Volume 27
1 July 1985—30 June 1986
Federal Aid in Fish Restoration F-10-1
and
Anadromous Fish Studies

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KENAI RIVER HABITAT STUDY

by Christopher Estes

RT-3 Kenai River Habitat Study

State of Alaska
Bill Sheffield, Governor
Alaska Department of Fish and Game
Don W. Collinsworth, Commissioner
Division of Sport Fish
E. Richard Logan, Director
Juneau, Alaska

VOLUME 27
JULY 1, 1985 - JUNE 30, 1986
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STATE OF ALASKA

Bill Sheffield, Governor

Annual Performance Report for

KENAI RIVER HABITAT STUDY

by

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ALASKA DEPARTMENT OF FISH AND GAME
Don W. Collinsworth, Commissioner

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RESEARCH PROJECT SEGMENT

State:	Alaska	Name:	Sport Fish Investigations of Alaska
Project:	F-10-1		
Study:	RT	Study Title:	STATEWIDE RESEARCH/ TECHNICAL STUDIES
Job:	3	Job Title:	Kenai River Habitat Study

Cooperators: Christopher C. Estes and Karl J. Kuntz

Period Covered: July 1, 1985 to June 30, 1986

ABSTRACT

This report presents 1985 findings describing the progress of a new fish habitat program initiated in 1985. The program is designed to provide information for establishing policies required to arrest the degradation of habitat essential for sustaining the Kenai River sport fishery. Two specific activities were conducted: collection of fish habitat data and the development of a contract for obtaining low-level aerial-photography.

Fish habitat data were collected to evaluate and describe the open-water season distribution and habitat utilization of rearing juvenile chinook salmon in selected bank-type habitats of the Kenai River between the mouth of the Kenai River and the outlet of Skilak Lake. Data indicate that depth, velocity, and cover can be used to assess the usability of habitat at a site for rearing of juvenile chinook salmon fry. In terms of importance, velocity and cover appear to be the most important of these three variables in influencing the usability of a site for rearing of juvenile chinook salmon. Further research is required to validate these preliminary findings and to provide an understanding of the seasonal habitat utilization and requirements of other life phases and species.

A Request for Proposal for contractual services to provide low-level aerial-photography of the Kenai River and portions of its major tributaries was prepared and advertised. The photography in conjunction with ground truthing will be used to delineate, classify, inventory, and map instream and riparian habitats within the Kenai River watershed. The resulting maps are required by the Kenai River Advisory Board to delineate areas where preestablished land and water management

guidelines (to protect fish and wildlife) will apply. Four proposals from aerial-photography firms have been received and reviewed by a contractor selection committee. As of 30 June 1985, the recommendation of the committee was being reviewed and it is anticipated the final decision will be made in July 1986, after which the contract can be let and the photography obtained.

KEY WORDS

Kenai River, Alaska, fish habitat, riparian habitat, macrohabitat, rearing, depth, cover, velocity, chinook salmon, weighted usable area, aerial-photography.

BACKGROUND

The Kenai River watershed (Figure 1) is undergoing increased private and commercial development that have the potential of negatively impacting valuable fishery habitat. Fortunately, the present level of degradation is limited and can thus be controlled and possibly reversed if action is taken now. Accordingly, the Alaska Department of Fish and Game (ADF&G) has initiated a study that will provide the necessary fishery and habitat data on which to establish a long-term program to formulate developmental policies for the river and its watershed. These policies will be designed to protect the fishery resources of the Kenai River.

The Kenai River is located in southcentral Alaska on the Kenai Peninsula. The river and its associated tributaries drain a watershed of approximately 2,200 square miles, encompassing an area extending from the icefields of the Kenai Mountains westward to Cook Inlet. Summer flows, ranging from 5,000 to 30,000 cfs, are dominated by melt water originating from the icefields in the river's headwaters and accordingly convey a load of glacial flour that gives the waters their renowned turquoise-green color. Winter flows, ranging from 800 to 5,000 cfs, are dominated by waters originating from groundwater sources and the river's large natural lake reservoirs. Based on nineteen years of data, the mean annual flow of the river measured at Soldotna (U.S. Geological Survey Gage No. 15266350) is 5,900 cfs (Bigelow et al., 1985).

The waters and associated riparian lands of the Kenai River watershed support diverse and abundant fishery resources which are of considerable recreational, commercial, and cultural value to the people of Alaska. The Kenai River recreational fishery is the largest in Alaska (14 percent of the total sport fishing effort in Alaska). In 1984, 274,400 angler days were expended to harvest chinook [*Oncorhynchus tshawytscha* (Walbaum)], coho [*O. kisutch* (Walbaum)], sockeye [*O. nerka* (Walbaum)], and pink salmon [*O. gorbuscha* (Walbaum)], Dolly Varden [*Salvelinus malma* (Walbaum)], rainbow trout (*Salmo gairdneri* Richardson), Arctic grayling [*Thymallus arcticus* (Pallas)], and round whitefish [*Prosopium cylindraceum* (Pallas)] from the Kenai River (Mills, 1985). The chinook salmon of this system are among the largest in the world (Hammarstrom and Larson, 1985). These fish resources are also important to the upper Cook Inlet commercial fishery because the Kenai River is the largest producer of sockeye salmon for this fishery (Cross, 1985).

The production and maintenance of the fish resources in the Kenai River are dependent on a multitude of factors. Perhaps the most significant factor is the unique and favorable combination of riparian and instream habitat conditions that are present in the river basin. This combination of habitat conditions is thought to maintain the river's natural productivity. Recent evaluations, for example, have suggested that the principal factors limiting the productivity of salmon stocks in the Kenai River are the quality and quantity of rearing habitat, and that rearing habitat is dependent on a sensitive balance between riparian bankside and instream conditions (Burger et al., 1982; Platts, 1984).

During the past several years, private, recreational, and commercial development adjacent to and within the Kenai River have increased dramatically. This development, with its resulting high increase in the recreational fishery, has resulted primarily from the productive sport fishery and the close proximity to Anchorage. Development within the river includes boat docks, riprap, groins, boat ramps, canals, and boat basins. Development adjacent to the river includes residences, recreational areas (seasonal), and businesses. In support of this development along the banks of the Kenai, riparian vegetation is being removed, wetlands filled, and roads built.

If uncontrolled, this development will degrade the habitat required to support the existing fishery resources. Accordingly, local, state, and federal agencies; private citizens; business concerns; and special interest groups have joined together and formed the Kenai River Advisory Board (KRAB). Their goal is to develop a long-range unified plan (based on existing and future information) to protect the habitat required to support the fishery resources of the Kenai River. To date, the KRAB has established management guidelines for protecting fish and wildlife habitat in riparian, wetland, and floodplain areas and areas having high erosion potential along the Kenai River and portions of its major tributaries. Of these areas, the riparian vegetation and banks with high erosion potential have not been defined and mapped because of insufficient resources.

Accordingly, in the spring of 1985, the ADF&G accepted the tasks of identifying, classifying, and mapping these riparian, wetland, floodplain, and high erosion areas. It initiated this process by funding a contract for acquiring low-level aerial-photography of portions of the Kenai River watershed and by starting a multiyear field program to define seasonal habitat utilization and requirements of juvenile chinook salmon. The photography will provide the basis for another contract that will be let to ground truth, define, and map these areas. It also serves as a basis for monitoring habitat alterations in this system over time and evaluating the effectiveness of the KRAB guidelines so that modifications can be made as required.

The fish habitat studies will provide the basis for identifying the importance of seasonal instream fish habitat and conditions, and will ultimately be used to determine their relationship to riparian habitat.

Other research has also been conducted to better identify seasonal distribution of juvenile salmon (Litchfield, 1985). A complete summary of Kenai River studies conducted by the ADF&G is presented in Estes et al. (1986).

Efforts by other states to restore and rehabilitate their degraded fish habitat have been costly and only partially successful because they were initiated too late. Accordingly, the initiation of this program while this river system is still healthy is a cost-effective means to protect the fishery habitat and fishery.

The goal of this project is to prevent erosion and protect important instream and riparian fish and wildlife habitat in the Kenai River watershed. Depending on the success of this program, it may serve as a model for protecting other rivers in the state.

RECOMMENDATIONS

1. Continue with the aerial-photography contracting process.

2. After the photography has been obtained, begin the process of ground truthing, classifying, and mapping riparian habitats along the Kenai River.

3. Further classify and inventory the seasonal availability of instream macrohabitats of the Kenai River and its tributaries. To date, this and previous studies have been confined to evaluating a narrow range of the seasonally available instream macrohabitats of the Kenai River and its tributaries that have been considered important for rearing by juvenile chinook salmon during the open-water season. A comprehensive scheme has not been formulated to classify and inventory the overall range of seasonally available instream macrohabitats of the Kenai River and its tributaries. Such information is required to fully evaluate the utilization of the overall range of seasonally available instream macrohabitats of the Kenai River to juvenile chinook salmon and other species/life phases.

4. Further evaluate and describe the seasonal distribution and abundance of rearing juvenile chinook salmon in the overall range of instream macrohabitats of the Kenai River watershed. This and other studies to date have focussed primarily on describing the open-water season distribution and abundance of rearing juvenile chinook salmon in a limited range of available instream macrohabitats that are predominately

associated with bank-type habitats known to be used by rearing juvenile chinook salmon. Little study effort has been directed towards other non-bank habitats or seasons. As a result, it is not possible at this time to rank and weight each of the available instream macrohabitat types of the Kenai River according to their seasonal importance for rearing by juvenile chinook salmon.

5. Further evaluate and describe the influence of selected instream microhabitat variables on the usability of instream habitats for rearing juvenile chinook salmon. This study and others have focussed on the influence of two principal instream microhabitat variables (depth and velocity) on the usability of instream habitats for rearing juvenile chinook salmon. Preliminary investigations to evaluate the influence that a third variable (cover) has on the usability of instream habitats was introduced in this study. Little effort, however, has been directed towards evaluating the seasonal influence of other variables such as temperature and food availability on the usability of instream habitat for juvenile chinook salmon rearing. Thus a comprehensive evaluation of the independent and possible interrelated effects of these and other instream habitat variables should be undertaken to describe their influence on juvenile chinook salmon rearing.

6. Evaluate and describe the influence that naturally occurring instream (channel shape, substrate, gradient, flow, dead falls, etc.) or riparian (vegetation, bank slope, soils, etc.) habitat characteristics have on the seasonal usability of instream habitats for rearing by juvenile chinook salmon. To date, limited information has been obtained to evaluate and describe the influence that naturally occurring instream or riparian characteristics have on the seasonal usability of habitats for juvenile chinook salmon rearing. As a result, it is difficult to evaluate the influence of artificial changes in these characteristics on rearing juvenile chinook salmon; e.g., the introduction of structures such as docks, jetties, and boat ramps or the alteration of habitats such as the removal or riparian vegetation and the adding of rip rap. Such information is necessary to evaluate the effects of these developmental activities on juvenile chinook salmon rearing habitat; only then can developmental policies for the river and its riparian habitats be formulated.

7. Evaluate and describe the seasonal distribution and abundance of other sport fish species and life phases in the overall range of instream macrohabitats of the Kenai River watershed. This information is unavailable and is needed to evaluate the importance of all habitats associated with the seasonal production of fishery resources within the Kenai River.

8. Evaluate and describe the influence that selected instream microhabitat variables have on the seasonal usability of

instream habitats for other sport fish species and life phases supported by the Kenai River. This information is unavailable and is required to evaluate changes in habitat characteristics that may influence the seasonal production of other fish species/life phases within the Kenai River.

9. Evaluate and describe the influence that naturally occurring instream or riparian habitat characteristics have on the seasonal usability of instream habitat by other species and life phases. This information is unavailable and is required to evaluate the influence of man induced alterations to natural conditions and determine the effects of these alterations on seasonal fish habitat usability.

10. Obtain the services of a hydraulic engineer to develop a best management practices and design manual for riparian and instream structures for the Kenai River. This manual would provide a reference for developing instream and riparian modifications that improve or maintain important habitat characteristics required for fish production in the Kenai River. Desirable habitat characteristics would be defined by recommendations 1 through 9.

11. Obtain the services of a hydraulic engineer on an ongoing basis to provide assistance in reviewing permits for structures adjacent to and within the Kenai River and its tributaries. This would enable biologists to work with an engineer to design acceptable structures and guidelines for modifying instream and riparian habitats while developing the design manual (recommendation 10).

OBJECTIVES

To establish a long term program for providing habitat data (biologic and hydrologic) necessary to formulate developmental policies for the Kenai River and its watershed which will protect the fishery resources of the Kenai River.

TECHNIQUES USED

In 1984, the ADF&G requested the services of William Platts, Research Fisheries Biologist with the U.S. Forest Service (USFS), to develop a plan for protecting the habitat of the Kenai River. Platts, an expert on the topic of riparian habitat, devised a series of studies (Platts, 1984, 1985) that serve as the basis of Departmental programs designed to protect the habitat of this river system. Using procedures developed by Platts (1985 et al.), the multiyear plan is based on analyzing fish habitat and riparian vegetation from aerial-photography in conjunction with ground truthing. Program elements performed during the period of

1 July 1985 to 30 June 1986 included the preparation of a Request for Proposal (RFP) to obtain aerial-photography of the Kenai River and portions of its tributaries through contractual arrangement and an assessment by the ADF&G of open-water season juvenile chinook salmon distribution and habitat utilization in select areas of the Kenai River. Procedures for developing and letting contracts are outlined in Reaume (1984). Specifications for producing the photographic products are outlined in Estes (1986). Procedures for conducting the juvenile chinook salmon rearing habitat studies follow:

The lower nine miles of the river below Beaver Creek is primarily an area of tidal influence. The river channel in this area is not armored and is free to meander. Little spawning or rearing habitat occurs in this reach, with the reach being primarily used as a migrational corridor (Burger et al., 1982). Accordingly, the lower nine miles of the river downstream of Beaver Creek were excluded from these studies and the remaining river between Beaver Creek and Skilak Lake was segmented into three distinct evaluation reaches (Figure 2) based on geomorphic differences as described by Scott (1982).

Lower Reach [River Mile (RM) 9.0-17.6]: The lower evaluation reach extends from Beaver Creek upriver to the lower edge of the Soldotna Terrace. The reach is characterized by a lower overall gradient; lower mid channel velocities; and, smaller, less armored, substrate types than either the middle or upper evaluation reaches. The river channel in this reach is only partially entrenched. Thus it is relatively free to meander. Areas of submerged debris with surrounding accumulations of sand and silt are present throughout the reach. Bank erosion is high, resulting in the reach having a high sensitivity to development (Scott, 1982). The potential for further riparian and instream habitat alteration through heavy river use and bank development is high, as this area is adjacent to the City of Soldotna and has road access. The reach also encompasses the primary sport fishing areas for Kenai River chinook salmon.

Middle Reach (RM 17.6-39.4): This reach extends from the lower edge of the Soldotna Terrace upriver to the Naptowne Rapids. The channel is sinuous to straight, entrenched, and mostly armored. Bed material is coarser than that present in either the upstream or downstream reaches. It is geomorphically the most stable of the three reaches and is thus relatively insensitive to development (Scott, 1982).

Upper Reach (RM 39.4-50.3): This reach extends from the Naptowne Rapids to the crescentic dunes at the outlet of Skilak Lake (Scott, 1982). The channel is meandering and free to migrate and its bed material is relatively fine-grained due to the extremely coarse material at the Naptowne end moraine, which acts as a control for this section. Instream and riparian bankside habitat in this reach has been significantly altered as a result of residential, recreational, and commercial development. This reach is highly sensitive to development (Scott, 1982).

A classification and inventory of seasonally available instream and bankside habitats of the Kenai River were not available at the start-up of this study. Therefore, specific study areas within each of the three evaluation reaches were selected based on a review of aerial photographs and the results of a reconnaissance field trip to preliminarily identify the instream habitat types present in each of the three evaluation reaches. Based on the results of this trip, four habitat types were defined: erosional banks, grassy banks, sloughs, and gravel bars. Only bank-type habitats were selected for evaluation as previous studies (Burger et al., 1982; Litchfield, 1985) showed little utilization of nonbank type habitats because of their typically high and, thus, unsuitable velocities. A description of each of the four habitat types follows:

Erosional banks: This habitat type is characterized by steep eroded banks that often have slumped mats of vegetation and unstable slopes of gravel or rubble. The most common situation is one in which the dominant vegetation is spruce or cottonwood that either has fallen into the water or gradually lists toward the surface of the water before actually falling into it. The vegetation, as well as the velocity break created within and below it, offer excellent cover to rearing juvenile salmon.

Grassy banks: This habitat type is characterized by 3- to 8-feet-high, moderately stable banks vegetated with grasses and/or low alders. These banks are typically scalloped because of slumping. The scalloping creates an irregular shoreline having indentations that are often undercut with overhanging riparian vegetation and numerous velocity breaks. These conditions provide good cover for rearing juvenile chinook salmon at medium to high flows.

Sloughs: This habitat type typically consists of a low-velocity area behind an upstream cobble-bar barrier. As such, this habitat type usually acts as a settling area. Due to the low velocities, the visible substrate is often silt, sand, or fine organic litter covering a base substrate of gravel, rubble, and cobble. Cover at these habitat types is generally low throughout the season, increasing only when high flows moves the water's edge into the bankside vegetation. Given these conditions, moderate quantities of rearing habitat are present at these habitat types throughout much of the open-water season.

Gravel bars: This habitat type typically occurs along the inside banks of river meanders. As a result, the morphology of these habitat types reflects the interface of a main channel shearing away from the shore and toward the opposite bank. This condition produces a very shallow, gently sloping bank profile, consistent substrate, and gradually increasing velocities from the bank. Little object cover is present until the seasonal high water, at which time the water's edge moves up into the grasses and shrubs on the bank. These conditions result in moderate levels of rearing habitat being present throughout the open-water season. Due to the favorable velocity and substrate conditions, these habitat types are often used by spawning salmon.

These areas also represent the sites described by Scott (1982) as the least-destructive sites for the construction of boat launches and public access to the Kenai River.

One study area containing each of these four habitat types was selected in each of the three evaluation reaches (Figures 2 and 3). Detailed study site descriptions are presented in Appendix C. In general, study areas were selected to meet the following criteria:

1. Each of the habitat types must be present within each evaluation reach.

2. The general morphologic, hydraulic, and water quality conditions within each area must be typical of those found within its evaluation reach and habitat types.

3. The areas could be sampled for rearing juvenile chinook fry with baited fry traps and must be accessible by boat at typical river discharges.

An erosional-bank habitat type was not selected for evaluation in the middle river study area because it did not represent potential rearing habitat for salmon fry. Erosional banks in the middle reach are 30-70 feet high, with base talus consisting of cobble and boulders. The channel morphology in this reach tend to form chutes, resulting in high, unsuitable velocities and little object cover.

Each study area was approximately 2500 feet in length. Within each one, sections of river bank habitat 150 feet in length, representing each of the habitat types present in that reach, were designated as habitat type study sites for sampling. These sites were selected so that the basic morphology and available instream habitat appeared to be relatively consistent throughout the length of that site. The 150-foot length was considered a manageable size for efficient collection of fisheries and habitat data.

Within each habitat type study site, transects were established that intersected the stream channel at right angles. One or two transects were established to represent the depth, velocity, and cover conditions present at each site. A head pin on the river bank defined the end of each transect for consistent measurement.

The width of each study site varied, extending to a point in the channel where velocities became greater than 2.3 feet per second; this point is defined as the velocity sheer. It is the velocity beyond which the movement of fry in the length category under study (35-100 mm) is limited (Burger et al., 1982).

To describe the relative distribution and abundance of rearing juvenile chinook salmon at and between each of the study sites, fry were collected with traps having a mesh size of 0.64 mm baited with salmon roe that had been treated with Betadine disinfectant. Fifteen traps per study site were fished for a single set of 30 minutes duration. In addition to the sample traps within a study site, an array of baited barrier traps were placed at the downstream study site boundary. These traps were situated to maximize capture of fish drawn upstream by the attractance of salmon roe used capture fish in the study site.

All captured fish, with the exception of those captured in the barrier traps, were placed in oxygenated live boxes until the sampling at the study site was completed. Subsequently, all fish for each study site were identified to species. Fork lengths of the first 50 chinook salmon fry trapped at from each study site were measured.

To evaluate the degree to which the population of rearing juvenile chinook salmon at a study site was open or closed to recruitment, freeze branding of the juveniles was conducted at each study site. A freeze-branding unit similar to the model described in Stratton (1986) was used for branding fish. Fish were branded on their left or right side, beneath or posterior to the dorsal fin following branding procedures described in Stratton (1986). Two branding symbols were used in this study. The three potential marking positions on each side of the fry and the four orientations of each brand allowed for a total of 24 unique marks. This allowed branded fry to be identified by capture date and site. Branded fish were returned to their capture site for release.

Selected habitat variables thought to influence juvenile chinook salmon rearing in the Kenai River were assessed and recorded at each study site. Variables assessed included water quality, hydraulics, and cover; presence of instream structures or development; and proximity of the site to lakes, natal areas, or tributaries.

Water quality variables measured within each study site on each sampling occasion included dissolved oxygen, pH, temperature, and conductivity. Measurements were made using a model 4041 Hydrolab following procedures described in ADF&G (1981a). Water samples were taken each sampling day for later turbidity analysis using an HF DRT-15 turbidimeter following procedures outlined in the manufacturer's operating manual.

Water velocity and depth were measured at each time of sampling at 1.0 foot intervals along each transect within each study site to produce a profile of these variables. Water depths were measured to a tenth of a foot with a six foot top-setting wading rod. Water velocities were measured in feet per second with a Marsh-McBirney Model-201M velocity meter at 0.6 of the distance from the top of the water column if less than 2.6 feet deep, or the average of 0.2 and 0.8 of the depth otherwise.

Cover type on each transect was measured once during low/clear water conditions and recorded at 1.0-foot intervals using procedures described in Suchanek et al. (1985). The cover coding system (Table 1) used in this study describes the cover available to a hypothetical juvenile chinook salmon 100 mm in length. To reduce bias, cover at all sites was estimated by the same observer. Cover was recorded by distance from the transect bank marker.

A map of each study site was also drawn at each time of sampling to record notable habitat variations and pertinent instream developments. In addition, proximity of the site to lakes, natal areas, and/or tributary mouths was noted. Photographs were also taken to document on-site conditions.

Two 12-day sampling periods were conducted during the 1985 open water season. The periods were 1 to 15 July (henceforward referred to as the July sampling period) and 30 September to 15 October (henceforward referred to as the October sampling period). Within each sampling period, each of the study areas was sampled for fishery and habitat data four times, once every three days according to the schedule presented in Table 2. All study sites within each study area were sampled on the same day.

Juvenile chinook capture data collected in this study can be analyzed and treated as catch-per-unit-effort (CPUE) data. Since 15 traps were fished at each study site for a soak time of 30 minutes apiece, the units for CPUE in this study are "x" catch per 450 minutes effort. However, because equal effort was conducted at each site, the CPUE data within this study will be directly compared as catch data.

To compare the relative abundance and distribution of juvenile chinook salmon at and between habitat type study sites, catch data for each evaluation reach and study site were compared for the July and October sampling periods. Since each study site was sampled four times during each sampling period, the mean and standard deviation of the catches of the four sampling times were the variables used for the comparison.

To evaluate whether there were significant differences in catch rates between habitat types within reaches and sampling periods, an analysis of variance (ANOVA) was performed. The hypothesis tested was whether juvenile chinook catches were affected by habitat type, reach, and/or sampling period.

The hypothesis was evaluated by setting up a factorial design, in which reach of river and month of sampling were blocking factors, while habitat type was the treatment factor of interest. The response variable was catch, as measured in numbers of juvenile chinook salmon collected by 15 fry traps in a study site for the standard soak time. Replicates for the factorial design were the four sampling times during the 12-day sampling period each month. Accordingly, it was assumed that distribution and abundance of rearing juvenile chinook salmon within each study site did not change appreciably during the 12-day sampling period. The design was flawed in that the erosional habitat type was not sampled in the middle reach, while eight samples were taken in two sites classified as grassy in the middle reach. A summary of the sampling effort by month is presented in Table 3.

The first step in the analyses was to investigate transformations of the response variable to approximate normality. This was required due to the necessity of using a parametric technique to analyze a factorial design with missing cells. Two transformations were investigated. The first was the inverse hyperbolic sine which has been suggested (Zar, 1974) for catch statistics which often follow a negative binomial distribution (Bannerot and Austin, 1983; Nedelman, 1983; Tripathi, 1985). The second transformation investigated was the natural logarithm of the catch plus one. This transformation often works well with positively skewed data such as fry trap data (Emerson, 1983; Emerson and Stoto, 1983). Accordingly, this transformation would most likely reduce this skew. The transformed data was tested for normality by comparing the standardized cumulative distributions versus the standard normal cumulative distribution (Stephens, 1982). The test statistic used was the Kolmogorov-Smirnov D statistic. The nontransformed catch data and the inverse hyperbolic sine transformed catch data was significantly (alpha=0.05) different from normality. The natural logarithm of the catch plus one was not significantly different from normality (alpha=0.05). Accordingly, this transformation was used in all subsequent analyses.

The overall model investigated was:

$$C^{*}_{i,j,k,l} = mu + R_i + M_j + H_k + R_iM_j + R_iH_k + M_jH_k + R_iM_jH_k + e_{i,j,k,l}$$

where: $C^{*}_{i,j,k,l}$ = $\log_e$ (catch +1), observed in each combination of reach, month, habitat, and sample;

mu = mean response for all data;

R_i = effect of reach, i=1,2,3;

M_j = effect of month, j=7,10;

H_k = effect of habitat, k=1,2,3,4; and

$e_{i,j,k,l}$ = error term associated with each observation where l=replicates in each combination.

The ANOVA of the overall model indicated that the three-way interaction term (RMH) and the interaction term between reach and month (RM) were not significant effects; all ANOVA analyses were completed utilizing the General Linear Models procedure of the Statistical Analysis System (SAS, 1982). Accordingly, a reduced model without these terms was fitted. This reduced model indicated that the remaining interaction terms [between reach and habitat (RH) and month and habitat (MH)] were significant effects. Therefore, the research hypothesis could not be directly evaluated with the reduced overall model. Accordingly, the next step in the analysis evaluated the individual groups of data as defined by reach and month.

The individual models fit for each unique grouping were:

$$(C^*_{k,l} = mu + H_k + e_{k,\ l})_{ij}.$$

where:

$C^*_{k,l}$ = $\log_e$ (catch + 1), observed in combination of habitat and sample;

mu = mean response for all data;

H_k = effect of habitat, $k = 1,2,3,4$;

$e_{k,l}$ = error term associated with each observation where k = habitat and l = sample; and

$_{i,j}$ = reach and month factors

The null hypotheses for each of these models were:

$$H_o: H_1 = H_2 = H_3 = H_4.$$

The alternative hypotheses were that any one of the above equalities were not valid.

The mean fork length of juvenile chinook salmon fry captured during this study was determined from the length data taken on the first 50 chinook salmon fry captured at each study site. Data were analyzed grouping by reach and sampling period.

To determine the degree to which the population of juvenile chinook salmon fry at a study site was closed or open to recruitment, the number of marked and unmarked fish captured during each of four sampling times conducted during the July and October sampling periods for each of the habitat type study sites was tabulated and compared for differences; large fluctuations in daily catches were indicative of relatively open populations at a site.

A brief narrative describing the general habitat characteristics of each study site was prepared. Included in each narrative was a description of the pertinent hydraulic, hydrological, and cover conditions at the site. Also included was a description of significant habitat variations at each site as well as proximity of the site to lakes, natal areas, or tributary mouths.

Measurements of water quality and depth, velocity, and cover made at each study at the time of each sampling were tabulated. Data were tabulated by study site, sampling period, and evaluation reach.

To evaluate and compare the influence that depth, velocity, and cover have on the usability of habitat for rearing juvenile chinook salmon, weighted usable area (WUA) functions were calculated for each study site for each time of sampling. WUA is an index of the capacity of a site to support the species/life phase under investigation (IFG, 1980). As such, it is not a direct measure of the number of fish at a site but only an index of the quantity and quality of fish habitat at that site at a specified flow or range of flows.

Calculation of WUA functions are generally based on three principal components (Estes, 1984).

1. Physical Projections - The collection and assessment of instream hydraulic and/or geomorphic data to summarize a range of instream conditions at a specified flow or range of flows that are considered important for the species/life phase under investigation.

2. Habitat Criteria Analyses - The determination of behavioral responses of the species/life phase under investigation to a range of instream hydraulic and/or geomorphic conditions present at a specified flow or range of flows that are considered important for the species/life phase under investigation.

3. Habitat Projections - The combination of the first two components to project WUA functions for a specified flow or range of flows for the species/life phase under investigation.

Several methods exist for calculating WUA functions (IFG, 1980; Bovee, 1982; Estes, 1984). In this study, a simplistic procedure, not based on predictive hydraulic modelling procedures (IFG, 1980; Bovee, 1982), was devised to calculate WUA functions for juvenile chinook salmon rearing habitat at each study site at the time of each sampling. The method calculates a WUA for a site by summing the WUA's calculated for each of its one foot wide by 150-foot-long cells extending from the site's waters edge out to its midchannel velocity sheer.

The WUA of each cell was calculated as follows:

$$WUA_{cell} = WF_{cell} \times Area_{cell}$$

where:

$$WF_{cell} = \text{Cell weighting factor}$$

$$= WF_d \times WF_v \times WF_c$$

where:

WF_d = Depth weighting factor or suitability,

WF_v = Velocity weighting factor or suitability, and

WF_c = Cover weighting factor or suitability.

Based on this, the WUA for each cell was then calculated as follows:

$$WUA_{site} = \sum_{n=1}^{m} WUA_{cell}$$

where:

m = number of cells.

Additionally, the gross surface area of each cell was calculated by summing each of the site's cell areas as follows:

$$Area_{site} = \sum_{n=1}^{m} Area_{cell}$$

Because the surface areas of sites varied depending upon the distance of the velocity sheer from each site's bank, direct comparisons of WUA's between sites were not considered valid. In order to facilitate such comparisons, the ratio of each site's WUA to Area, designated as the Habitat Availability Index (HAI), was calculated as follows (Steward et al., 1985):

$$HAI_{site} = WUA_{site}/Area_{site} \times 100$$

(The factor was multiplied by a factor of 100 for ease of reporting the resulting data.)

The cell-weighting factor (WF_{cell}) was calculated as the product of individual cell habitat variable weighting factors ($WF_d \times WF_v \times WF_c$). Habitat variable-weighting factors were derived, when possible, from literature pertaining to the Kenai River, or, if such information was unavailable, from the opinion of biologists familiar with the habits of rearing juvenile chinook salmon in the Kenai River. The weighting factors for depth were based on data described in Burger et al. (1982). These data indicate that water depths below 0.2 feet are unsuitable for juvenile chinook rearing and that there are no differences in the suitabilities of depth greater than 0.2 feet. Based on this, a weighting factor of 0.00 was assigned to depths less than 0.2 feet and a weighting factor of 1.00 was assigned to all depths equal to or exceeding 0.2 feet (Figure 3).

The weighting factors for velocity were also derived based on data described in Burger et al. (1982). These data indicate that water velocities of 0.4 feet per second are preferred for rearing by juvenile chinook salmon. Based on this, a weighting factor of 1.00 was assigned to this velocity. The data also indicate that water velocities greater than 2.2 feet per second are unsuitable for rearing juvenile chinook salmon. For this reason, a weighting factor of 0.00 was assigned to all velocities greater than 2.2 feet per second. Weighting factors for velocities less than 0.4 feet per second and between 0.41 feet per second and 2.2 feet per second were assigned based on data in Burger et al., (1982), as shown in Figure 4.

The weighting factors for cover were derived based on the professional opinion of biologists familiar with juvenile chinook rearing in the Kenai River (Figure 5). These factors were assigned as follows:

Cover category 1 represents the code for no object cover. A total lack of cover at a study site was deemed totally unsuitable for rearing by juvenile chinook salmon and accordingly assigned a weighting factor of 0.00.

Cover category 2 represents the code for emergent vegetation. Emergent vegetation on the Kenai River predominately consists of riparian grasses and/or small-shrub vegetation that become inundated at medium to high flows. This inundated vegetation provides good cover for rearing juvenile chinook salmon by virtue of the velocity buffer it produces. In addition, it provides good cover in that the bonding characteristics of the vegetation's root systems allow fairly deep (1-2 feet) undercut banks to develop. Also, when sloughing of the bank occurs, a scalloped bank typically forms which provides a good cover source. The cumulative effects of these factors lead to the assignment of a 0.65 weighting factor to this cover category.

Cover category 3 (aquatic vegetation) was also assigned a weighting factor of 0.65. Aquatic vegetation on the Kenai River typically consists of mats of green or brown algae that are found in clear water areas such as sloughs. These mats provide good cover by virtue of the velocity break they create and the primary and secondary production they support.

Cover category 4 is the code for deadfall. The predominant source of deadfall on the Kenai River consists of spruce and deciduous trees which have fallen into the river. Very few large accumulations of deadfall were noted, with one to three trees typically forming a deadfall accumulation. These deadfall accumulations provided excellent cover by virtue of the velocity break and hiding places they created. Based on these considerations, this cover category was assigned a weighting factor of 1.00.

Cover category 5 is the code for overhanging riparian vegetation. Overhanging riparian vegetation on the Kenai River typically consists of listing spruce or shrub vegetation. This provides good cover by virtue of the hiding cover and dropping food sources it provides. Based on these factors, this cover code category was assigned a weighting factor of 0.50.

Undercut banks on the Kenai River typically occur in areas of highly vegetated banks that have undergone erosion. Because the banks are typically highly vegetated, the erosion often results in scalloping of the banks. This scalloping coupled with undercutting of the banks offers excellent cover to rearing juvenile salmon. Based on this, cover category 6 was assigned a weighting factor of 0.90.

Substrate cover was placed in three size-dependent categories. Cover category 7 was assigned to gravel substrates of the size range from 1/2 to 3 inches. Cover category 8 was assigned to rubble substrates of the size range 3 to 5 inches. Cobble substrates of the size range greater than 5 inches were assigned to cover category 9.

Because gravel substrates at the study sites were typically present in areas of low velocity and embedded with finer materials that resulted in a low cover value, they were assigned a weighting factor of 0.25. Rubble and cobble substrates were assigned a weighting factor of 0.35 each, as they provided slightly better cover than gravel substitutes because of less embeddedness.

All computations were carried out on a microcomputer, using commercially available spreadsheet software programs. During the analytical process, the data base was screened for errors and inconsistencies to assure accuracy of results.

To determine whether there was any relationship between the amount of usable habitat and the catch of rearing juvenile chinook at each study site, the computed HAIs for each sampling time were plotted against the corresponding catches of juvenile chinook salmon. In addition, these data were also plotted by reach, grouping habitat type study sites; by habitat type, grouping evaluation reaches; and by sampling period, grouping study sites. Coefficient of linear correlations (r) were also calculated for each of these relationships to determine the degree of linear correlation between catch and usable habitat area for each data grouping.

To evaluate whether there were significant differences between catch rates that could be explained on the basis of habitat quality and quantity, an analysis of covariance was performed. Whether HAI explained the observed variation in juvenile chinook salmon catches at a study site was the hypothesis tested.

The research hypothesis was evaluated by setting up an analysis of covariance (ANACOVA) in which the factor variables were treated as blocks. The covariate was the HAI ratio. The blocks were defined by reach of river and month of sampling. Habitat type was not used as either a blocking factor or treatment factor, because a significant correlation was found to exist between habitat type and HAI. This correlation indicated that either one or the other factor should be used in the model but not both. Because the habitat factor was the focus of the previous ANOVA analyses, only the HAI factor is included in the current analysis. Accordingly, the results of these analyses represent only one approach to looking at these data. The previous ANOVA analyses represent an additional approach. It should be cautioned that in both cases, the analyses conducted are only related to addressing the appropriate research hypotheses for the collected data set and <u>not</u> for making inferences to some unknown "population" of possible relationships.

The covariate (HAI) in the ANACOVA is the ratio of weighted usable area to total wetted surface area. There are three reaches of river: 1=lower, 2=middle, and 3=upper. The months sampled were July and October. Habitat types were as follows: 1=erosional, 2=grassy, 3=slough, and 4=gravel bar. The response variable was catch, as measured in numbers of juvenile chinook salmon collected by 15 minnow traps in a study site for the standard soak time. Replicates for the factorial design were the four samples taken during the 12-day sampling period each month. The design was flawed in that habitat type 1 (erosional) was not sampled in the middle reach, while eight samples were taken in two sites classified as grassy in the middle reach (refer to Table 3).

The first step in the analyses conducted was to investigate transformations of the response and covariate variable to approximate normality. The transformation chosen for catch was the natural logarithm of the catch plus one. The transformation used for the HAI index was the square root of the arc sine of HAI. This transformation often works well with proportion data [i.e., ratios between 0 and 1 (Snedecor and Cochran, 1980)].

The overall model investigated was:

$$C^*_{i,j,k} = mu + B_1 H^*_{i,j,k} + R_i + M_j + B_1 H^*_{i,j,k} R_i + B_1 H^*_{i,j,k} M_j + R_i M_j + B_1 H^*_{i,j,k} R_i M_j + e_{i,j,k}$$

where: $C^*_{i,j,k}$ = log (catch +1), observed in each combination of reach, month, and sample;

mu = mean response for all data;

B_1 = regression (or slope) parameter for HAI transformed index;

$H^*_{i,j,k}$ = square root [arc sine (HAI)] observed in each combination of reach, month, and sample;

R_i = effect of reach, i=1,2,3;

M_j = effect of month, j=7,10;

$e_{i,j,k}$ = error term associated with each observation, k=replicates in each combination.

The analyses of covariance of the overall model indicated that the three-way interaction term (BH*RM) was not a significant effect; all ANACOVA analyses were completed utilizing the General Linear Models procedure of the Statistical Analysis System (SAS 1982). Accordingly, a reduced model without this term was fitted. This reduced model indicated that of the two-way interaction terms only the BH*M term was significant. Therefore, the research hypothesis could not be directly evaluated with the reduced overall model. Accordingly, the next step in the analysis was to evaluate the individual groups of data as defined by month.

The individual models fit for each unique grouping were:

$$(C^*_{i,k} = mu + B_1 H^*_{i,k} + R_i + e_{i,k})_{.j.}$$

The null hypotheses for each of these models were:

H_o: $B_1 = 0$.

The alternative hypotheses were:

H_o: $B_1 0$.

FINDINGS

Results

Four responses to the Request for Proposal (RFP) for low-altitude photography of the Kenai River were received from private contractors. A committee reviewed the proposals and recommended one. The final selection of the contractor will be determined by the Commissioner of Fish and Game. It is anticipated the first set of photography will be obtained in August 1986.

Catches of juvenile chinook salmon at each of the habitat type study sites during each of the four sampling times conducted during the July and October sampling periods are shown in Table 4. Catches within a sampling period ranged from a high of 1550 fish (3.44 juveniles per minute, jpm) at the upper-river grassy habitat type study site during the July sampling period to a low of 0 fish (0 jpm) at the lower-river slough habitat type study site during the October sampling period. Catches for a given sampling day ranged from a high of 708 fish (1.57 jpm) in the middle river slough habitat type study site during day 2 of the July sampling period to a low of 0 fish (0 jpm) at several habitat type study sites.

Means ($\bar{x}$) and standard deviations (sd) of the juvenile chinook salmon catches at each habitat type study site for the four sampling times conducted during the July and October sampling periods are shown in Table 5 and Figure 6. These data indicate that during the July sampling period juvenile chinook salmon appear to be distributed by river reach.

Greater numbers of juvenile chinook fry were captured in the upper reach than the middle reach which in turn had more captures than the lower reach. In contrast, the data for the October sampling period indicate that juvenile chinook salmon are relatively equally distributed among the three reaches. With the exception of the middle reach which had slightly lower catches, the upper and lower reaches had comparable catches.

A summary of the results of the ANOVA for each of the six catch models developed to test for differences in catch rates between habitat types (with consideration of reach and sampling period) are presented in Table 6. These results show that there were no significant differences in catches at lower and upper river habitat types during the July sampling period and at the middle river habitat types during the October sampling period, but that significant differences in catches occurred at lower and upper river habitats during the October sampling period and at the middle river habitat types during the July sampling period.

Due to the similarity in the results for reaches 1 and 3, the data for these reaches were combined and another ANOVA performed (Table 7 and Appendix B). These results show that there were no significant differences in lower or upper river habitat type catches during the July sampling period; however, there were significant differences in catches during the October sampling period, with catches being highest in erosional type habitats followed by grassy, gravel bar, and slough habitat types.

Lastly, the results of a ANOVA model which had been adjusted to evaluate catch differences in middle reach habitats without regard to sampling period showed that significant differences in catches occurred in middle run habitat types during the July and October sampling periods; catches were highest in slough-type habitats followed by gravel bar and grassy habitat types (Appendix B and Table 7).

The mean fork lengths of juvenile chinook salmon fry captured in each river reach by sampling period is presented in Table 8. Based on these data, little differences in mean fork length occurred between reaches during either the July or October sampling periods. As expected, however, significant differences in mean fork length occurred within reaches between sampling periods with the mean fork length in each reach increasing from the July to October sampling period. During the July sampling period, the mean fork length for grouped habitats was 55.1 mm (sd=10.0). This compares to a mean fork length of 70.3 mm (sd=6.8) for grouped habitats during the October sampling period.

A summary of the results of the freeze-branding mark/recapture efforts are presented in Table 9. The large fluctuations in catches between sampling days at many of the study sites indicate that the population of rearing juvenile chinook salmon is relatively open. That is, significant movement of juvenile chinook salmon to and from each of the study sites seem to occur. For this reason, it was not possible to calculate population numbers for each study site.

Brief narratives describing the general habitat characteristics present at each of the habitat type study sites are presented in Appendix B. Included in each narrative is a discussion of the pertinent riparian and instream conditions present at the site as well as the proximity of the site to natal areas, lakes, or tributary mouths.

A summary of the water quality measurements (dissolved oxygen, pH, temperature, and conductivity) taken at each study site at each time of sampling are presented in Table 10. Depth, velocity, and cover data collected at each habitat type study site at each time of sampling are on file at the ADF&G Anchorage Sport Fish Division office.

A summary of the computed habitat response functions (AREA, WUA, and HAI) and juvenile chinook salmon catch data for each habitat type study site at each time of sampling are presented in Tables 11-13. In addition, the HAI functions plotted against the corresponding catch data for each habitat type study site at each time of sampling are presented in Figure 7. These data are also plotted by reach grouping habitat type study sites (Figures 8-10), by habitat type grouping evaluation reaches (Figures 11-14), and by sampling period grouping habitat type and evaluation reaches (Figures 15-17). The number of points plotted and the computed coefficient of linear correlation for these relationships are presented in Table 14.

These data indicate that there is an overall positive relationship, as indicated by a "r" value of 0.45, between study site habitat usability (as indexed by HAI) and the catch of rearing juvenile chinook at that study site. The relationship appeared stronger for some groupings of the data than other groupings. In terms of reach, the relationship appeared strongest for the lower river grouping and non-existent for the middle river grouping. In terms of habitat type, the relationship appeared strongest for erosional type habitats followed by grassy, gravel bar, and slough type habitats. In terms of sampling period, the relationship appeared stronger for the October grouping than for the July grouping.

The results of the ANACOVA for the two habitat test models are presented in Appendix A. These data indicate that the relationship between HAI and catch is significant for all study sites grouped during the October sampling period and that the relationship is positive in nature. No significant relationship was found to occur between these two variables for all study sites grouped during the July sampling period.

Discussion

The first year of this new program provided the groundwork for future efforts to protect and properly manage riparian and instream habitat that are essential to the production of this recreational fishery. As the program evolves, it is anticipated that the various products will provide the guidelines necessary to allow for the continued health of the state's largest recreational fishery while at the same time providing for economic development which is properly planned and in concert with the ecological balance of this watershed.

Selection of specific habitat types for evaluation in this study was based on a review of aerial-photography and the results of a reconnaissance level field trip to preliminarily identify the various habitat types present in each of the evaluation reaches. A comprehensive evaluation to identify and classify all habitats within the Kenai River has not been conducted. Therefore, it is possible that not all habitat types present within each of the three evaluation reaches were represented in the four habitat types selected for evaluation. It is believed, however, that the four habitat types selected for evaluation (erosional, grassy, slough, and gravel bar) represent the most important habitat types present in each of the three evaluation reaches studied for rearing juvenile chinook salmon.

It was only possible to evaluate one study area containing each of the four habitat types within each of the three evaluation reaches. Because of this, it is possible that the habitat type study sites selected for evaluation in each of the three evaluation reaches did not represent the full range of those habitat types present in each of the respective evaluation reaches. At this time, insufficient data are available to determine the degree to which the selected habitat type study sites represent the range of those habitat types present in each of the respective evaluation reaches. Insufficient data are also available at this time to weight the results obtained for each of the habitat type study sites in each of the evaluation reaches in terms of the relative amount of that habitat types in its respective reach. Because of this, the results of this study should not be extrapolated beyond the limits of the study sites.

It was also only possible to sample study areas twice during the open-water season. Because of this restriction, analyses of the data (in terms of describing seasonal juvenile chinook salmon abundance and distribution at and between study sites) are limited to the two sampling periods conducted during the course of the study. This restriction also makes it difficult to fully examine seasonal changes in rearing habitat within each of the three evaluation reaches.

Baited fry traps were chosen in this study as the preferred method for the capture of rearing juvenile chinook salmon. Other means of capture, such as electrofishing and beach seining were deemed unfeasible due to steep bank and high velocities at many of the study sites.

Several inherent biases are associated with the use of baited fry traps for the capture of rearing juvenile chinook salmon. One such bias is associated with the size of fish captured. Fry traps are not an effective means of capturing fry less than 35 mm in length. This was not considered to be a large problem in this study as the vast majority of rearing juvenile chinook salmon at the study sites during the early (July) sampling period should have already surpassed this length (Burger et al., 1982).

Another bias is associated with the capture efficiency of the fry traps. Habitat variables such as temperature have been known to influence the capture efficiency of baited fry traps. The small differences in water temperature measured at sampling sites during the July and October sampling periods (from a low of 5°C to a high of 12°C) did not likely significantly influence the catch efficiency of fry traps in this study.

Another bias is associated with the capture of fish not rearing in the study site at the time of sampling due to the attractiveness of the baited traps. Attractance to baited traps of fish that are outside of the study area was limited by placement of barrier traps along the downstream boundary of the site. It was assumed that fry downstream of the study site that were drawn up to the site by the scent of bait were captured by the barrier traps. Thus they were not subject to capture by the sample traps within the site.

Bias associated with subsequent trap avoidance after initial capture was minimized by allowing a 3-day interval between sampling times. Stress due to capture, sizing, and branding was also minimized to the fullest extent possible.

Length data collected for juvenile chinook salmon in this study may have been biased because of a flaw in the sampling procedure used to collect the length data. The bias results from the possible nonrandom selection of fish for length measurement in catch samples above 50 fish. Because the first 50 fish were measured, rather than 50 fish at random, it is possible that in instances where the catch was greater than 50 that bias occurred. It is believed, however, that such bias is small as catches at a study site were typically less than 50, and care was taken to randomly select fish for measurement when catches were greater than 50.

The analyses of habitat data performed in this study are based on the underlying assumption that the quality and quantity of rearing habitat at a site can be described on the basis of a set of habitat factors that determine its usability for rearing. In this study, it was assumed that the set of habitat variables of depth, velocity, and cover were the habitat variables that most influence the usability of a site for juvenile chinook rearing. The effect that other habitat variables, such as temperature or food availability, have on the usability of habitat for rearing was not evaluated in this study. It is believed, however, that these variables are of lesser importance than those evaluated within this study and that the usability of habitat at a study site can be described on the basis of a set of weighting factors for depth, velocity, and cover.

A possible limitation of the habitat analyses conducted in this study is associated with the process used to select study sites. Because only bank-type habitats were evaluated, the range of depths and velocities sampled over the course of this study were limited. This, coupled with the fact that cover weighting factors were developed partially based on information collected during the course of this study, may result in the relative importance of the cover variable being overestimated.

Juvenile chinook salmon fry captured during this study had a mean fork length of 63.0 mm (sd=11.4 mm, n=1032), indicating that the majority of fish captured during the course of this study were Age 0.0+ (Burger et al., 1982). The mean fork length of captured juveniles at all study sites increased from the July sampling period ($\bar{x}$=55.1 mm, sd=10 mm, n=492) to the October sampling period ($\bar{x}$=70.3 mm, sd=6.8 mm, n=541). This represents an estimated growth of 22% between these sampling periods. It must be cautioned when viewing this growth rate, however, that, because sample sizes were small and individual fish used to calculate this estimate were not marked, that this growth estimate does not represent an absolute growth rate for fish at these sites.

Catch rates of juvenile chinook salmon fry in this study varied from 0-1550 juveniles captured per 450 minutes effort, or 0-3.44 juveniles per minute. These catch rates are comparable to previously published catch rates for Kenai River juvenile chinook of 0-3.97 juveniles per minute (Burger et al., 1982) and 0.32-1.57 juveniles per minute (Litchfield, 1986) and are significantly higher than published catch rates for Susitna River juvenile chinook of 0-0.02 juveniles per minute (ADF&G, 1981b).

The ANOVA results for the catch data showed that differences in catch rates occurred at habitat type study sites within reaches and sampling periods; that is, juvenile chinook salmon were distributed unevenly among habitat types within reaches between sampling periods. Because of interaction between the habitat type and reach functions and the habitat type and month functions in the ANOVA model, it was not possible to determine whether catches differed between reaches when grouping habitat types and sampling periods or sampling periods when grouping habitat types and reaches.

The ANOVA results did show, however, that the catch data collected within the lower and upper reaches were similar in that the effect of sampling period and habitat type on catch rates was similar. For these two reaches, there were no significant differences in catch rates between habitat types during the July sampling period. A possible explanation for this is that juvenile chinook did not have sufficient time as of the July sampling period to distribute themselves in the river from their natal areas.

In contrast, during the October sampling period significant differences in catch rates between habitat types occurred; erosional type habitats had the largest catch rates, followed in order by grassy, gravel bar, and slough habitat types. These differences in catch rates likely result from specific differences in the quality and quantity of cover at these habitat types. Erosional habitat types in these reaches provided much cover in the form of highly suitable deadfall, overhanging riparian vegetation, and undercut banks. Grassy habitat types also provided much cover in the form of emergent vegetation and undercut banks. Gravel bar and slough habitat types provided less cover, with gravel-to-cobble substrates providing the most cover at gravel bar habitat types and aquatic vegetation providing some cover at slough habitat types.

The ANOVA results also showed that significant differences in catch rates occurred within months among middle river habitat types. Catch rates were highest in the slough habitat type, followed by gravel bar and grassy habitat types. As in the upper and middle reaches, these differences are probably a result of the cover present at these sites. Much cover is present at the slough habitat type in this reach mostly in the form of highly suitable emergent vegetation. Less suitable cover is present at the middle river grassy and gravel bar habitat types with emergent vegetation and various sized substrate providing the most cover at these habitat types.

Taken together, these findings indicate that one of the most important habitat variables influencing the presence of rearing juvenile chinook salmon at a habitat type study site is the quality and quantity of cover. This is likely related to the fact that cover at a particular site not only provides hiding and feeding places but also velocity breaks, which thereby improves the overall usability of the site in terms of cover and velocity suitability. It must be cautioned, however, that because only bank-type habitats were sampled during the course of this study, the range of depths and velocities evaluated were limited. As a result, the relative importance of cover may be overestimated.

The findings of the habitat analyses generally support these conclusions. In general, these data indicate that an overall positive relationship exists between habitat usability (as indicated by the HAI function) and the catch of rearing juvenile chinook at a study site. This indicates that depth, velocity, and cover can be used to describe the usability of a site for rearing juvenile chinook salmon. These findings also suggest that although particular habitats may be more suitable for rearing than other habitats, that in general the river has many areas that are suitable for rearing by juvenile chinook salmon.

The results of the habitat analyses also indicate that the relationship between habitat usability and catch is stronger for some subgroupings of the data than for others. In terms of habitat type, the relationship appeared strongest for erosional-type habitats, followed by grassy, gravel bar, and slough-type habitats. As stated previously, these differences are likely related to the availability of usable cover at these various habitat types, supporting the conclusion that the quality and quantity of cover at a habitat type study site is important in terms of the usability of that site for rearing by juvenile chinook salmon.

In terms of sampling period, the results indicate that the relationship between habitat availability and catch is stronger for all study sites grouped during the October sampling period than during the July sampling period. A possible explanation for this is that juvenile chinook salmon fry may not have had sufficient time as of the July sampling period to distribute themselves among the various habitat types available in the river from their natal rearing areas.

The results of the freeze-branding effort indicate that the population of rearing juvenile chinook fry at a particular site in the river is open rather than closed; that is, significant recruitment of juvenile chinook fry into and out of the site occurs over time. Generally, this indicates that, although particular habitats within the river may be more suitable for rearing than other habitats, the river has many areas that are suitable for rearing.

Conclusions:

1. The catch rates of juvenile chinook salmon fry observed during the course of this study are comparable to previously published catch rates for Kenai River chinook juveniles and are significantly higher than those observed in other Alaskan glacial river systems.

2. An overall positive relationship exists between habitat usability and the catch of rearing juvenile chinook salmon fry at a given habitat type study site indicating that depth, velocity, and cover can be used to describe the usability of a site for rearing by juvenile chinook salmon during the open-water season.

3. Velocity and cover appear to be the two most important habitat variables influencing the usability of a study site for juvenile chinook rearing. Of these, cover may be the most important because it provides hiding and feeding places and velocity breaks.

4. Significant differences in catch rates occurred between habitat types within reaches and sampling periods; the differences were probably attributable to the quality and quantity of cover available at each of the habitat types.

5. The relationship between habitat usability and juvenile chinook salmon catch is stronger for the October sampling period than for the July sampling period. A possible explanation for this is that juvenile chinook salmon may not have had sufficient time as of the July sampling period to distribute themselves from their natal areas to the various habitat types available in the river.

6. The population of rearing juvenile chinook salmon fry at a particular area in the river appears relatively open rather than closed, indicating significant recruitment of fry occur into and out of the site over time. Generally, this suggests that, although particular habitat types in the river may be more suitable for rearing than others, the river has many areas that are suitable for rearing.

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ACKNOWLEDGEMENTS

The authors would like to acknowledge the Juvenile Chinook Salmon Study crew (D. Litchfield, T. Tobias, J. Kelly, and D. Westerman) of the ADF&G Fisheries Rehabilitation Enhancement and Development Division for their able assistance in the field portion of this study. Special thanks is also extended to L. Flagg for providing the assistance of these staff and his equipment.

The authors also wish to acknowledge D. Schmidt for his advice and comments on the design of this study. The authors also wish to express thanks to A. Bingham for his advice and assistance regarding the statistical analyses performed in this study.

The authors also express their gratitude to A. Armstrong for her diligent effort and patience in typing the numerous drafts of this document and to C. Hepler for drafting assistance.

Lastly, the authors wish to express special thanks to D. Vincent-Lang and P. Suchanek for their assistance in writing, analyzing, and editing portions of the report.

APPENDICES

Appendix A:

Figures and Tables.

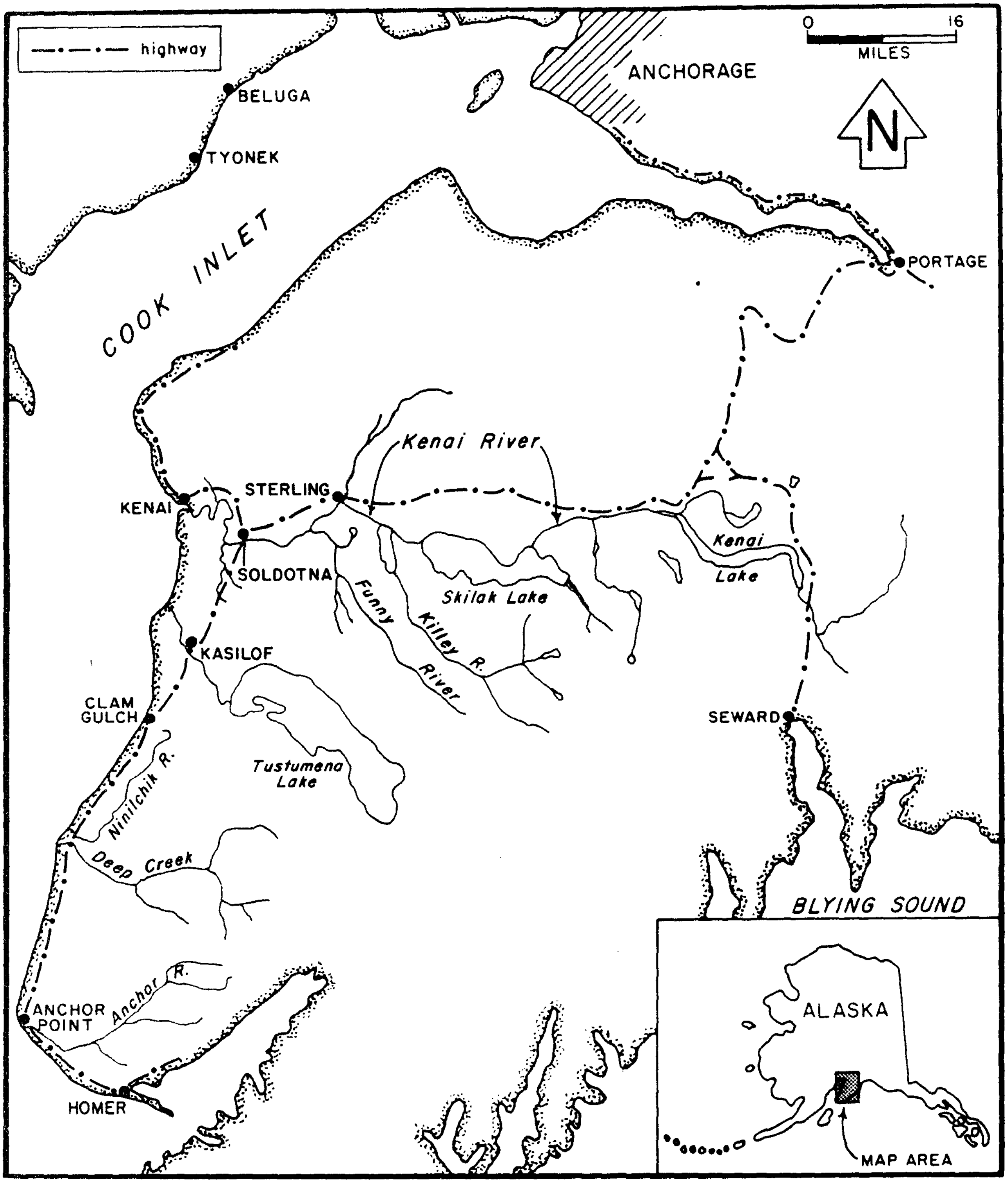


Figure 1. Kenai River basin, Kenai Peninsula, Alaska.

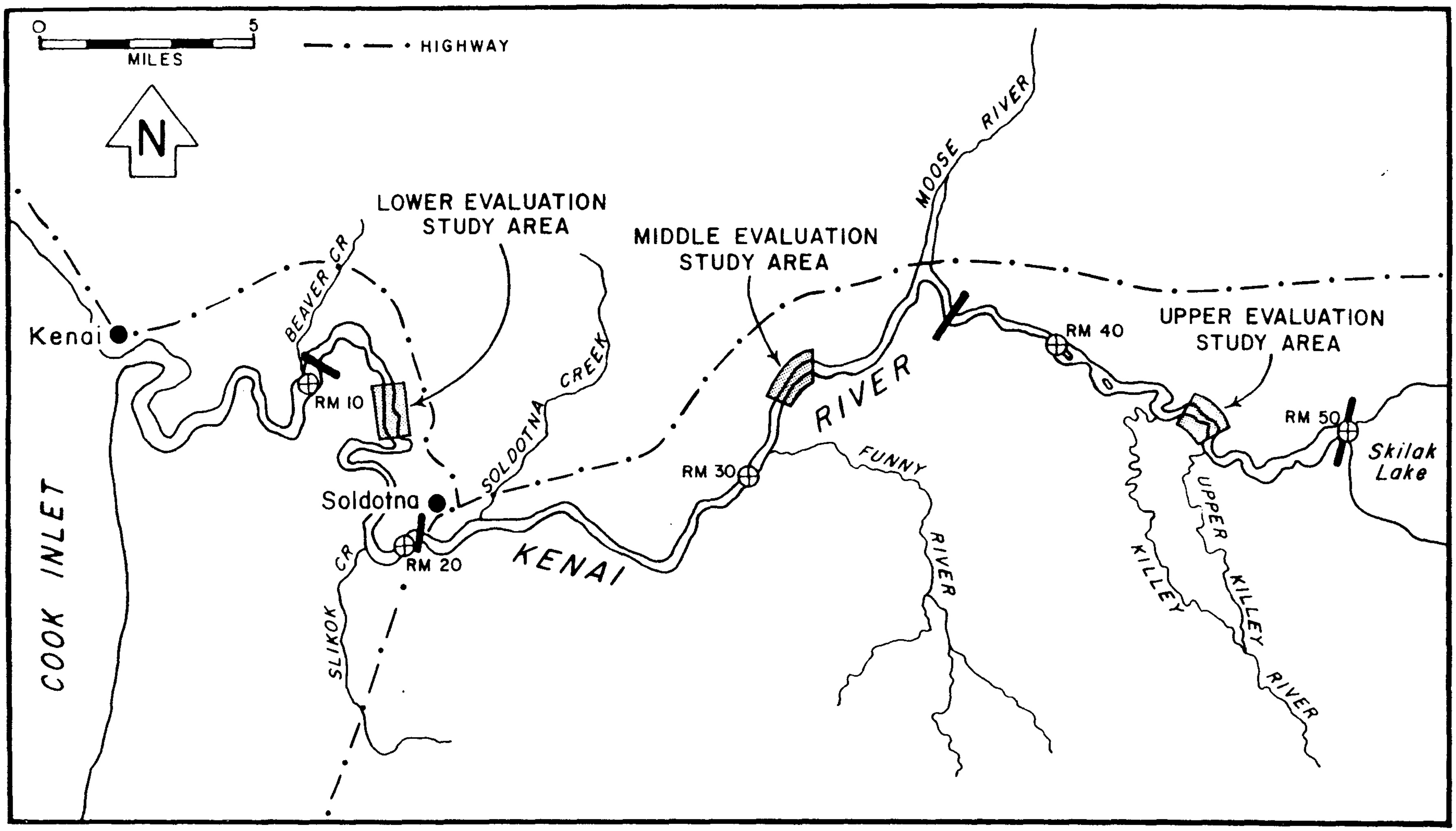


Figure 2. Locations of evaluation reaches and their study areas.

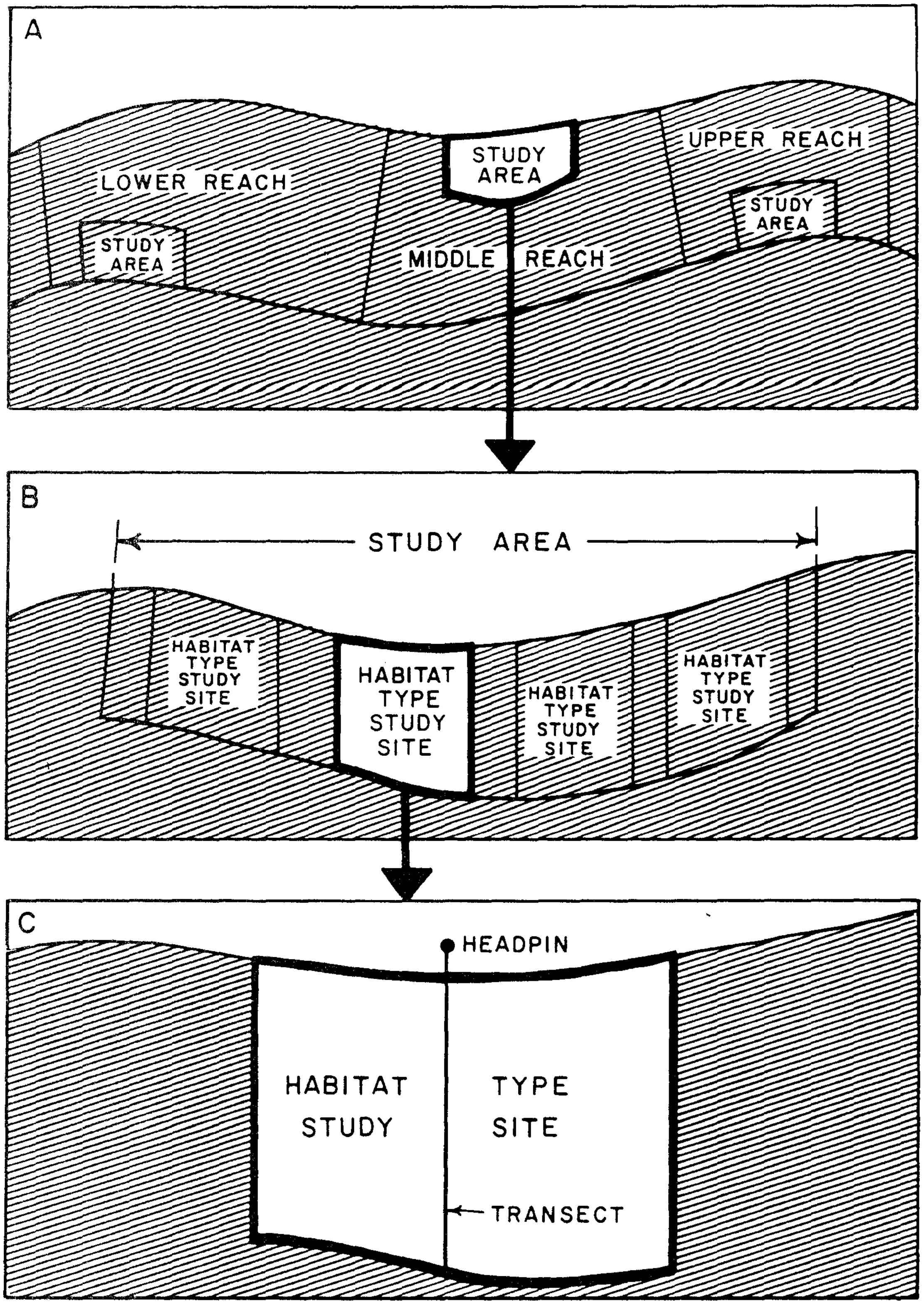
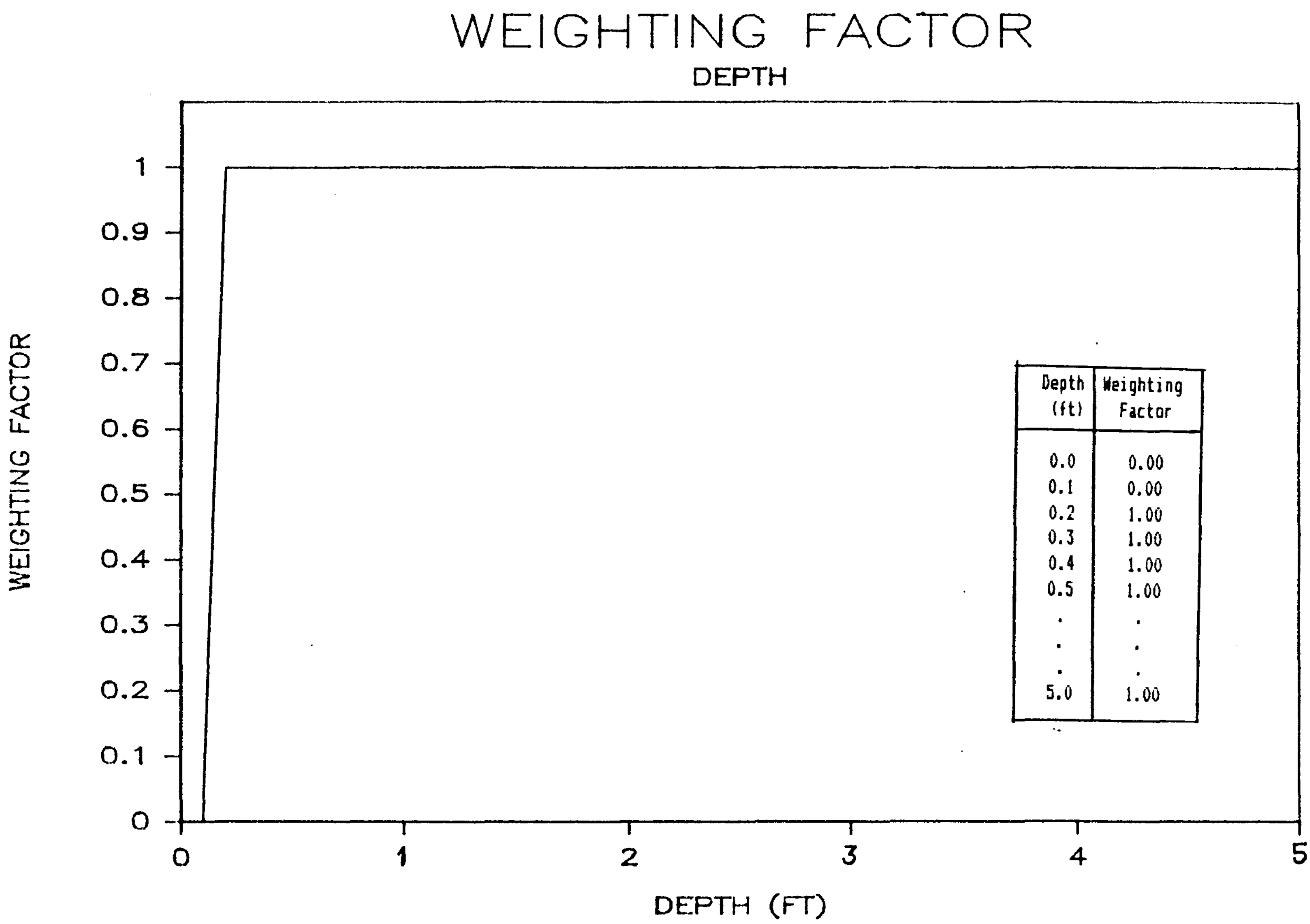
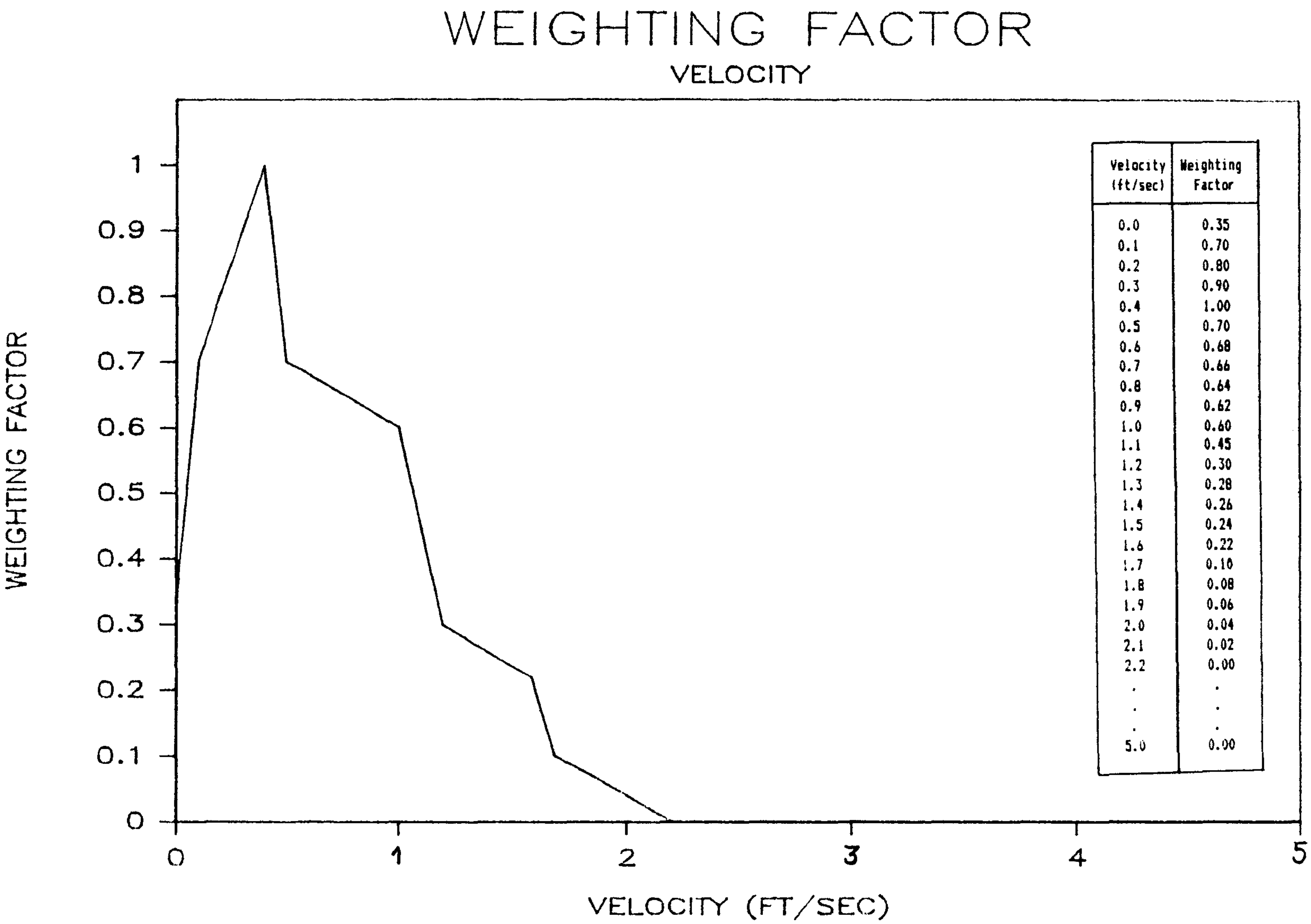


Figure 3. Hierarchical approach used to select study sites.



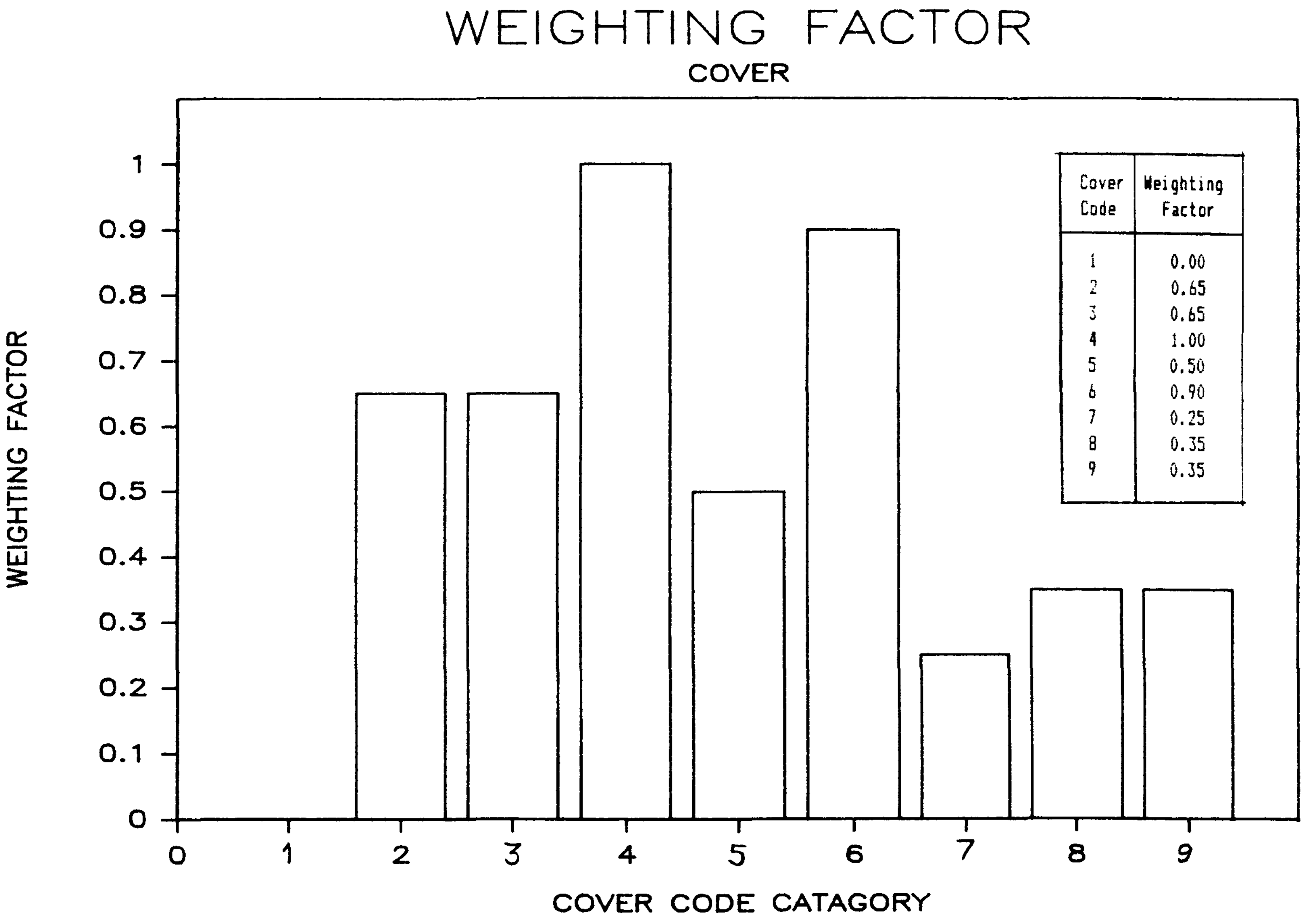
Depth (ft)	Weighting Factor
0.0	0.00
0.1	0.00
0.2	1.00
0.3	1.00
0.4	1.00
0.5	1.00
.	.
.	.
.	.
5.0	1.00

Figure 4. Depth weighting factor for juvenile chinook salmon rearing in the Kenai River.



Velocity (ft/sec)	Weighting Factor
0.0	0.35
0.1	0.70
0.2	0.80
0.3	0.90
0.4	1.00
0.5	0.70
0.6	0.68
0.7	0.66
0.8	0.64
0.9	0.62
1.0	0.60
1.1	0.45
1.2	0.30
1.3	0.28
1.4	0.26
1.5	0.24
1.6	0.22
1.7	0.10
1.8	0.08
1.9	0.06
2.0	0.04
2.1	0.02
2.2	0.00
.	.
.	.
.	.
5.0	0.00

Figure 5. Velocity weighting factor for juvenile chinook salmon rearing in the Kenai River.



Cover Code	Weighting Factor
1	0.00
2	0.65
3	0.65
4	1.00
5	0.50
6	0.90
7	0.25
8	0.35
9	0.35

Figure 6. Cover weighting factors for juvenile chinook salmon rearing in the Kenai River.

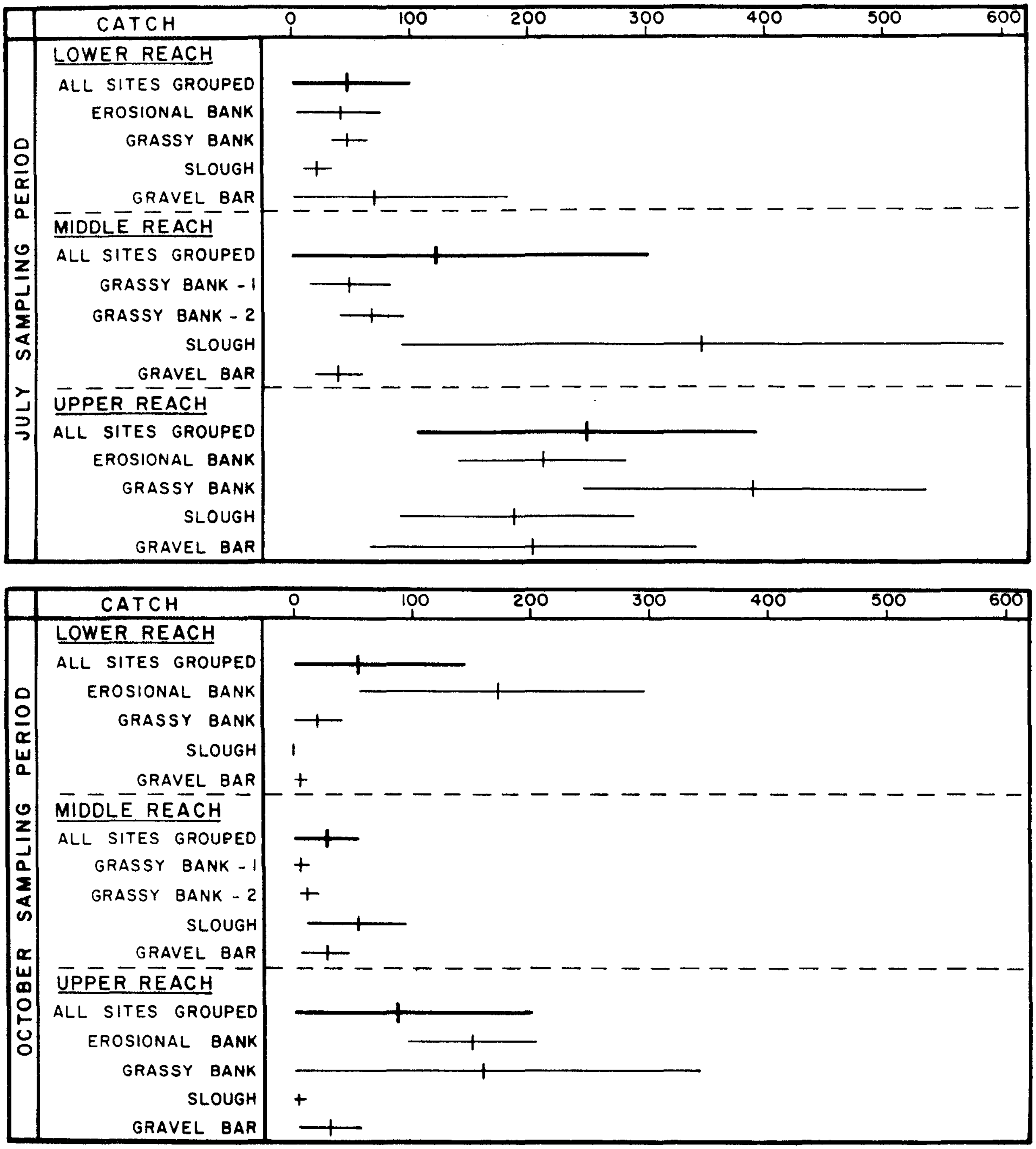


Figure 7. Means (|) and standard deviations (——) of catches of juvenile chinook fry at habitat type study sites for each of the four sampling times conducted during the July and October sampling periods.

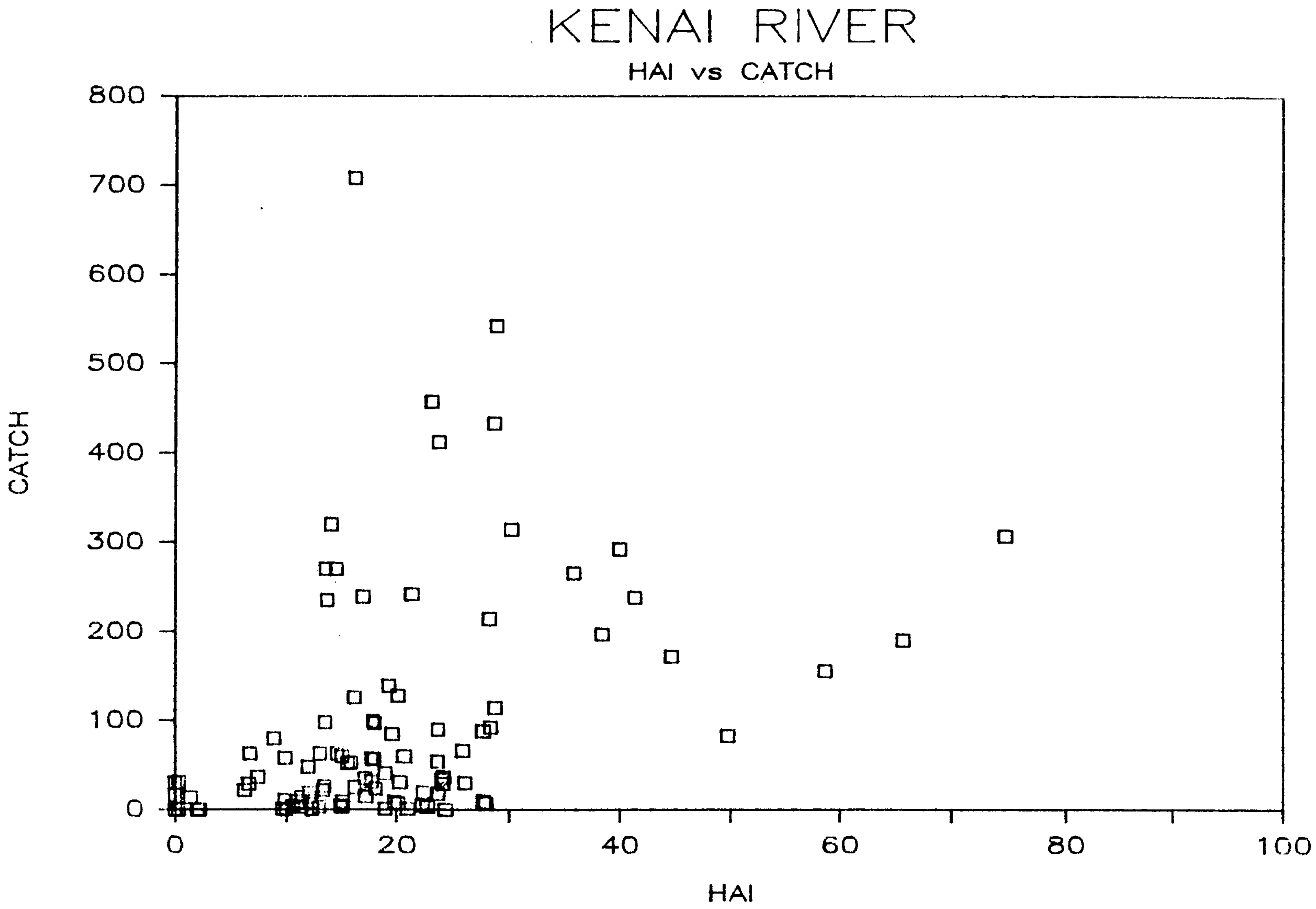


Figure 8. Plot of HAI versus juvenile chinook salmon catches for all habitat type study sites on all dates of sampling.

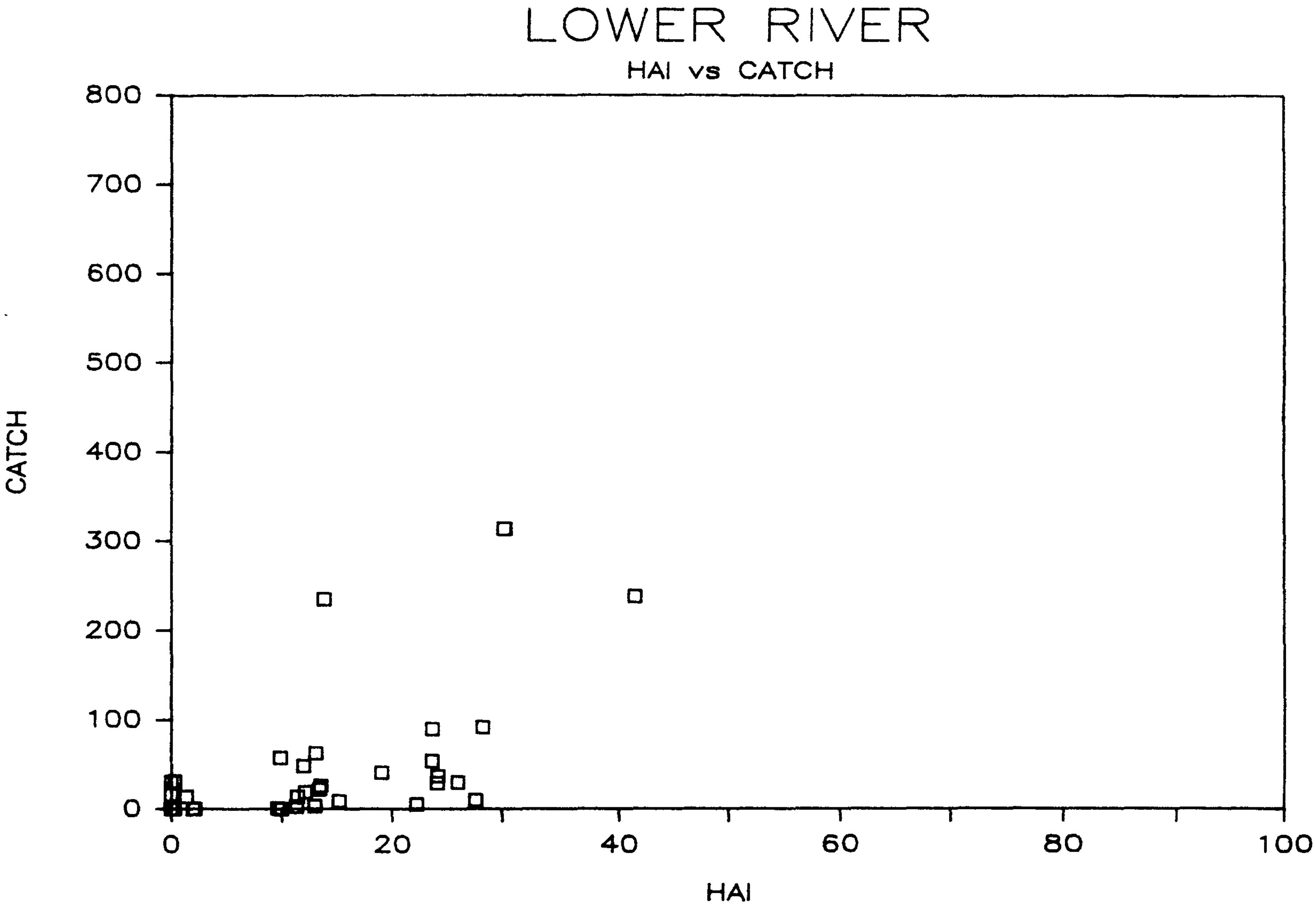


Figure 9. Plot of HAI versus juvenile chinook salmon catches for lower river habitat type study sites on all dates of sampling.

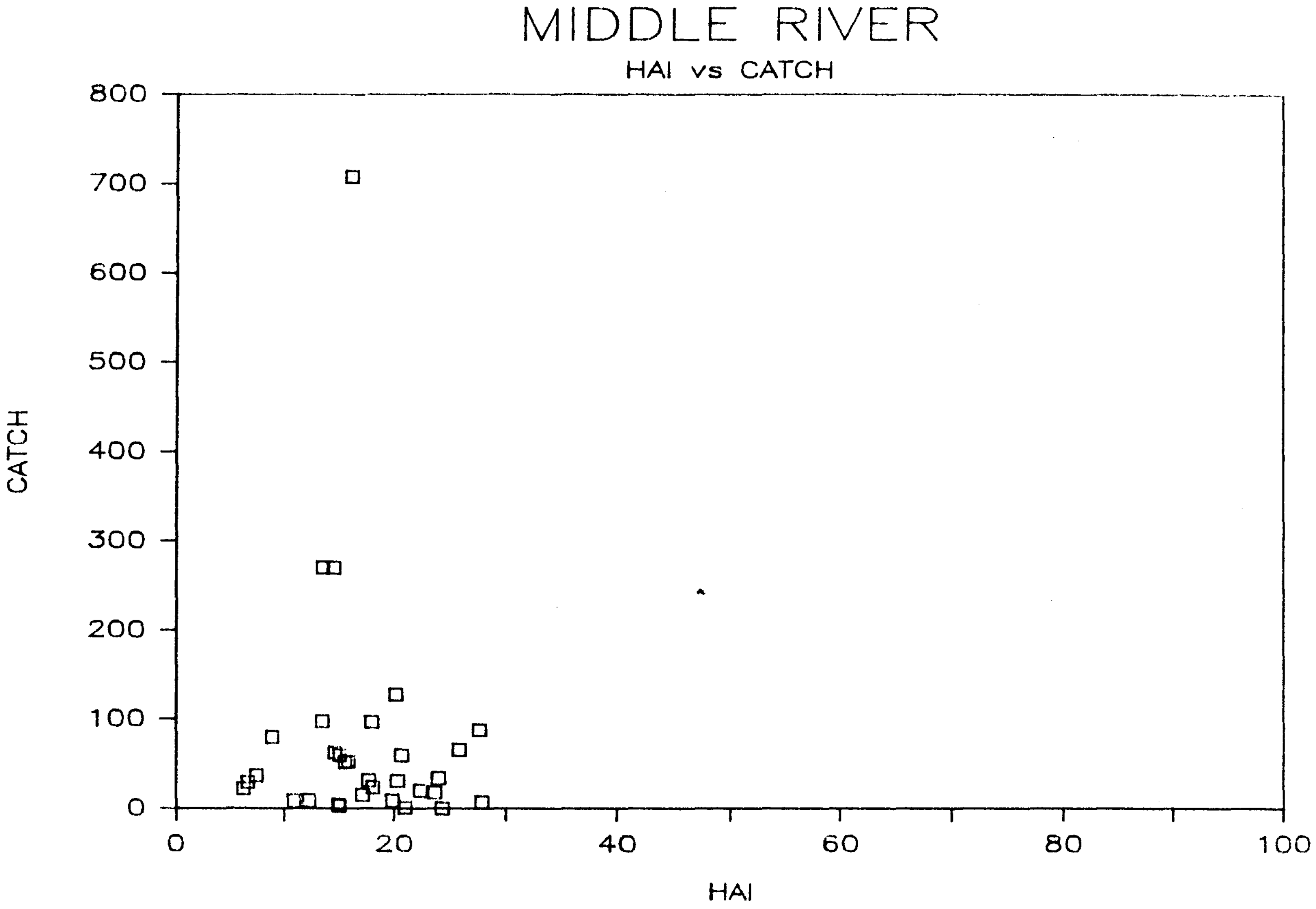


Figure 10. Plot of HAI versus juvenile chinook salmon catches for middle river habitat type study sites on all dates of sampling.

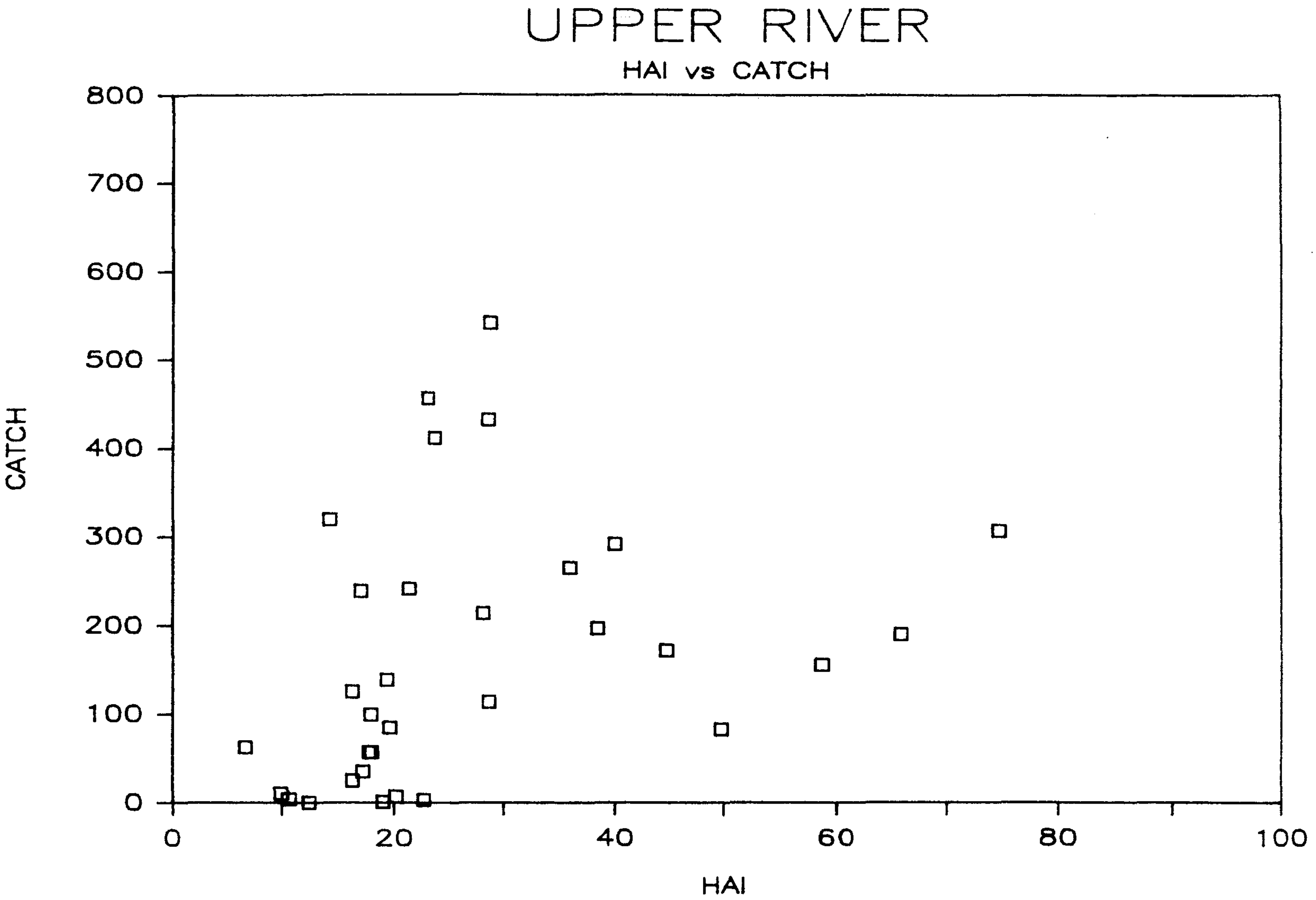


Figure 11. Plot of HAI versus juvenile chinook salmon catches for upper river habitat type study sites on all dates of sampling.

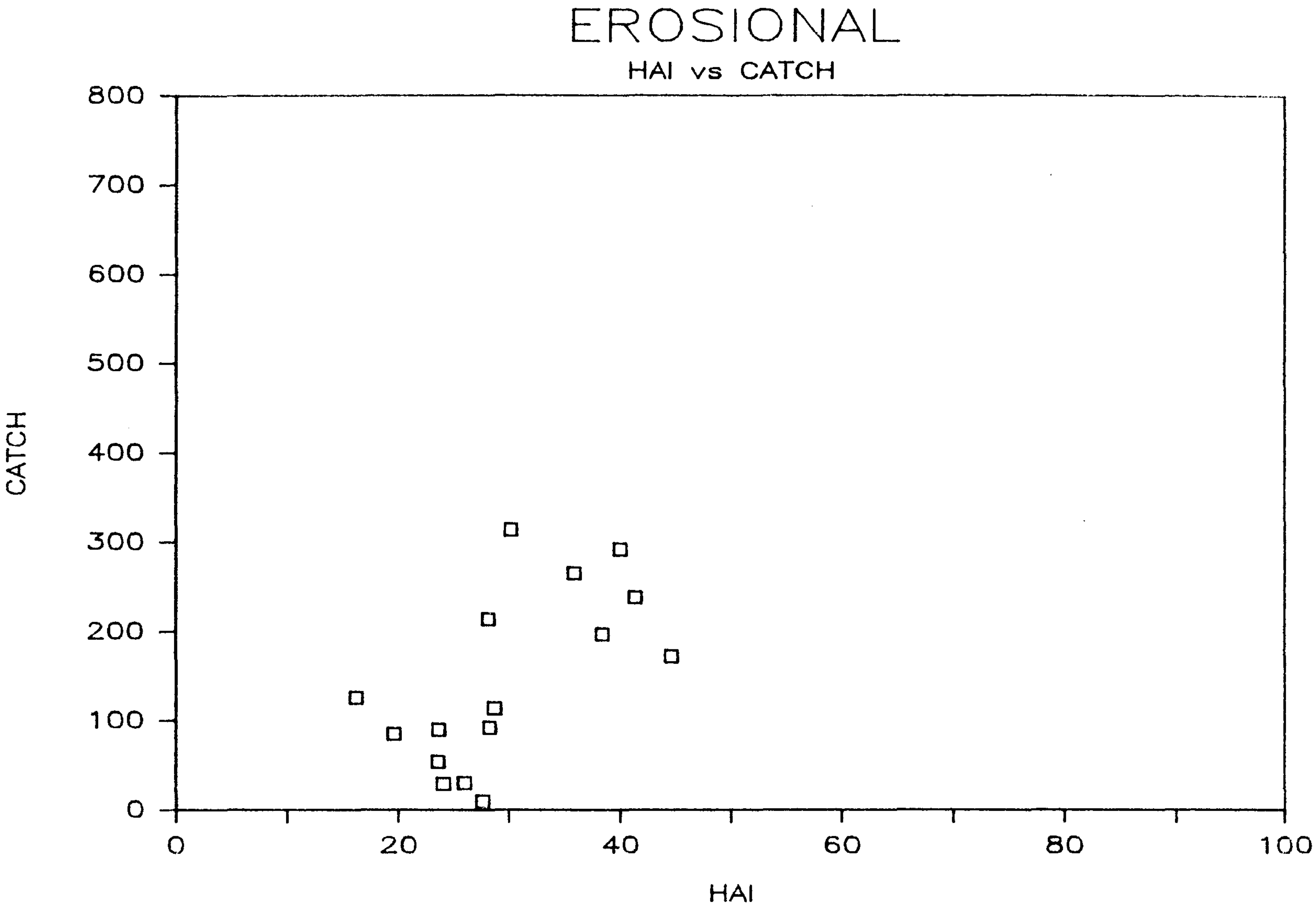


Figure 12. Plot of HAI versus juvenile chinook salmon catches for all erosional habitat type study sites on all dates of sampling.

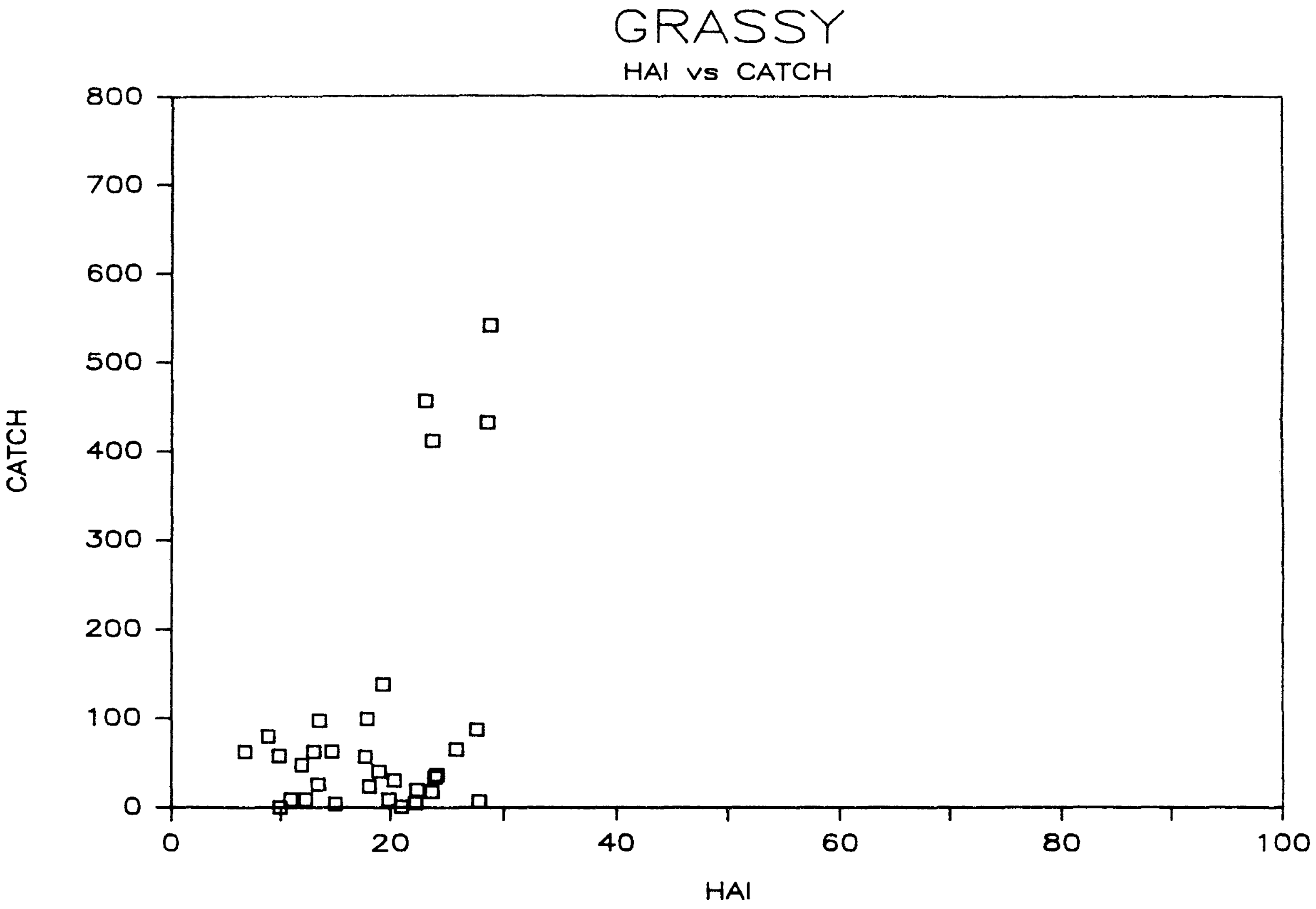


Figure 13. Plot of HAI versus juvenile chinook salmon catches for all grassy habitat type study sites on all dates of sampling.

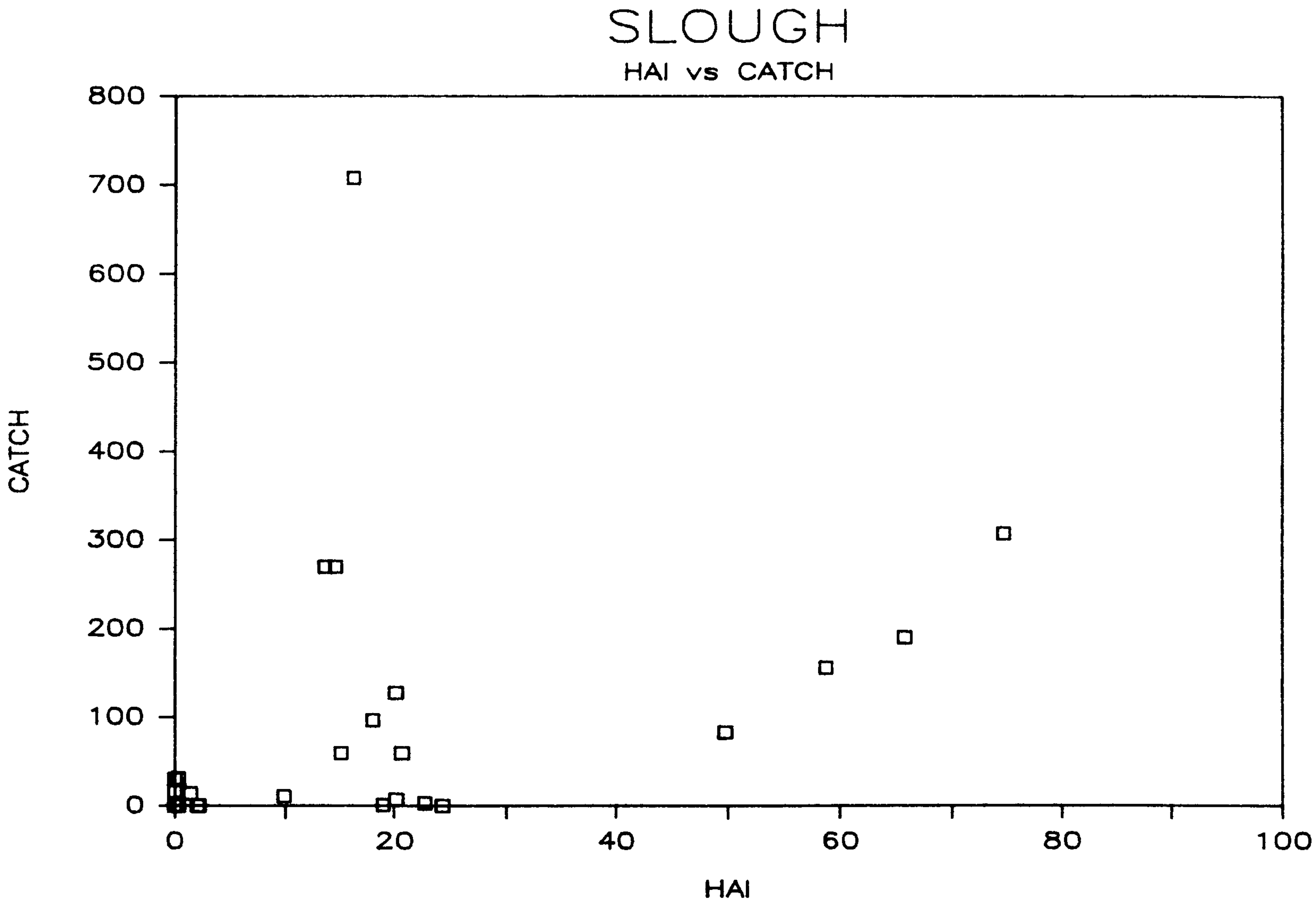


Figure 14. Plot of HAI versus juvenile chinook salmon catches at all slough habitat type study sites on all dates of sampling.

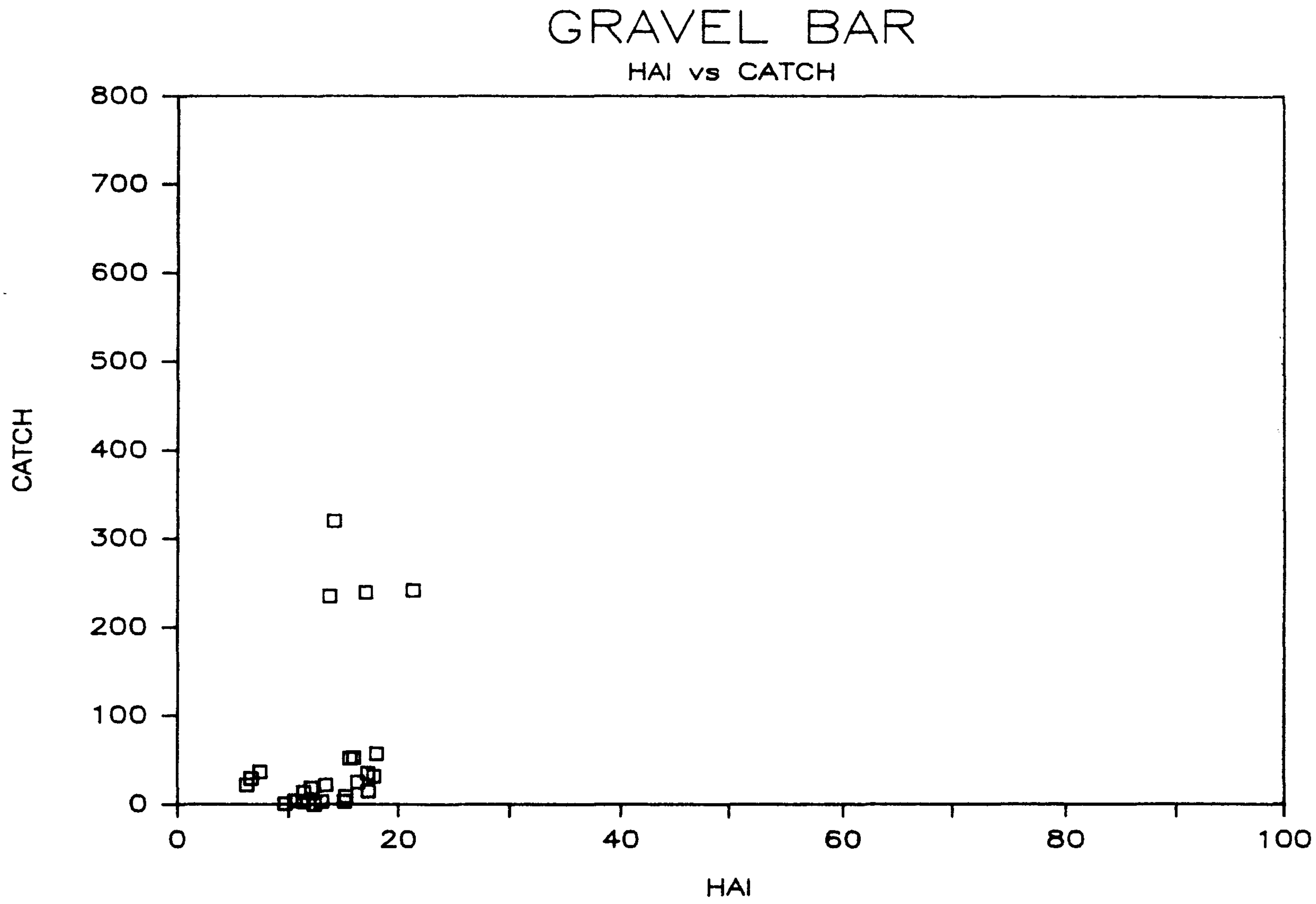


Figure 15. Plot of HAI versus juvenile chinook salmon catches at all gravel bar habitat type study sites on all dates of sampling.

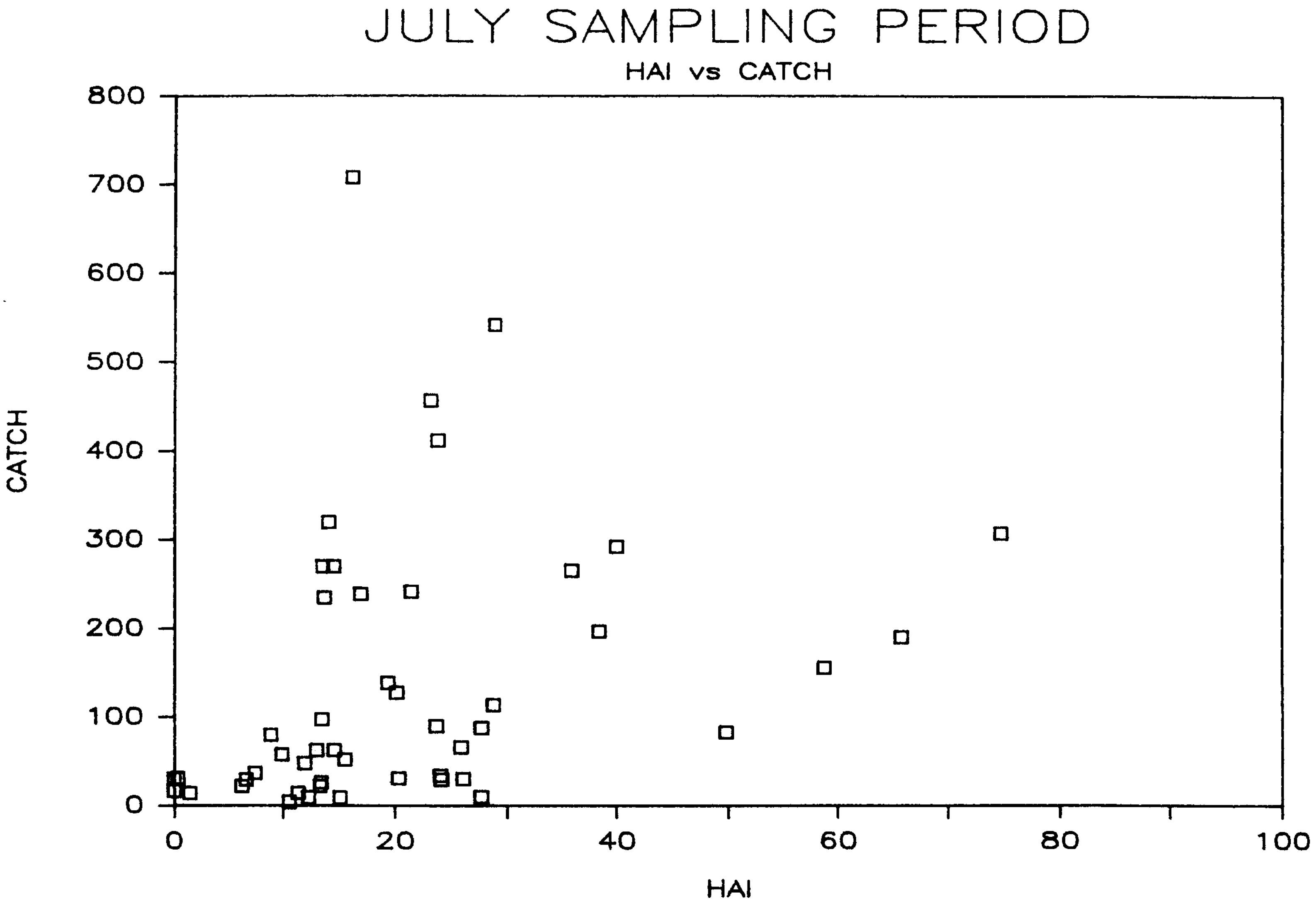


Figure 16. Plot of HAI versus juvenile chinook salmon catches for the July sampling period at all habitat type study sites.

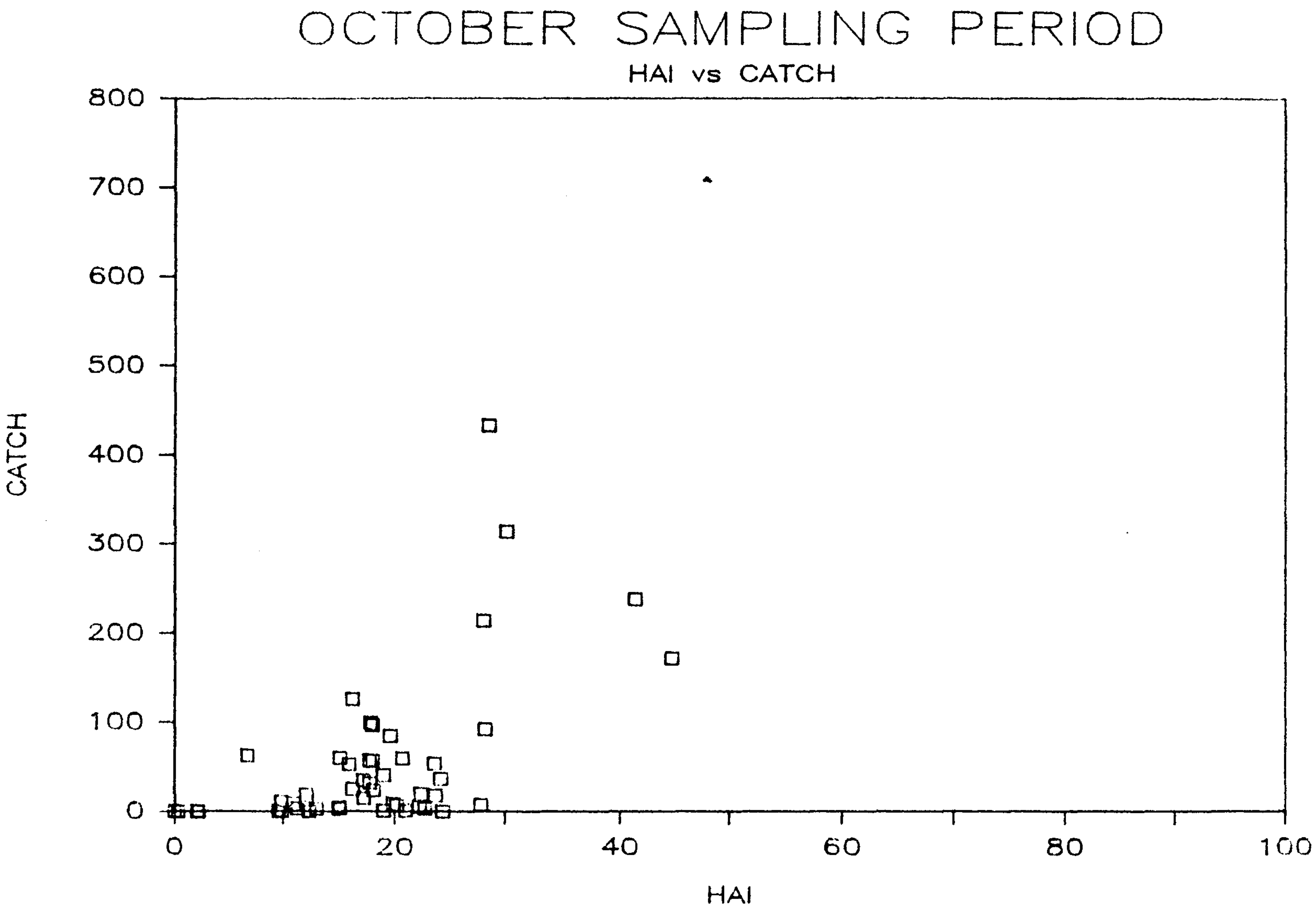


Figure 17. Plot of HAI versus juvenile chinook salmon catches for the October sampling period at all habitat type study sites.

Table 1. Categories used to code predominant cover type at habitat type study sites.

Cover Code Category	Cover Type
1	No object cover
2	Emergent vegetation
3	Aquatic vegetation
4	Debris or deadfall
5	Overhanging riparian vegetation
6	Undercut banks
7	Gravel (1" to 3" diameter)
8	Rubble (3" to 5" diameter)
9	Cobble (>5" diameter)

Table 2. Schedule used to sample study sites.

Sampling Period	Sampling Day	Date of Sampling Lower Reach	Middle Reach	Upper Reach
July	1	July 1	July 2	July 3
	2	July 5	July 6	July 7
	3	July 9	July 10	July 11
	4	July 13	July 14	July 15
October	1	Sept. 30	Oct. 1	Oct. 2
	2	Oct. 4	Oct. 5	Oct. 6
	3	Oct. 8	Oct. 9	Oct. 10
	4	Oct. 12	Oct. 13	Oct. 14

NOTE: All habitat type study sites within each evaluation reach were sampled on the same date.

Table 3. Summary of sampling effort conducted in each of the three evaluation reaches.

Habitat Type	Reach		
	Lower	Middle	Upper
Erosional Bank	4	0	4
Grassy Bank	4	8	4
Slough	4	4	4
Gravel Bar	4	4	4

Table 4. Catch of juvenile chinook salmon at habitat type study sites within each evaluation reach by sampling time.

Reach	Sample Period	Habitat Type Study Site	Catch by Sampling Day				
			Day 1	Day 2	Day 3	Day 4	Total
Lower	July	Erosional Banks	10	29	30	90	159
		Grassy Banks	58	26	48	63	195
		Slough	30	16	31	14	91
		Gravel Bars	9	22	14	235	280
	October	Erosional Banks	238	92	314	54	698
		Grassy Banks	41	37	5	0	83
		Slough	0	0	0	0	0
		Gravel Bars	3	3	19	1	26
Middle	July	Grassy Bank-1	9	34	66	88	197
		Grassy Bank-2	31	63	80	98	272
		Slough	128	708	270	270	1376
		Gravel Bar	52	29	22	37	140
	October	Grassy Bank-1	9	9	20	1	39
		Grassy Bank-2	7	18	24	4	53
		Slough	97	60	60	0	217
		Gravel Bar	15	32	53	3	103
Upper	July	Erosional Bank	114	292	265	197	868
		Grassy Bank	139	542	457	412	1550
		Slough	156	307	83	190	736
		Gravel Bar	4	320	242	239	805
	October	Erosional Bank	214	172	126	85	597
		Grassy Bank	433	100	57	63	653
		Slough	3	11	7	1	22
		Gravel Bar	35	25	57	0	117

Table 5. Means and standard deviations of juvenile chinook salmon catches for study sites for the four sampling times during the July and October sampling periods (n=number of points used to calculate means).

Reach	Sample Period	Habitat Type Study Site	Catch Mean	Catch Standard Deviation	n
Lower	July	All sites grouped	45.3	55.2	16
		Erosional Bank	39.8	34.7	4
		Grassy Bank	48.8	16.4	4
		Slough	22.8	9.0	4
		Gravel Bar	70.0	110.1	4
	October	All sites grouped	50.4	92.9	16
		Erosional Bank	174.5	122.2	4
		Grassy Bank	20.8	21.2	4
		Slough	0.0	0.0	4
		Gravel Bar	6.5	8.4	4
Middle	July	All sites grouped	124.1	174.1	16
		Grassy Bank-1	49.3	34.8	4
		Grassy Bank-2	68.0	28.5	4
		Slough	344.0	251.7	4
		Gravel Bar	35.0	12.9	4
	October	All sites grouped	25.8	27.8	16
		Grassy Bank-1	9.8	7.8	4
		Grassy Bank-2	13.3	9.4	4
		Slough	54.3	40.2	4
		Gravel Bar	25.8	21.7	4
Upper	July	All sites grouped	247.0	141.2	16
		Erosional Bank	217.0	79.5	4
		Grassy Bank	387.5	174.2	4
		Slough	184.0	93.4	4
		Gravel Bar	201.3	136.7	4
	October	All sites grouped	86.8	111.9	16
		Erosional bank	149.3	55.9	4
		Grassy Bank	163.3	180.8	4
		Slough	5.5	4.4	4
		Gravel Bar	29.3	23.6	4

Table 6. Summary of the ANOVA results for each of the six catch test models.

Sampling Reach	Sampling Period	Habitat Type	Statistical Difference*	Order
Lower	July	Erosional Grassy Slough Gravel Bar	None	-
	October	Erosional Grassy Slough Gravel Bar	Yes	1 2 3 2
Middle	July	Grassy1-2 Slough Gravel Bar	Yes	2 1 2
	October	Grassy 1-2 Slough Gravel Bar	None	-
Upper	July	Erosional Grassy Slough Gravel Bar	None	-
	October	Erosional Grassy Slough Gravel Bar	Yes	1 1 2 2

* alpha = 0.05

Table 7. Summary of the ANOVA results of the grouped catch test models.

Sampling Reach	Sampling Period	Habitat Type	Statistical Difference*	Catch Order
Lower & Upper	July	Erosional Grassy Slough Gravel Bar	None	-
	October	Erosional Grassy Slough Gravel Bar	Yes	1 2 4 3
Middle	July & October	Grassy 1-2 Slough Gravel Bar	Yes	2 1 2

* alpha = 0.05

Table 8. Summary of juvenile chinook salmon fork length data collected during the July and October sampling periods.

Sampling Period	Statistic Variable*	Reach			
		Lower	Middle	Upper	Grouped
	n	145	198	148	491
	$\bar{x}$	58.8	55.8	50.4	55.1
July	sd	12.3	8.2	7.4	10.0
	min	44.0	44.0	41.0	41.0
	max	95.0	90.0	91.0	95.0
	n	178	160	203	541
	$\bar{x}$	72.1	68.2	70.4	70.3
October	sd	6.2	6.3	7.1	6.8
	min	56.0	51.0	54.0	51.0
	max	91.0	85.0	98.0	98.0
	n	323	358	351	1032
	$\bar{x}$	66.1	61.3	62.0	63.0
Grouped	sd	11.5	9.6	12.2	11.4
	min	44.0	44.0	41.0	41.0
	max	95.0	90.0	98.0	98.0

* n=number, $\bar{x}$=mean, s^d=standard deviation, min=minimum, max=maximum

Table 9. Results of the freeze branding effort conducted at each habitat type study site.

			Catch by Sampling Day							
			Day 1		Day 2		Day 3		Day 4	
Sampling Reach	Sampling Period	Habitat Type	* u	** *** m	u	m	u	m	u	m
Lower	July	Erosional	10	...	29	0	29	1	90	0
		Grassy	58	...	22	4	47	1	53	10
		Slough	30	...	16	0	31	0	14	0
		Gravel	9	...	22	0	13	1	233	2
	October	Erosional	238	...	88	4	302	12	44	10
		Grassy	41	...	35	2	4	1	0	0
		Slough	0	...	0	0	0	0	0	0
		Gravel	3	...	3	0	19	0	1	0
Middle	July	Grassy-1	31	...	63	0	80	0	91	7
		Grassy-2	9	...	34	0	65	1	80	8
		Slough	128	...	706	2	261	9	250	20
		Gravel	52	...	29	0	21	1	35	2
	October	Gravel-1	9	...	9	0	19	1	1	0
		Gravel-2	7	...	18	0	23	1	3	1
		Slough	97	...	58	2	56	4	0	0
		Gravel	15	...	32	0	51	2	2	1
Upper	July	Erosional	114	...	283	9	242	23	164	33
		Grassy	139	...	534	8	368	89	335	77
		Slough	156	...	306	1	79	4	176	14
		Gravel	4	...	320	0	229	13	196	43
	October	Erosional	214	...	162	10	117	9	77	8
		Grassy	433	...	91	9	48	9	54	9
		Slough	3	...	11	0	7	0	1	0
		Gravel	35	...	25	0	56	1	0	0

* u = Number of unmarked fish captured

** m = Number of marked fish captured

*** No marked fish were captured on Day 1

Table 10. Water chemistry data collected at selected study sites.

Site*	Date	Temperature (C)	Turbidity (NTU's)	Conductivity (mg/l)	pH	Dissolved Oxygen (mg/l)
102	104	5.5	2	60	8.3	9.9
102	108	6.5	3	61	8.7	9.7
102	705	9.5	14	60	11.4	12.0
102	709	9.4	10	59	...	10.4
102	701	12.6	3	64	7.5	9.2
103	930	7.1	...	57	6.7	10.2
103	1012	5.9	...	63	9.6	10.2
104	713	11.1	3	59	7.9	9.7
202	105	5.3	2	64	8.3	9.8
202	702	9.4	18	58	-	9.1
202	706	9.5	14	60	7.2	10.4
202	1013	5.9	2	64	8.9	10.5
203	101	6.0	...	57	6.7	9.8
204	109	6.7	...	59	8.8	9.9
212	710	8.9	3	58	7.8	10.3
212	714	9.0	1	57	9.1	9.7
301	102	7.1	2	60	6.9	9.8
301	106	6.8	2	59	8.3	9.3
301	703	8.1	2	63	8.1	10.5
301	715	9.5	...	61	9.2	10.5
302	711	8.7	1	61	8.1	10.6
302	1010	7.0	2	59	8.8	9.6
302	1014	6.1	...	59	8.8	9.5
303	707	8.0	1	60	7.8	10.3

* Site code: 102 = lower river grassy; 103 = lower river slough; 104 = lower river gravel bar; 202 = middle river grassy 1; 203 = middle river slough; 204 = middle river gravel bar; 212 = middle river grassy 2; 301 = upper river erosional; 302 = upper river grassy; 303 = upper river slough.

Table 11. Summary of habitat variable response functions and juvenile chinook salmon catch data for lower river habitat type study sites.

Sampling Period	Habitat Type Study Site	Sampling Day	Habitat Function			Site Catch
			Area	WUA	HAI	
July	Erosional	1	1500	414	27.6	10
		2	2400	578	24.1	29
		3	1800	468	26.0	30
		4	2100	496	23.6	90
	Grassy	1	600	59	9.8	58
		2	840	113	13.5	26
		3	1140	136	11.9	48
		4	990	129	13.0	63
	Slough	1	3600	0	0.0	30
		2	12750	0	0.0	16
		3	10500	35	0.3	31
		4	4800	68	1.4	14
	Gravel Bar	1	3000	455	15.2	9
		2	7350	980	13.3	22
		3	5550	629	11.3	14
		4	4200	577	13.7	235
October	Erosional	1	2400	993	41.4	238
		2	3300	932	28.2	92
		3	3750	1131	30.2	314
		4	4650	1097	23.6	54
	Grassy	1	840	160	19.0	41
		2	960	232	24.2	37
		3	900	200	22.2	5
		4	1110	110	9.9	0
	Slough	1	9600	0	0.0	0
		2	12000	248	2.1	0
		3	11850	261	2.2	0
		4	9900	29	0.3	0
	Gravel Bar	1	4050	456	11.3	3
		2	4650	603	13.0	3
		3	4950	596	12.0	19
		4	9450	907	9.6	1

Table 12. Summary of habitat variable response functions and juvenile chinook salmon catch data for middle river habitat type study sites.

Sampling Period	Habitat Type Study Site	Sampling Day	Habitat Function			Site Catch
			Area	WUA	HAI	
July	Grassy-1	1	1500	184	12.3	9
		2	1200	288	24.0	34
		3	1500	387	25.8	66
		4	1350	373	27.6	88
	Grassy-2	1	3000	610	20.3	31
		2	2250	330	14.7	63
		3	3450	305	8.8	80
		4	2100	284	13.5	98
	Slough	1	3300	665	20.2	128
		2	3000	485	16.2	708
		3	3150	427	13.6	270
		4	2850	415	14.6	270
	Gravel Bar	1	3600	561	15.6	52
		2	2550	169	6.6	29
		3	3600	224	6.2	22
		4	2400	178	7.4	37
October	Grassy-1	1	1200	238	19.8	9
		2	1800	196	10.9	9
		3	1350	302	22.4	20
		4	2100	440	21.0	1
	Grassy-2	1	2850	794	27.9	7
		2	3300	780	23.6	18
		3	3300	598	18.1	24
		4	2400	359	15.0	4
	Slough	1	3600	650	18.1	97
		2	5550	836	15.1	60
		3	7350	1520	20.7	60
		4	9300	2262	24.3	0
	Gravel Bar	1	4800	827	17.2	15
		2	5100	906	17.8	32
		3	5100	811	15.9	53
		4	4350	655	15.1	3

Table 13. Summary of habitat variable response functions and catch for upper river habitat type study sites.

Sampling Period	Habitat Type Study Site	Sampling Day	Habitat Function Area	Habitat Function WUA	Habitat Function HAI	Site Catch
July	Erosional	1	1650	473	28.7	114
		2	1800	720	40.0	292
		3	1950	699	35.8	265
		4	1650	634	38.4	197
	Grassy	1	1200	232	19.3	139
		2	1200	345	28.8	542
		3	1200	277	23.1	457
		4	1500	356	23.7	412
	Slough	1	2700	1585	58.7	156
		2	2850	2130	74.7	307
		3	6450	3210	49.8	83
		4	2400	1578	65.8	190
	Gravel Bar	1	13500	1421	10.5	4
		2	8400	1186	14.1	320
		3	5700	1218	21.4	242
		4	6000	1017	17.0	239
October	Erosional	1	1800	506	28.1	214
		2	1006	450	44.7	172
		3	2100	340	16.2	126
		4	1950	383	19.6	85
	Grassy	1	1200	343	28.6	433
		2	1650	295	17.9	100
		3	1500	266	17.7	57
		4	1800	121	6.7	63
	Slough	1	12300	2792	22.7	3
		2	12000	1181	9.8	11
		3	13950	2815	20.2	7
		4	15600	2963	19.0	1
	Gravel Bar	1	7650	1316	17.2	35
		2	8700	1412	16.2	25
		3	6000	1080	18.0	57
		4	7650	938	12.3	0

Table 14. Numbers of points (n) and coefficients of linear correlations (r) for data plotted in Figures 7-14.

x (HAI)	y (CATCH)	n	r
All sites	All sites	96	0.40
All lower river sites	All lower river sites	32	0.55
All middle river sites	All middle river sites	32	-0.08
All upper river sites	All upper river sites	32	0.32
All erosional sites	All erosional sites	16	0.61
All grassy sites	All grassy sites	32	0.43
All slough sites	All slough sites	24	0.34
All gravel bar sites	All gravel bar sites	24	0.36
July sampling period	July sampling period	48	0.31
October sampling period	October sampling period	48	0.57

APPENDIX B:

Catch and Habitat Model Statistics.

A summary of the ANOVA results for the six catch models and associated multiple comparisons (protected LSD test, Ott 1977) when effect of habitat is significant follows:

Reach	Month	Source	df	SS	MS	F	PR>F
1	7	Habitat	3	1.1309	0.3770	0.49	0.6937
		Error	12	9.1722	0.7664		
		Total	15	10.3031			

Therefore we fail to reject H_o.

1	10	Habitat	3	50.8380	26.9460	14.27	0.0003
		Error	12	14.2488	1.1874		
		Total	15	65.0868			

Therefore we reject H_o.

Protected LSD at alpha=0.05 indicates that:

$C_1 > C_2 = C_4 > C_3$

2	7	Habitat	2	10.9608	5.4804	12.01	0.0011
		Error	13	5.9344	0.4565		
		Total	15	16.8952			

Therefore we reject H_o.

Protected LSD at alpha=0.05 indicates that:

$C_3 > C_2 = C_4$

2	10	Habitat	2	2.6150	1.3075	0.75	0.4906
		Error	13	22.5825	1.7371		
		Total	15	25.1975			

Therefore we fail to reject H_o.

3	7	Habitat	3	3.2539	1.0846	0.90	0.4684
		Error	12	14.4195	1.2016		
		Total	15	17.6734			

Therefore we fail to reject H_o.

3	10	Habitat	3	30.4191	10.1397	8.02	0.0034
		Error	12	15.1628	1.2636		
		Total	15	45.5819			

Therefore we reject H_o.

Protected LSD at alpha=0.05 indicates that:

$$C_1 = C_2 > C_4 = C_3$$

Due to the similarity in the results for reaches 1 and 3, the data for these two reaches were combined and another ANOVA performed. This resulted in the three way and the two way interaction terms between reach and month (RM) and reach and habitat (RH) being not significant (substantiating the similarity between these two reaches). Accordingly, the reduced models of:

$$(C_{i,k,l} = mu + R_i + H_k + e_{i,k,l})_j$$

were fit to each month of data. The ANOVA results for these models are summarized as follows:

Reach	Month	Source	df	SS	MS	F	PR>F
1 & 3	7	Reach	1	25.0119	25.0119	27.55	0.0001
		Habitat	3	3.4648	1.1549	1.27	0.3038
		Error	27	24.5118	0.9078		
		Total	31	52.9884			

Therefore we fail to reject H_o.

1 & 3	10	Reach	1	13.6221	13.6221	10.32	0.0034
		Habitat	3	75.0369	25.0123	18.95	0.0001
		Error	27	35.6318	1.3197		
		Total	31	124.2908			

Therefore we reject H_o.

Protected LSD at alpha=0.05 indicates that:

$$C_1 > C_2 > C_4 > C_3$$

Finally, a model was fit to the reach 2 data. The two way interaction term between month and habitat (MH) was not significant, so the reduced model of:

$$C_{j,k,l} = mu + M_j + H_k + e_{j,k,l}$$

was fit to this data. The ANOVA results for this model are summarized below:

Reach	Month	Source	df	SS	MS	F	PR>F
2	7 & 10	Month	1	19.9899	19.9899	17.56	0.0003
		Habitat	2	10.2128	5.1064	4.48	0.0204
		Error	28	31.8798	1.1386		
		Total	31	62.0825			

Therefore we reject H_0.

Protected LSD at alpha=0.05 indicates that:

$$C_3 > C_4 = C_2$$

A summary of the results of the two ANACOVA's associated with each model follows, with associated estimates of B_1 (for cases when H_0 is rejected):

Month	Source	df	SS	MS	F	PR>F
7	HAI	1	1.5574	1.5574	1.58	0.2151
	Reach	2	11.0919	5.5460	5.63	0.0066
	Error	44	43.3143	0.9844		

Therefore we fail to reject H_0.

10	HAI	1	50.2019	50.2019	25.79	0.0001
	Reach	2	5.7913	2.8957	1.49	0.2371
	Error	44	85.6643	1.9469		

Therefore reject H_0 at $\alpha = 0.05$.

The estimate of $B_1 = 7.8747$ (estimated standard error of this estimate = 1.5508).

Symbol key: Reach 1=Lower, 2=Middle, 3=Upper

Habitat C_1=Erosional, C_2=Grassy, C_3=Slough, C_4=Gravel Bar

APPENDIX C:

Habitat Type Study Site Descriptions.

1. Lower Evaluation Reach: The study area in this evaluation reach is located within a 1.5 mile reach of the river located between RM 12.5 and RM 14.0, approximately eight miles downstream of the Sterling Highway Bridge in Soldotna. The area is located in a portion of the mainstem known to support chinook spawning and is five miles downstream of Slikok Creek, an important chinook spawning tributary. One each of the four evaluation habitat types was selected for study in this reach.

   a. Erosional Study Site: This study site is located on the east bank of the river at RM 13.3. It is characterized by steep eroding banks that are vegetated with a spruce overstory. This results in much deadfall being present at the site both in the form of submerged and listing spruce trees. As a result, velocities at the site tend to be reduced resulting in excellent rearing habitat at the site. At present, there is no significant instream or bankside development at the site.

   b. Grassy Study Site: This study site is located on the west bank of the river at RM 13.4. It is situated just upstream of an outside bend in the river. At present, there is no instream or bankside development at the site. The site is characterized by slowing eroding undercut banks that are vegetated by grasses and low brush. This results in the formation of relatively stable undercut banks that have overhanging vegetation. As a result of these conditions, good rearing habitat is present at the site throughout much of the open-water season.

   c. Slough Study Site: This study site is located on the east bank of the river at RM 13.6. It is situated along the inside bend of the river between a small vegetated island and the river bank. The site is separated from the mainstem by an upstream cobble bar that is only overtopped at high mainstem flows. The site can be generally characterized as a pool-type habitat with slow velocities and silt/sand substrates. Little cover occurs at the site until high flows; at that time the water covers bankside vegetation. This results in little rearing habitat being present at the site throughout much of the open water season. At this time, no significant instream or riparian development is present at the site.

   d. Gravel Bar Study Site: This study site is located on the upstream portion of a large midchannel vegetated island located at RM 12.8. The banks at the site are relatively high (6-8 feet) and steep, with little near-bank vegetation. A shallow channel, which is dewatered at low and medium flows, exists at the foot of the bank. Substrate in this channel is predominately cobble; the remaining substrate at the site consists of gravels. As a result, little object cover is present at the site making it marginal for rearing. Numerous chinook redds were observed at the site, indicating that the site may support natal rearing.

2. Middle Evaluation Reach: The study area in this evaluation reach is located within a 1.5 mile reach of the river between RM 31.0 and RM 37.5, just downstream from Bing's Landing. It is situated in an area of the mainstem known to support chinook spawning and is four miles downstream of Moose River, an important chinook spawning and rearing tributary. One slough, and one gravel bar, and two grassy habitat type study sites were selected for evaluation in this reach. An erosional habitat type was not selected for evaluation in this study area for reasons described in section 2.1.

   a. Grassy 1 Study Site: This study site is located on the west bank of the river at RM 32.3. It is situated along the outside bank of a river bend. At present, there is no significant riparian or instream development at the site. Banks at this study site are steep and eroding and vegetated with grasses and low shrubs. This results in the formation of relatively stable undercut banks with overhanging vegetation. Substrates at the site range from large cobbles and boulders to gravels. This combination of factors results in the study site having good rearing habitat throughout the open water season.

   b. Grassy 2 Study Site: This study site is located on the west bank of the river downstream of the Grassy 1 study site at RM 32.0. As such, it is situated at the downstream portion of the inside bank of a river bend. At present, there is no instream development at the site. There is, however, significant riparian development at the site with agricultural clearing occurring behind the bank. Banks at the site are gently sloping and vegetated by grasses, which become inundated at medium and high flows. Substrates at the site range from cobbles and boulders to small gravels. These combination of factors result in this study site having good rearing habitat throughout the open-water season.

   c. Slough Study Site: This study site is located on the east bank of the river at RM 31.6. It is situated along a relatively straight portion of the river between an unvegetated cobble bar and the river bank, just downstream of a small upland slough. The site is separated from the mainstem proper by an upstream cobble bar that is overtopped at medium to high flows. Banks at the site are gradual and vegetated. Substrates range from silt and sand to gravels and rubbles. These conditions offer moderate rearing habitat conditions at the site throughout much of the open-water season. No significant instream development is present at the site; however, some bankside riparian development is present and is principally limited to agricultural clearing.

   d. Gravel Bar Study Site: This study site is located opposite the Grassy 1 study site at RM 32.4. As such, it is situated along the inside bank of a river bend. At present, there is no significant instream development at the site. Significant riparian development is present; however, agricultural clearing occurs directly behind the bank. Banks at the site are gently sloping and sparsely vegetated. Substrates range from cobbles and boulders to gravels and rubbles. These conditions result in the site having moderate rearing habitat throughout much of the open-water season.

3. Upper Evaluation Reach: The study area in this evaluation reach is located within a 1-mile reach of the river between RM 44.0 and RM 45.0, five miles below the outlet of Skilak Lake. The site is situated in area previously known to support limited mainstem chinook spawning and is just upstream of the outlet of the Killey River, an important chinook spawning and rearing tributary. One each of the four evaluation habitat types was selected for study in this reach.

    a. Erosional Study Site: This study site is located on the north bank of the river at RM 44.4. The site is characterized by steep eroding banks that are vegetated with an overstory of spruce and cottonwood. This results in much deadfall being present at the site both in the form of submerged and listing spruce and cottonwood trees. The presence of this vegetation results in the formation numerous velocity buffers. These areas provide excellent rearing habitat for juvenile chinook throughout the open water season. No significant instream or riparian development is evident at the site.

    b. Grassy Study Site: This study site is located on the north bank of the river at RM 44.5, situated along the outside bank of a river bend. Banks at the site are relatively steep and eroding, and vegetated with grasses. This results in the formation of relatively stable undercut banks with overhanging grasses. Velocities at the site increase rapidly offshore, limiting the amount of rearing habitat at the site to a narrow band along the bank. No significant instream or riparian developments were evident at the site.

    c. Slough Study Site: This study site is located on the north bank of the river at RM 44.8. It is situated along a relatively straight portion of the river between an unvegetated cobble bar and the river bank, just downstream of a small upland slough that partially drains Torpedo Lake. The site is separated from the mainstem proper by an upstream cobble bar that is only overtopped at high flows. Banks at the site are gently sloping and sparsely vegetated and have no evident instream or riparian developments. Generally, the site can be characterized as a pool-type habitat with minimal velocities and silt/sand substrates. As a result of these conditions, little rearing habitat is evident at the site as a result of these conditions.

d. Gravel Bar Study Site: This study site is located on the north bank of the river at RM 44.9, just upstream of the slough study site. Banks at the study site are steep and eroding, tapering to a shelf vegetated with grasses which appeared to have sloughed off the bank. The channel slopes gently away from the bank to the velocity sheer. Substrate at the site is predominately composed of gravels and rubbles. These conditions result in moderate amounts of rearing habitat at the site throughout the open-water season. Numerous chinook redds were evident at the site, indicating the site may support natal rearing. At present, no significant instream or riparian development is evident at the site.