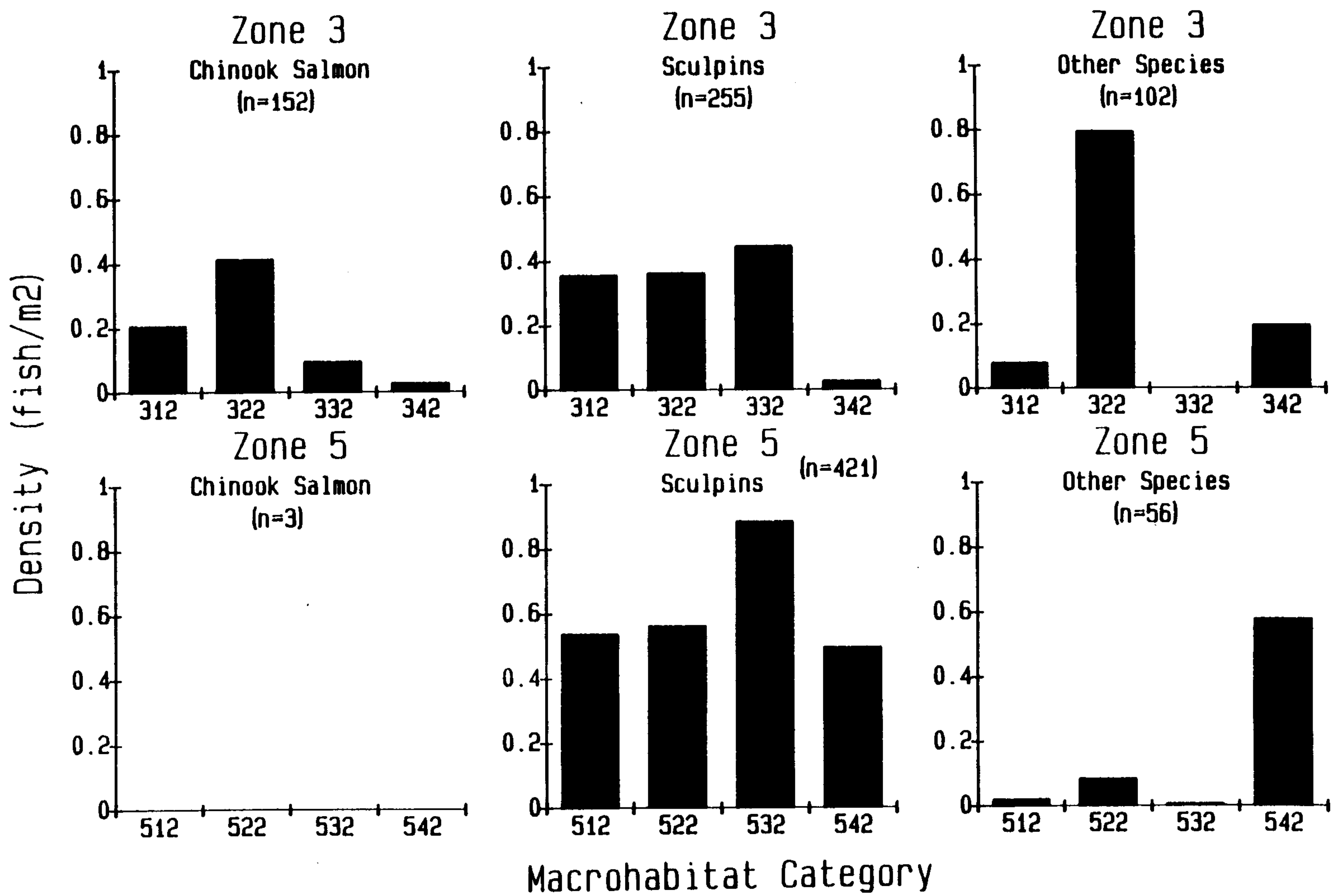

Figure 18. Winter densities of chinook salmon, sculpin, and other species by macrohabitat category for combined sampling occasions in zones 3 and 5 of the mainstem Kenai River, 1987 to 1988.

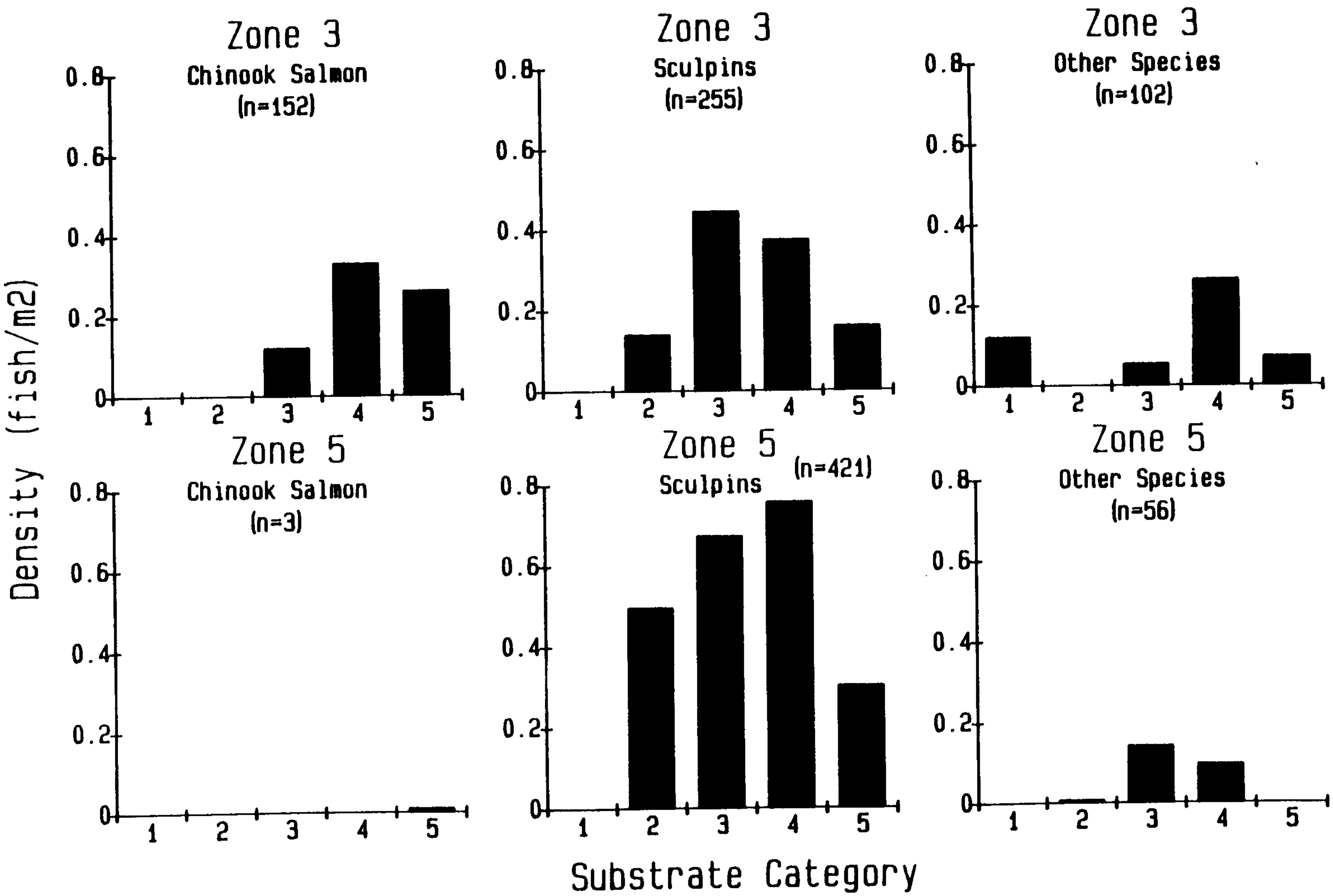

Figure 19. Winter densities of chinook salmon, sculpin, and other species by substrate category for combined sampling occasions in zones 3 and 5 of the mainstem Kenai River, 1987 to 1988.

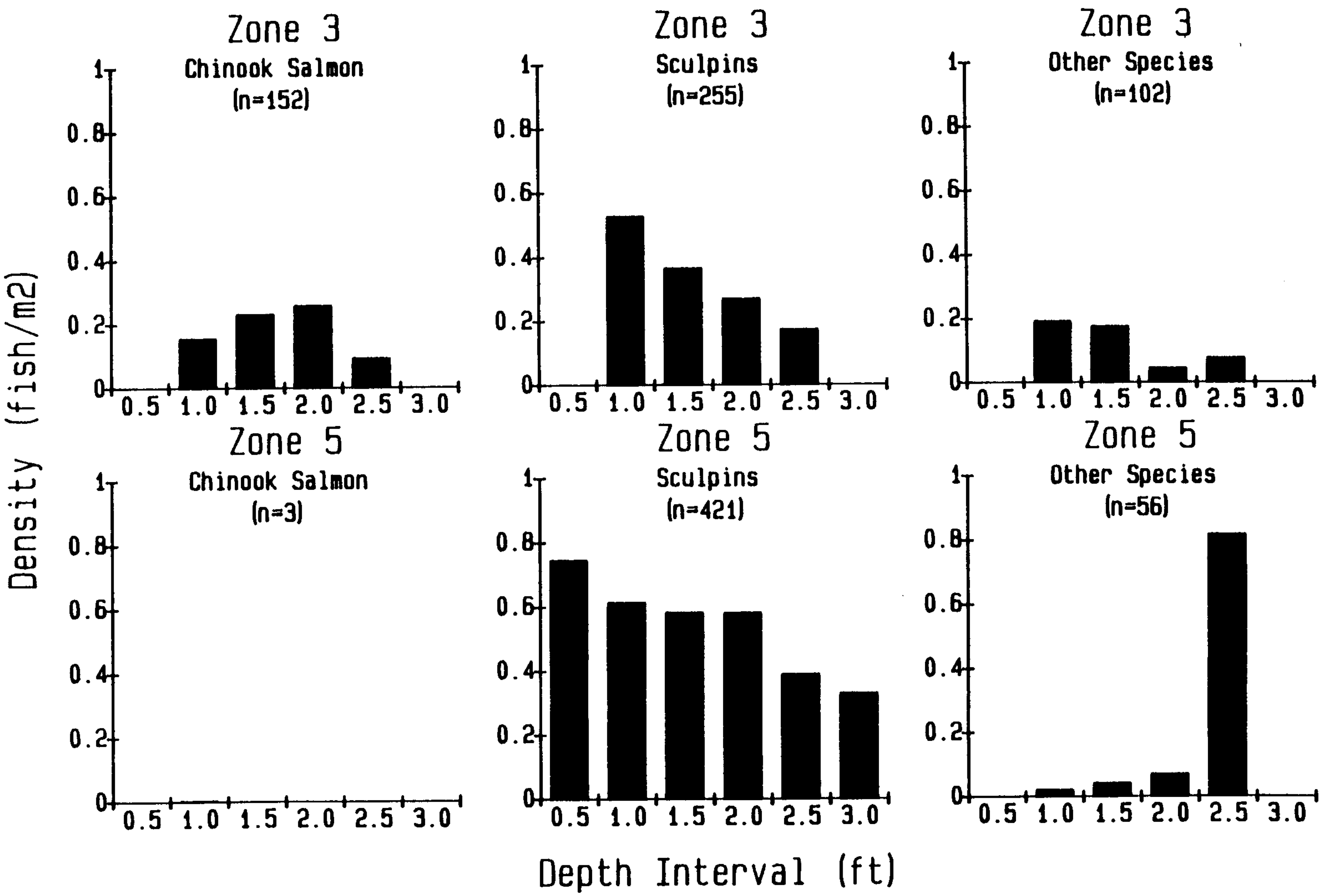

Figure 20. Winter densities of chinook salmon, sculpin, and other species by depth intervals for combined sampling occasions in zones 3 and 5 of the mainstem Kenai River, 1987 to 1988.

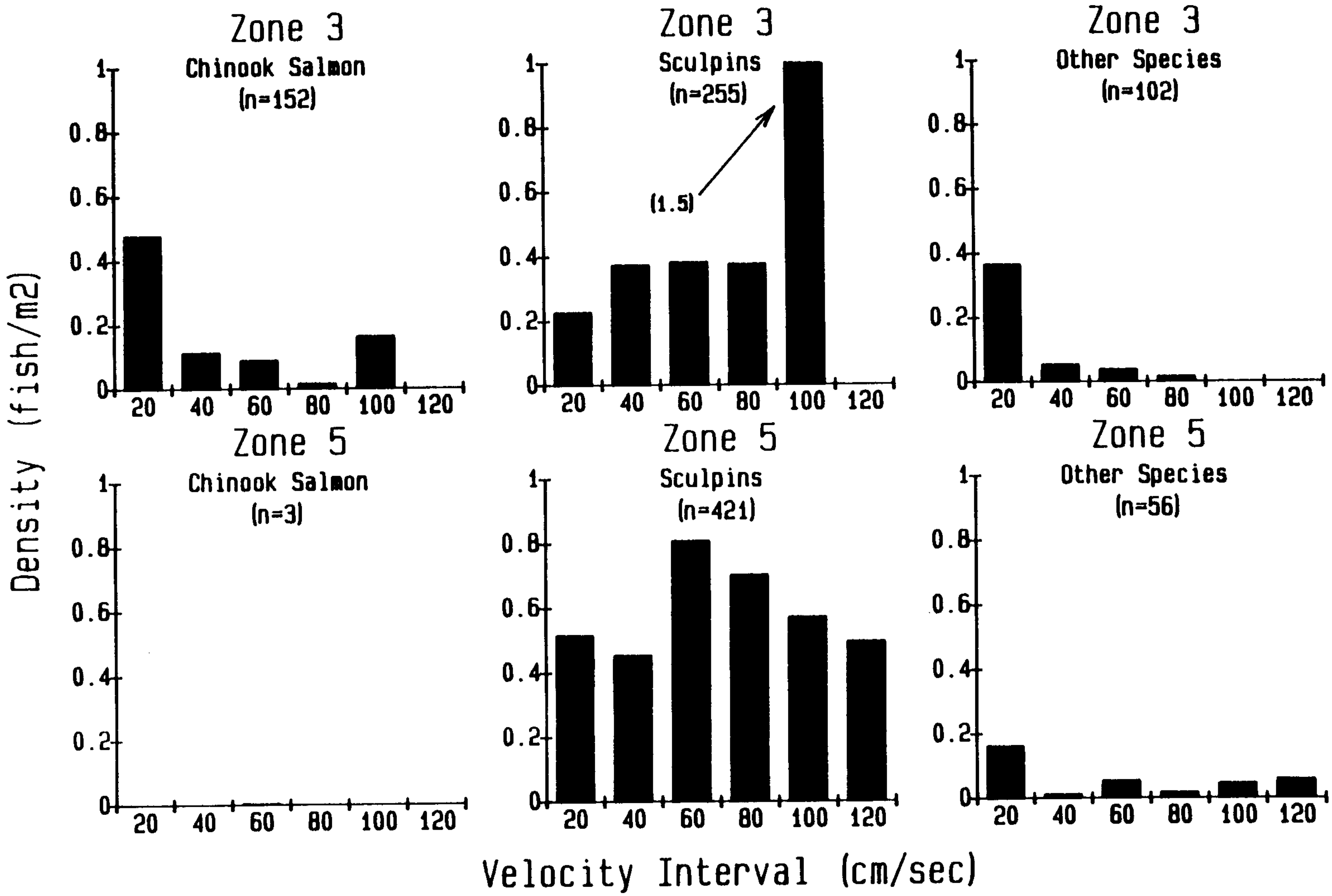

Figure 21. Winter densities of chinook salmon, sculpin, and other species by velocity intervals for combined sampling occasions in zones 3 and 5 of the mainstem Kenai River, 1987 to 1988.

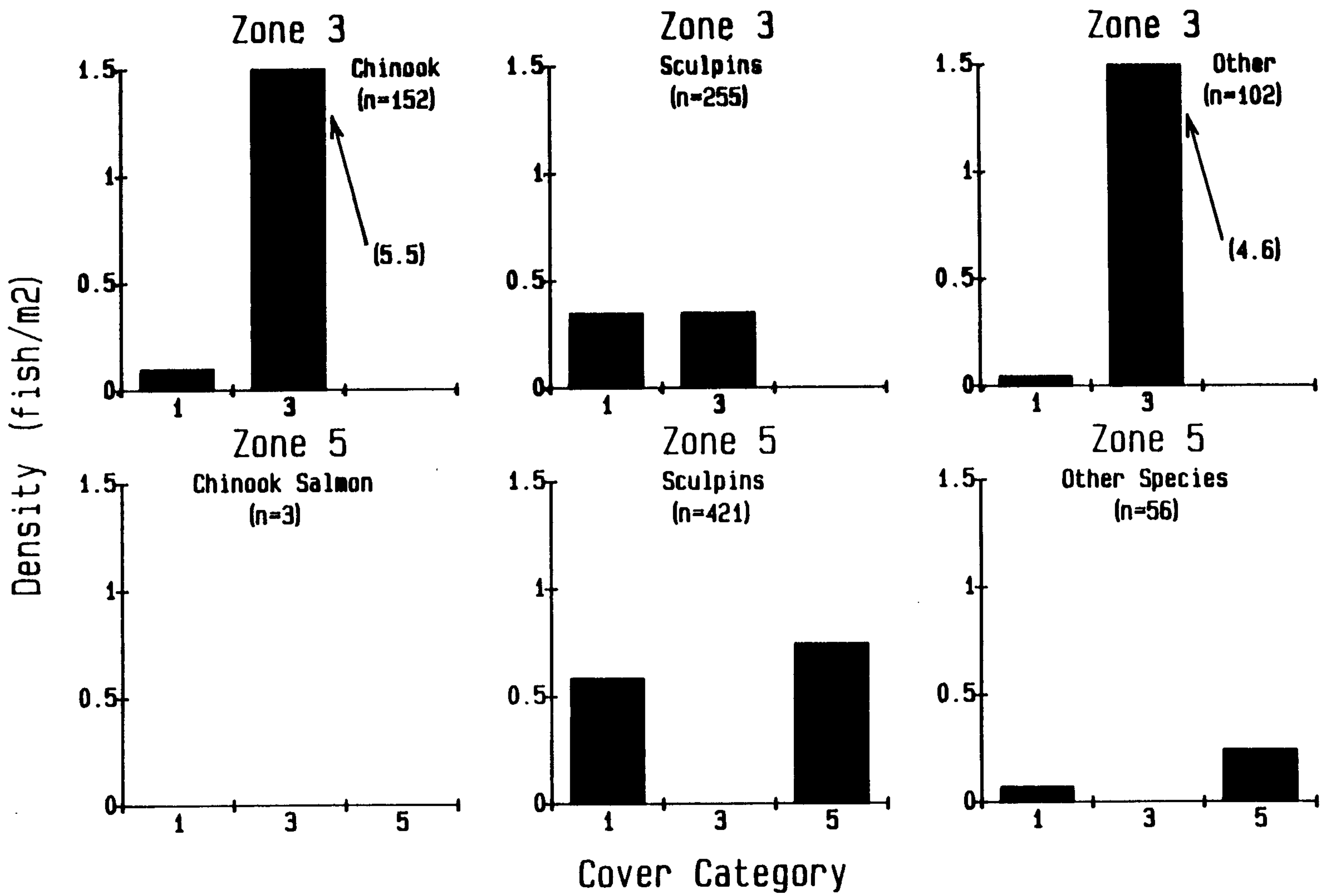

Figure 22. Winter densities of chinook salmon, sculpin, and other species by cover categories for combined sampling occasions in zones 3 and 5 of the mainstem Kenai River, 1987 to 1988.

DISCUSSION

Species Diversity in the Kenai River

The species diversity in the Kenai River delta is higher than that reported for other mainstem or tributary reaches (Bendock and Bingham 1988). Twenty-three of 27 species reported to inhabit the Kenai River were found in the delta. Seven marine species and Bering cisco are limited in distribution to the delta, while the remaining species range widely throughout the drainage. Species diversity decreases with distance above the Kenai River mouth. The proportions of juvenile salmon in beach seine catches increase with distance above the mouth, while proportions of marine species decrease. The catch proportions of chinook and sockeye salmon declined from July through October which may be the result of smolts outmigrating to Cook Inlet and sub-yearlings migrating to overwintering areas beyond the delta. Catch proportions of juvenile coho salmon increased during the sampling period. Elliott and Finn (1984) found large numbers of coho entering the mainstem Kenai River from tributaries in the fall, which may explain the increase we observed in coho salmon catch proportions.

Summer Rearing Conditions For Juvenile Salmon

Habitat diversity along the margins of the Kenai River is high during summer months and decreases in the fall as water levels decline. The lack of significant relationships between juvenile salmon catch rates and habitat conditions at randomly selected sample sites implies that the range of these conditions encountered at all locations fell within useable limits for rearing salmon.

All macrohabitat categories including modified and unmodified sites were occupied by rearing salmon and there was no significant difference in catch rates between sites. Burger et.al. (1983) captured 80% of their 51 to 100 mm chinook salmon in mean water-column velocities below 33 cm/sec. In our random sample of 64 sites, the mean velocity for each macrohabitat category was less than 30 cm/sec, well within the optimum range suggested in the previous study.

At locations with instream or riparian cover, the type of macrohabitat and substrate at a site did not significantly affect salmon catch rates. Depth had a marginal affect on chinook salmon catch rates but did not influence catches of sockeye or coho salmon. However, in the absence of cover, catches for all species were higher at sites with lower velocities and coarser substrates. These findings suggest that the availability of either instream or riparian cover was the most important habitat variable affecting catch rates in our study. This conclusion is consistent with the findings of other habitat investigations in the Kenai River (Estes and Kuntz 1986). Seventy-six percent of all sample sites were associated with one or more categories of cover. Thus, in zone 2, cover was abundant along the margins of the Kenai River.

Summer catch rates of juvenile chinook salmon observed during this study are comparable to previously published catch rates for the Kenai River and are significantly higher than those observed in other Alaskan glacial river systems (Burger et. al. 1983; Estes and Kuntz 1986). Chinook were the predominant salmon captured at mainstem summer study sites. They represented 88% of the entire catch and were captured at a frequency 8.6 times higher than the other salmon species combined. This suggests that habitat conditions along mainstem shorelines are more suited to chinook rearing requirements than those of other salmon species. Again, this is consistent with the findings of Burger et. al. (1983) who found optimum velocities for coho and sockeye salmon to be considerably less than those for chinook (0.0 and 6.1 cm/sec vs. 33.0 cm/sec respectively). Consequently, they found higher proportions of coho and sockeye salmon in off-channel pools, tributary mouths, and man-made canals while Elliott and Finn (1984) determined that coho were the most abundant salmon species in several tributaries to the lower Kenai River. Abundant cover and moderate velocities along the stream margin result in the excellent summer rearing conditions for chinook salmon observed in the mainstem Kenai River.

Winter Rearing Conditions For Juvenile Salmon

Winter study results for November samples indicated that juvenile chinook salmon in zone 3 inhabited all four instream macrohabitat categories with the highest densities observed at side channel sites. Densities were highest in cobble substrates; velocities less than 20 cm/sec; and depths between 1.0 and 2.5 ft. While casual preferences for winter habitat conditions were evident, the only significant relationships found were for mean chinook salmon density by cover category and by sampling period in zone 3. Mean values for chinook salmon density by macrohabitat, substrate, depth and velocity categories were not significantly different suggesting that juvenile chinook salmon exploit a wide range of these conditions in the mainstem Kenai River. These data may indicate upper and lower limits of suitability for chinook salmon in selected habitat conditions, but failed to demonstrate preferences within each condition.

Cover diversity is substantially reduced during winter months in the mainstem Kenai River (Bendock and Bingham 1988). Only two cover categories were encountered at winter sample stations in zone 3. There was no object cover at 98% of the sample stations while aquatic vegetation occurred at 2% of the stations. Chinook salmon densities were significantly higher at sites with aquatic vegetation. Fifty-one percent of the chinook salmon catch occurred in 2% of the sample stations suggesting a strong affinity for the small amount of instream cover that remains available during the fall. Rooted mats of water crowfoot (*Ranunculus trichophyllus*) are utilized extensively as cover by salmonids, lamprey, and stickleback during fall and early winter harboring densities as high as 44 fish/m^2. The quality and use of aquatic vegetation as cover is later reduced as a result of declining water levels and mutilation by drifting ice. At that time, all remaining catches of chinook salmon occurred in the substrate.

Trout and salmon in many Idaho streams enter the substrate when stream temperatures decline to 4-6 ^oC (Chapman and Bjornn 1969; Everest 1969). Bjornn (1971) postulated that a suitable substrate providing adequate interstices is necessary for overwintering, or fish leave. In our study, both zones 3 and 5 had large proportions of rubble, cobble, and boulder substrates, yet chinook salmon had departed zone 5 by November and zone 3 following our November sampling effort. The variable relationships between chinook salmon density and selected habitat conditions raised two possibilities: 1) either our test apparatus (substrate sampler) and sample design were inadequate for capturing chinook salmon, or 2) juvenile chinook salmon migrate from mainstem habitats to more suitable overwintering areas in late fall. Consistent catches of sculpins and other inter-substrate dwelling species; the wide range of instream habitat conditions randomly sampled in the study design; and that juvenile chinook salmon were captured within the maximum depth and velocity extremes encountered in the field sampling effort; have led us to speculate that a fall migration takes place.

Chinook Salmon Migration Hypothesis

The density of juvenile chinook and coho salmon declined abruptly and significantly at all sites following the November sampling period. Chinook salmon density in zone 3 declined from 0.604 fish/m^2 during November to 0.004 fish/m^2 in March and remained low (0.025 fish/m^2) through April. Coho salmon in zone 3 declined from 0.246 fish/m^2 in November to 0.0 for the remaining two sample periods. Only 3 chinook salmon were caught in zone 5 during November, while none were found during February and March. We hypothesize that the decline in juvenile salmon densities is the result of a fall migration out of mainstem habitats to overwintering areas in Skilak Lake. Both upstream and downstream migrations of juvenile salmonids have been described for other waters (Northcote 1962, 1969; Raleigh 1967; LaBar 1971; Bjornn 1971; and Swales et. al. 1988). Innate behaviors, photo period, water temperature, cover availability, population density, and stream flow have been postulated as possible factors initiating migrations, or determining the direction of movement. In our study, chinook salmon which are very abundant during summer months (Burger et al., 1983; Litchfield and Flagg 1986) departed zone 5 prior to zone 3. During the November sampling period, zone 5 had faster, less deep, cooler, less turbid, and less conductive water conditions than zone 3, any of which may have contributed to an earlier departure of juvenile salmon. While it is clear that not all chinook salmon depart the lower Kenai River during winter months (Litchfield and Flagg 1986; Bendock and Bingham 1988), winter studies to date have failed to explain the severe disparity between high summer and low winter catch rates of juvenile salmon in mainstem habitats. Skilak Lake is thought to be a likely destination for overwintering migrants since lower tributaries to the Kenai River are also vacated by juvenile salmon in late summer and fall (Elliott and Finn 1984). The presence of a fall migration would have implications on mainstem rearing capacity, juvenile fish seasonal abundance and habitat preferences as well as the potential impacts from stream bank modifications that are proliferating along the Kenai River.

Implications For Development Activity

Stream bank developments including boat docks, launching facilities, boat basins, gravel revetments, and vegetation removal along residential and commercial properties were encountered at random sample sites in our summer sampling program. Analyses of minnow trap catch data indicate that juvenile chinook salmon catches at modified sites were not significantly different than catches along natural banks. Stream bank development within zone 2 has resulted in a mosaic of small bank alterations that are bordered above and below by natural stream banks. Thus, the hydraulic characteristics of large river reaches have not been altered by the current level of development and measurements of habitat conditions, particularly velocity, at modified sites fell within the limits of suitability for chinook salmon described by Burger et. al. (1983). If developed banks become contiguous over larger river reaches, habitat conditions including cover, depth, and velocity may be altered to the detriment of rearing chinook salmon.

Modified sites are developed to a large extent to accommodate sport fishing interests along the Kenai River during summer months. Many private residences and commercial facilities have fish cleaning tables along their shores and wastes from sport caught salmon provide a readily available food source for juvenile salmon at these sites. Providing other habitat conditions are within suitable limits, disproportionate numbers of juvenile salmon may be attracted to modified sites due to this readily available source of food.

Our data suggests that designs for stream bank development should include the maintenance of instream and riparian cover, as well as near-shore velocities below 30 cm/sec. In the absence of cover, lower velocities and increased substrate size may be necessary to optimize use of a site by rearing salmon.

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APPENDIX

Appendix Table 1. List of common names, scientific names, and abbreviations used for fish reported to occur in the lower 132.0 kilometers of the Kenai River.

Family Common Name	Scientific Name	Abbreviation
Salmonidae		
Chinook Salmon	*Oncorhynchus tshawytscha* (Walbaum)	KS
Sockeye Salmon	*Oncorhynchus nerka* (Walbaum)	RS
Coho Salmon	*Oncorhynchus kisutch* (Walbaum)	SS
Pink Salmon	*Oncorhynchus gorbuscha* (Walbaum)	PS
Chum Salmon	*Oncorhynchus keta* (Walbaum)	CS
Rainbow Trout	*Salmo gairdneri* Richardson	RT
Dolly Varden	*Salvelinus malma* (Walbaum)	DV
Lake Trout	*Salvelinus namaycush* (Walbaum)	LT
Arctic Grayling	*Thymallus arcticus* (Pallas)	GR
Round Whitefish	*Prosopium cylindraceum* (Pallas)	RWF
Bering Cisco	*Coregonus laurettae* Bean	BCI
Cottidae		
Coastrange Sculpin	*Cottus aleuticus* Gilbert	CSC
Slimy Sculpin	*Cottus cognatus* Richardson	SSC
Pacific Staghorn Sculpin	*Leptocottus armatus* Girard	PSC
Gasterosteidae		
Threespine Stickleback	*Gasterosteus aculeautus* Linnaeus	TST
Ninespine Stickelback	*Pungitius pungitius* (Linnaeus)	NST
Petromyzontidae		
Pacific Lamprey	*Entosphenus tridentatus* (Gairdner)	PLP
Arctic Lamprey	*Lampreta japonica* (Martens)	ALP
Catostomidae		
Longnose Sucker	*Catostomus catostomus* (Forster)	LNS
Osmeridae		
Eulachon	*Thaleichthys pacificus* (Richardson)	HOO
Longfin Smelt	*Spirinchus thaleichthys* (Ayres)	LSM
Esocidae		
Northern Pike	*Esox lucius* Linnaeus	NP
Clupeidae		
Pacific Herring	*Clupea harengus pallasi* Valenciennes	PH
Pleuronectidae		
Starry Flounder	*Platichthys stellatus* (Pallas)	SFL
Gadidae		
Pacific Tomcod	*Microgadus proximus* (Girard)	TCD
Cyclopteridae		
Snailfish	*Liparis spp*	LIP
Stichaeidae		
Slender Eelblenny	*Lumpenus fabricii* (Valenciennes)	SE

Appendix Table 2. Macrohabitat matrix developed for the lower 132.0 kilometers of the mainstem Kenai River.

1. INTERTIDAL 0.0 to 18.5 km

1. MAIN CHANNEL
    1. Modified
    2. Unmodified
2. SIDE CHANNEL
    1. Modified
    2. Unmodified
3. ISLAND
    1. Modified
    2. Unmodified
4. TRIBUTARY
    1. Modified
    2. Unmodified

2. TRANSITIONAL 18.5 to 35.0 km

1. MAIN CHANNEL
    1. Modified
    2. Unmodified
2. SIDE CHANNEL
    1. Modified
    2. Unmodified
3. ISLAND
    1. Modified
    2. Unmodified
4. TRIBUTARY
    1. Modified
    2. Unmodified

3. ENTRENCHED 35.0 to 63.5 km

1. MAIN CHANNEL
    1. Modified
    2. Unmodified
2. SIDE CHANNEL
    1. Modified
    2. Unmodified
3. ISLAND
    1. Modified
    2. Unmodified
4. TRIBUTARY
    1. Modified
    2. Unmodified

4. UPPER 63.5 to 80.5 km

1. MAIN CHANNEL
    1. Modified
    2. Unmodified
2. SIDE CHANNEL
    1. Modified
    2. Unmodified
3. ISLAND
    1. Modified
    2. Unmodified
4. TRIBUTARY
    1. Modified
    2. Unmodified

5. INTERLAKE 105 to 132 km

1. MAIN CHANNEL
    1. Modified
    2. Unmodified
2. SIDE CHANNEL
    1. Modified
    2. Unmodified
3. ISLAND
    1. Modified
    2. Unmodified
4. TRIBUTARY
    1. Modified
    2. Unmodified