Fishery Data Series No. 99-9

Assessment of Angler Impacts to Kenai River Riparian Habitats during 1997

by

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and

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June 1999

Alaska Department of Fish and Game Division of Sport Fish

Symbols and Abbreviations

The following symbols and abbreviations, and others approved for the Système International d'Unités (SI), are used in Division of Sport Fish Fishery Manuscripts, Fishery Data Series Reports, Fishery Management Reports, and Special Publications without definition. All others must be defined in the text at first mention, as well as in the titles or footnotes of tables and in figures or figure captions.

Weights and measures (metric)

centimeter	cm
deciliter	dL
gram	g
hectare	ha
kilogram	kg
kilometer	km
liter	L
meter	m
metric ton	mt
milliliter	ml
millimeter	mm

Weights and measures (English)

cubic feet per second	ft^3/s
foot	ft
gallon	gal
inch	in
mile	mi
ounce	oz
pound	lb
quart	qt
yard	yd
Spell out acre and ton.	

Time and temperature

day	d
degrees Celsius	°C
degrees Fahrenheit	°F
hour (spell out for 24-hour clock)	h
minute	min
second	s
Spell out year, month, and week.	

Physics and chemistry

all atomic symbols	
alternating current	AC
ampere	A
calorie	cal
direct current	DC
hertz	Hz
horsepower	hp
hydrogen ion activity	pH
parts per million	ppm
parts per thousand	ppt, ‰
volts	V
watts	W

General

All commonly accepted abbreviations.	e.g., Mr., Mrs., a.m., p.m., etc.
All commonly accepted professional titles.	e.g., Dr., Ph.D., R.N., etc.
and	&
at	@
Compass directions:	
east	E
north	N
south	S
west	W
Copyright	©
Corporate suffixes:	
Company	Co.
Corporation	Corp.
Incorporated	Inc.
Limited	Ltd.
et alii (and other people)	et al.
et cetera (and so forth)	etc.
exempli gratia (for example)	e.g.,
id est (that is)	i.e.,
latitude or longitude	lat. or long.
monetary symbols (U.S.)	$, ¢
months (tables and figures): first three letters	Jan,...,Dec
number (before a number)	# (e.g., #10)
pounds (after a number)	# (e.g., 10#)
registered trademark	®
trademark	™
United States (adjective)	U.S.
United States of America (noun)	USA
U.S. state and District of Columbia abbreviations	use two-letter abbreviations (e.g., AK, DC)

Mathematics, statistics, fisheries

alternate hypothesis	H_A
base of natural logarithm	e
catch per unit effort	CPUE
coefficient of variation	CV
common test statistics	F, t, χ^2, etc.
confidence interval	C.I.
correlation coefficient	R (multiple)
correlation coefficient	r (simple)
covariance	cov
degree (angular or temperature)	°
degrees of freedom	df
divided by	÷ or / (in equations)
equals	=
expected value	E
fork length	FL
greater than	>
greater than or equal to	≥
harvest per unit effort	HPUE
less than	<
less than or equal to	≤
logarithm (natural)	ln
logarithm (base 10)	log
logarithm (specify base)	log_2, etc.
mideye-to-fork	MEF
minute (angular)	'
multiplied by	x
not significant	NS
null hypothesis	H_O
percent	%
probability	P
probability of a type I error (rejection of the null hypothesis when true)	α
probability of a type II error (acceptance of the null hypothesis when false)	β
second (angular)	"
standard deviation	SD
standard error	SE
standard length	SL
total length	TL
variance	Var

FISHERY DATA SERIES NO. 99-9

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This investigation was partially financed by the Federal Aid in Sport Fish Restoration Act (16 U.S.C. 777-777K) under project F-10-13, Job No. H-8.

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This document should be cited as:
King, Mary A. and Patricia Hansen. 1999. Assessment of angler impacts to Kenai River riparian habitats during 1997. Alaska Department of Fish and Game, Fishery Data Series No. 99-9, Anchorage.

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ABSTRACT

Distribution of anglers along the banks of the Kenai River during 1997 was 60.5% on private land and 39.5% on public land. Land use by anglers in reach 1 (Kenai Lake to Skilak Lake) was 98.8% public. For reaches 2 (Skilak Lake to Moose River) and 4 (Soldotna Bridge to Warren Ames Bridge), use of public and private lands was nearly equal. For reach 3 (Moose River to the Soldotna Bridge), anglers tended to use private land more often, 60.4%. A comparison of public and private land use by anglers in 1996 and 1997 showed no change in reaches 1 and 2. A significant change was detected in reach 3 ($\chi^2 = 59.9$, $P < 0.001$) with a trend showing a 10% increase in angler use of public lands. There was a 7.6% decrease in use of public lands in reach 4 ($\chi^2 = 23.3$, $P < 0.001$). Of anglers observed, 86.9% fished from mainland banks. Of those anglers, 13.3% fished from boardwalks or docks, 58.2% stood in the water, and 28.5% fished while standing on the bank.

No significant relationship was detected between angler traffic and bank integrity variables (bank angle, undercut bank, overhanging vegetation, and stream depth) at habitat survey sites. There was a significant difference detected between bank angle and habitat type ($F = 8.22$, $P = 0.02$). Prefishery and postfishery changes in bank angle showed a general decrease in bank angle for shrub/herbaceous sites and an increase in bank angle for herbaceous sites. Review of the data suggested that changes in bank angle and undercut bank tend to be a cyclic phenomenon associated with erosion cycles and that anglers may accelerate the process. Improved sampling may better define the relationship of angler impact with bank angle, undercut bank, and overhanging vegetation. Stream depth changes were a function of seasonal flow rather than angler impacts.

The ability to measure erosion through the use of erosion pins was ineffective due to angler tampering. However, large areas of bank were documented to have calved at habitat survey sites receiving angler use.

There was no significant change detected between angler traffic and vegetation sampled with departure from the riverbank, but there was a significant change detected for each habitat type for vegetation sampled within 5 feet of the bank (herbaceous: $F = 4.12$, $P = 0.01$; and shrub/herbaceous: $F = 2.40$, $P = 0.01$). The nearshore area showed a postfishery trend of decreasing vegetative cover. A better sample design for the transects departing from the bank would better define the relationship between angler impacts and vegetation changes.

Penetrability measurements (soil resistance through the use of a penetrometer) were used as an indicator of soil compaction. There were no significant differences detected between angler traffic and penetrability measurements taken at 1 in, 3 in, and 6 in soil depths. Improved sample design may better define this relationship.

Trampling was assessed by photo imagery analysis of prefishery and postfishery photographs of permanent vegetation plots. Of the cover classes assessed, there were no significant differences detected between angler traffic with percent cover for bare ground and water. There were significant differences detected between angler traffic with percent cover of vegetation ($P < 0.01$) and litter ($P < 0.01$). Further analyses of these two cover classes by habitat type detected a significant difference for herbaceous habitats for vegetative cover ($P < 0.01$) and litter cover ($P < 0.01$), but not for shrub/herbaceous habitats.

Key words: Kenai River, shore anglers, riparian habitat, habitat assessment, trampling, angler impacts, bank erosion, vegetation assessment, GPS.

INTRODUCTION

BACKGROUND

The Kenai River (Figure 1) supports the largest freshwater sport fishery in Alaska with over 350,000 angler days of effort in 1996 (Howe et al. 1997). Fishing effort occurs throughout the mainstem of the river but primarily occurs over a relatively short time period during June, July, and August downstream from Skilak Lake. Targeted species include chinook salmon *Oncorhynchus tshawytscha*, coho salmon *O. kisutch,* sockeye salmon *O. nerka*, pink salmon *O. gorbuscha,* resident rainbow trout *O. mykiss,* and Dolly Varden *Salvelinus malma*.

In February 1996, the Alaska Board of Fisheries (BOF) adopted regulations increasing freshwater harvest opportunities for anglers targeting Kenai River late-run sockeye salmon. This

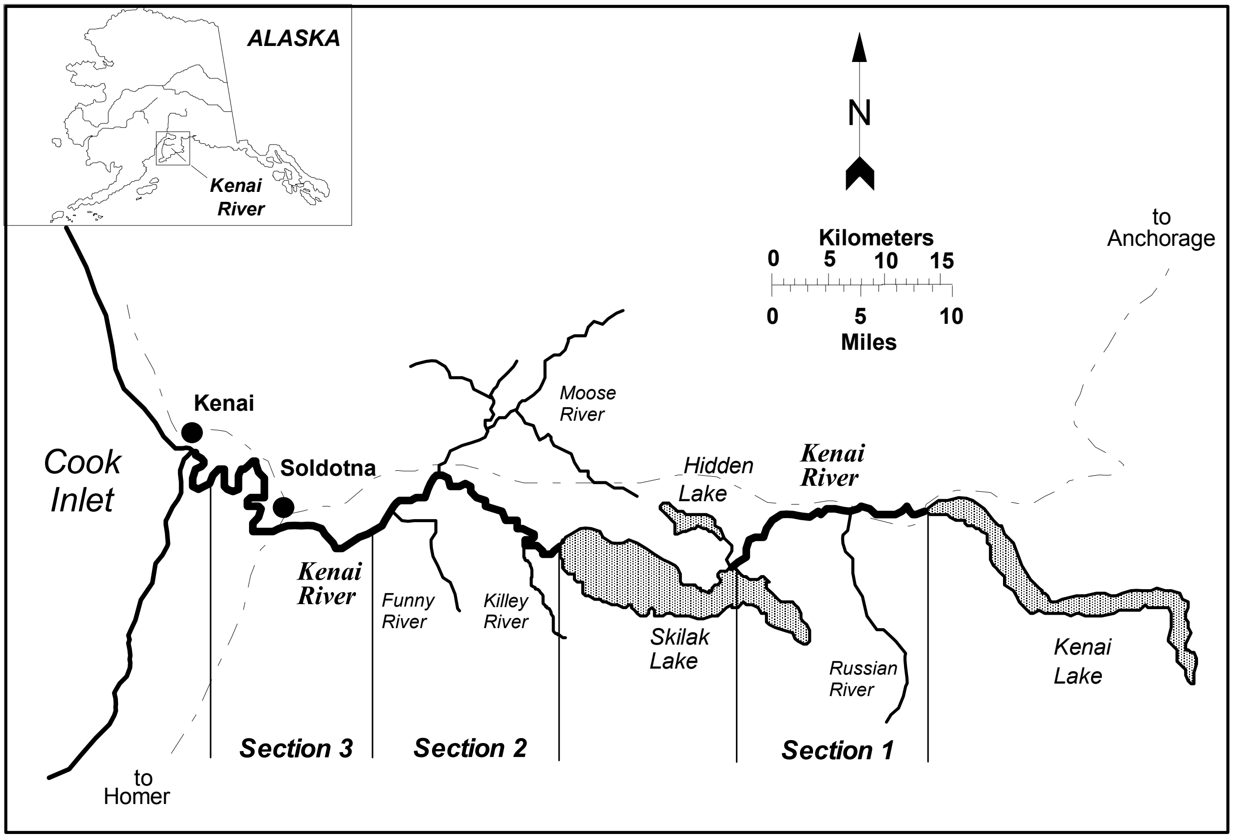

Figure 1.-Map of the Kenai River drainage showing river sections for conducting angler counts.

was effected by increasing the upper limit of the sonar goal for adult sockeye salmon returning to the Kenai River by 100,000 during 1996 and by an additional 25,000 in each of the next 2 years (1997-1998); thus establishing a sonar count range for sockeye salmon for 1996 of 550,000 to 800,000 and for 1998 and after of 550,000 to 850,000 (5 AAC 21.360) (Appendix A1). In addition, the BOF liberalized bag and possession limits, effective in 1996, for the inriver sport fishery and the personal use dip net fishery occurring at the mouth of the Kenai River.

Sockeye salmon sport fishing is prosecuted mainly from the riverbank or while standing in the river along gravel bars at or near the shoreline. Some sockeye salmon anglers use boats to access a desired fishing location, but anglers seldom fish from boats. Because sockeye salmon angling is principally a shorebased fishery, damage to riparian habitat is a major concern to fishery managers, Kenai River property owners, and stewards for Kenai River resources.

Realizing the importance of maintaining riparian habitats, the BOF expressed concern that their actions not result in further damage to critical riparian habitats along the Kenai River (5 AAC 56.065) (Appendix A2). The BOF also stated that they would reconsider the increased allocation of sockeye salmon if additional damage to riparian habitats occurred due to increased shore-based angling. To help mitigate potential impacts to riparian habitats from shorebased angling, the BOF granted the commissioner of the Department of Fish and Game regulatory authority to close state, federal or municipal riparian habitats to angling if that activity is likely to result in damage to riparian habitat which could negatively affect the fishery resources of upper Cook Inlet. Last, the BOF asked that the department monitor use and impacts to Kenai River riparian habitats and report findings at the next regularly scheduled Cook Inlet regulatory meeting during 1998.

The BOF requested that habitat assessment follow procedures described by Liepitz in Technical Report No. 94-6, *An Assessment of the Cumulative Impacts of Development and Human Uses on Fish Habitat in the Kenai River* (1994), more commonly referred to as the "309" study. The "309" study used the Habitat Evaluation Procedure (HEP) (Armour et al. 1984). The HEP is based on habitat units determined by using suitability index curves for a given indicator species (in this case, juvenile chinook salmon). During the first year of this habitat assessment study, the methodology of the "309" study was modified to increase repeatability and decrease variability. In addition to habitat assessment, the 1996 baseline work included assessments of trampling and angler use and distribution. Findings of the 1996 habitat assessment study indicated several problems with this approach to assess impacts to riparian habitats (Larson and McCracken 1998). Therefore, the focus of this study was changed from assessing impact through changes in habitat value to assessing how bank angling activities affect the riparian habitat, including bank integrity and the vegetative community of the nearshore upland area.

OBJECTIVES

The primary goals of this project in 1997 were to document angler distribution throughout the mainstem Kenai River during the late-run sockeye salmon fishery and to assess bank angler related impacts to selected riparian habitat sites. Specific objectives were to:

1. Estimate the distribution of shore anglers in the mainstem Kenai River during the sport fishery for late-run sockeye salmon from 8 July to 10 August.
2. Estimate shore angler movement within selected riparian areas during the sport fishery for Kenai River late-run sockeye salmon from 8 July to 10 August.
3. Assess the integrity of the riverbank at selected riparian areas before (1 June-7 July) and after (11 August-31 August) the sport fishery for Kenai River late-run sockeye salmon.
4. Assess nearshore upland areas at selected riparian areas before (1 June-7 July) and after (11 August-31 August) the sport fishery for Kenai River late-run sockeye salmon.

A Task: To conduct a pilot study of habitat assessment using a hydrogeomorphic approach (Appendix D1).

METHODS

DISTRIBUTION OF SHORE ANGLERS

The study area encompassed the mainstem Kenai River from its outfall at Kenai Lake to the Warren Ames Bridge and was divided into three sections for conducting angler counts (Figure 1):

Section	Description	River Mile
1	Outlet at Kenai Lake to Jim's Landing	82 – 69.6
2	Outlet of Skilak Lake to Power Line	50 - 28
3	Power Line to the Warren Ames Bridge	28 - 5

The area downstream of the Warren Ames Bridge was omitted from the study because very little angler activity occurs there.

During the sockeye salmon sport fishery (8 July-10 August 1997) 12 counts of shore anglers were conducted throughout the study area. Of the 12 counts, 9 occurred during peak days of the fishery, 1 prior to the peak, and 2 after the peak. Nine of the angler counts were also conducted at times of the day anticipated to have high angler participation, 1200-2000 hours (King 1995, 1997). Counts were conducted on 8 weekday days and 4 weekend days. The start time for a count was the same in each section and each count was completed in 3.5 hours.

Three motorized skiffs, each with two project personnel and a Garmin 45[1] differentially corrected geographic positioning system (DGPS) corrected to 10 meters, were required to conduct counts. The boat operator motored near the shore angler(s) being identified and provided the DGPS waypoint to the observer. The observer recorded the required data:

1. DGPS waypoint of the angler or group of anglers.
2. Number of anglers.
3. Habitat survey site number, if applicable, in which the angler(s) were located.
4. General location of the angler: primary river bank, island or gravel bar.
5. Specific location: on bank, in water, boardwalk, other (dock, jetty, etc.).

When conducting a count in section 2 or 3, anglers were counted as the boat operator drove the boat downstream from the boat launch, along the right bank, to the lower end of the assigned count section. The boat was then motored upstream on the left bank to the upper end of the count section; and, then motored downstream on the right bank until the boat had returned to the boat launch, completing a circle in a counter clockwise direction. (Left or right bank is determined by facing downstream; for example, right bank is on the right hand side when looking downstream.) For section 1, angler counts were conducted by operating the boat in a downstream only direction to minimize disturbance in a river area where outboard use is prohibited. While drifting downstream, the boat operator idled from bank to bank to obtain the DGPS waypoint for each angler or group of anglers. At the completion of each count, waypoints were uploaded from each GPS unit to a desktop computer.

Postseason, ArcView®[1] software was used to map the data. The 12 angler counts for every 10 meters were summed and overlaid onto a geographic information system (GIS) basemap. Summaries by angler use of public and private lands, and angler location along the riverbank by structural use (primary use: bank, island, gravel bar; secondary use: on bank, in water, on boardwalk, other structure) were also represented on the basemap.

Angler count data for 1997 were compared to 1995 and 1996 count data. Chi-square tests were used to test for significant shifts in the distribution of shore anglers among years, and between types of ownership and shifts in river reach. The river reaches used for these comparisons were defined as:

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[1] Use of a company's name does not constitute endorsement.

Reach	Description	River Mile
1	outlet at Kenai Lake to Jim's Landing	82 - 69.6
2	outlet at Skilak Lake to Moose River	50 - 36
3	Moose River to the Soldotna Bridge	36 - 21
4	Soldotna Bridge to the Warren Ames Bridge	21 - 5

ANGLER MOVEMENT

Two of the primary habitat types observed to be used by sockeye salmon anglers were assessed. These habitat types were characterized by modifying definitions used by Viereck et al. (1982):

1. Herbaceous: Over 5% of the survey site has a herbaceous canopy, but the shrub canopy cover is less than 25% and the tree canopy cover is less than 10%. Typically, herbaceous vegetation dominates the first 15 ft of the nearshore area with a few interspersed shrubs. Some mature trees may be present, usually more distal from the riverbank.
2. Shrub/Herbaceous: 25%-100% of the survey site has a shrub canopy, but less than 10% of the site has a tree canopy. The shrubs are generally less than 5 ft in height. Any tall shrubs are usually offset from the riverbank 10 ft or more. A herbaceous strip of 5-10 ft is generally present in the immediate nearshore area.

For each habitat type two nonimpacted sites and four impacted sites were selected for a total of 12 sites. A nonimpacted site was defined as being pristine, characterized by receiving little or no human use. An impacted site was defined as an area receiving high or moderate angler use. Site selection was based on previous angler count data (1995, 1996) and field inspection. Specific high use areas within parks, waysides, and campgrounds, which receive significant human activity for reasons other than angling, were not considered. Each habitat survey site was a rectangular plot, measured along the bank 150 ft and onshore 75 ft. Table 1 and Figure 2 provide definitions and locations for habitat survey sites.

During the sockeye salmon sport fishery, angler movement within the habitat survey sites was monitored by a technician accessing the site by boat or vehicle. Each site was evaluated for eight 4-hour periods from 8 July-10 August (conducted on the same days as the angler counts). A technician was stationed at a habitat survey site and provided with a data form depicting a simplistic map of the site on graph paper, to include landmarks (trees, rocks, signs, etc.) and relative distances. During each evaluation period an angler within the survey site was randomly selected and his/her movements (ground position changes measured in feet) were recorded on graph paper. After angler selection, the technician started a timer and recorded the angler's movement for 15 minutes. When documenting angler movements the technician initialized the angler location and drew a line on the map indicating the direction of movement and any landmarks relative to the new position. If the observation period was less than 15 minutes (angler departed the area, and was no longer visible), then the duration of observation was noted and distance traveled estimated. The next angler was not selected until the 15 minute interval elapsed in the event the initial angler might have returned and the observation period would have resumed for the remainder of the 15-minute period. When the observation period ended, the technician estimated and recorded the total distance traveled by that angler. Another angler was

Table 1.-Description and location of habitat survey sites along the Kenai River, 1997.

Habitat Type	Treatment	Site Code	Bank	Rivermile	Description
Herb	Control	HC1	Right	19.5	near ADF&G sockeye salmon sonar site
Herb	Control	HC2	Left	36.2	Moose River confluence
Herb	Impacted	HI1	Left	20.0	downstream of Centennial Campground
Herb	Impacted	HI2	Right	26.5	Moose Range Meadows
Herb	Impacted	HI3	Right	46.1	near Thompson's Hole
Herb	Impacted	HI4	Right	46.0	near Thompson's Hole
Shrub/Herb	Control	SHC1	Right	23.5	Soldotna Airport "Closed to Fishing" area
Shrub/Herb	Control	SHC2	Left	24.5	downstream of Moose Range Meadows
Shrub/Herb	Impacted	SHI1	Left	19.1	upstream of Slikok Creek confluence
Shrub/Herb	Impacted	SHI2	Left	19.0	upstream of Slikok Creek confluence
Shrub/Herb	Impacted	SHI3	Right	23.9	downstream of Swiftwater Campground launch
Shrub/Herb	Impacted	SHI4	Right	23.8	downstream of Swiftwater Campground launch

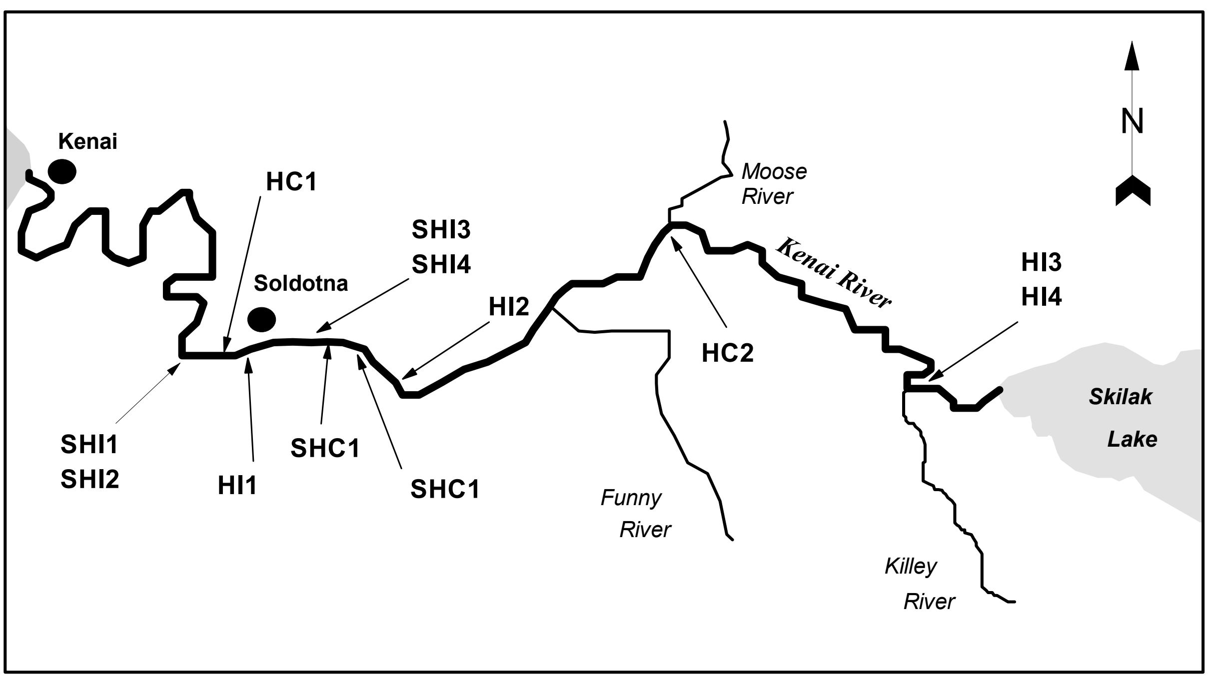


Figure 2.-Location of habitat survey sites on the Kenai River, 1997.

then selected and the process repeated for 4 hours. At most, 12 anglers, with no replacement, were observed per site visit.

The level of angler activity at a habitat survey site may be specific to that site due to physical constraints (distance back to the parking lot, deep channel, high cut bank, overhanging trees, etc.). Therefore, for each habitat survey site a mean angler movement was estimated ($\overline{M}_s$) by:

$$\overline{M}_s = \frac{\sum_{i=1}^{n}\left(\frac{d_k}{t_k}\right)}{n}, \tag{1}$$

where:

d_k = the total distance traveled by angler k at site s,

t_k = the total time of observation for angler k at site s, and

n = number of anglers observed at site s.

To compare angler activity between sites, the total number of anglers using a site, derived from the angler distribution counts, and the amount of movement per angler must be considered. Therefore, angler traffic (AT_s) for each site was estimated as:

$$AT_s = \overline{C}_s \times \overline{M}_s, \tag{2}$$

where:

$\overline{C}_s$ = the mean angler count at site s.

The variance was estimated using Goodman (1960):

$$\hat{V}(AT_s) = \overline{C}_s^2 V(\overline{M}_s) + \overline{M}_s^2 V(\overline{C}_s) - V(\overline{C}_s)V(\overline{M}_s). \tag{3}$$

BANK INTEGRITY

The twelve habitat survey sites described above were evaluated for bank integrity characteristics before (June) and after (August) the sport fishery for late-run sockeye salmon. The habitat assessment crew comprised six technicians, working in pairs, with one taking measurements and the other recording the data.

Riverbank integrity was assessed through the measurement of the following variables measured at ordinary high water (OHW) (Figure 3):

1. **Bank Angle** – This was determined by using a clinometer mounted on a yardstick following the protocol of Platts et al. (1983). A bank angle of 0 degrees was possible. Bank angle measurements were taken along the OHW line every 30 ft, starting at 15 ft from the upstream end of the habitat survey site (15 ft, 45 ft, 75 ft, 105 ft, and 135 ft).
2. **Depth of Undercut Bank** - A yardstick was placed perpendicular to and on the substrate while touching the bank at its outer most point; a second yardstick was placed horizontally with its origin at the deepest point of undercut and such that it was perpendicular to the first yardstick. The depth of undercut bank, recorded to the nearest 1/8 in, was determined by the measurement on the second yardstick as it intersected with the first (Platts et al. 1983). Measurements were taken at the same locations as Bank Angle.

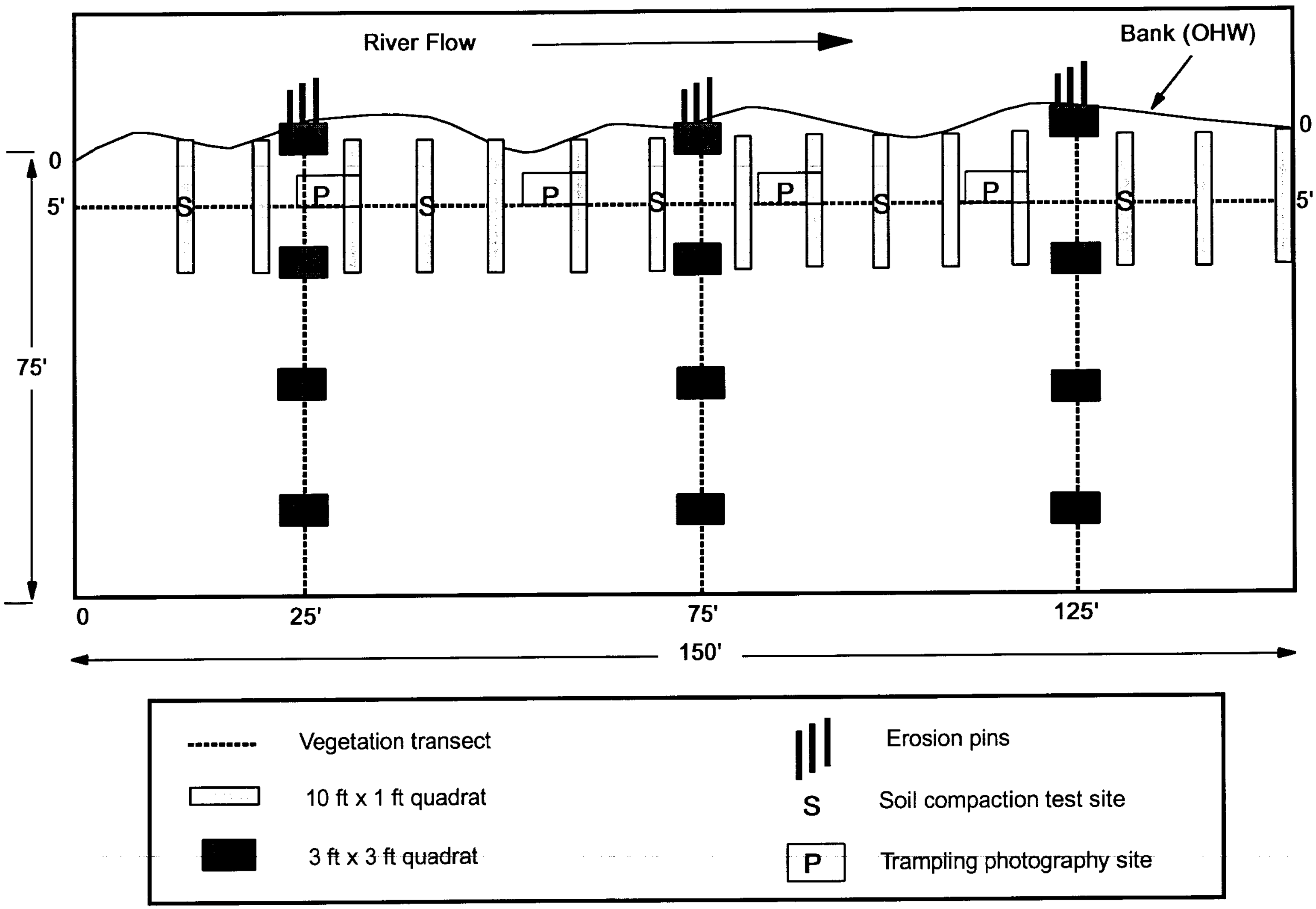


Figure 3.-Schematic of sampling locations at each habitat survey site, Kenai River, 1997.

3. **Overhanging Vegetation** - A yardstick was used to measure (nearest 1/8 in) the amount of overhanging vegetation, defined as the distance from the bank to the furthest point in which vegetation extended over the river and was within 12 in of the water surface (Platts et al 1983). Overhanging Vegetation measurements were taken at the same locations as Bank Angle.

~~4.~~4. **Stream Depth -** A yardstick was placed perpendicular to and on the substrate while touching the bank at its outermost point (based on OHW). The stream depth, determined at the point where the water surface intersected the yardstick, was recorded to the nearest 1/8 in (Platts et al. 1983). (A depth of 0 inches was possible.) Measurements were taken at the same locations as Bank Angle.

5. **Bank Erosion** – This was measured by placing erosion pins (smooth stainless steel rods 3 ft long X 0.375 inches in diameter) horizontally into the bank using procedures documented by Goudie (1981) and Thorne (1981). The erosion pins were located 25 ft, 75 ft, and 125 ft from the upstream boundary of the habitat survey site. At each erosion pinning location, three pins were inserted into the bank in a vertical array. Each pin was inserted such that the end was minimally exposed, approximately 1 in. A fourth pin was inserted into the substrate and in line with the other three pins. Two monuments (stakes) were located on top of the bank, one to each side of the pin array. Upon placement of the pins, measurements (nearest 1/8 in) were recorded for the distance from the center of each pin end to the base of each monument and to the center of the end of the substrate pin. Each time data were collected these distances were measured to ascertain if there was any horizontal shifting of the pin over time, and a measurement was made of total pin exposure. Once all measurements were taken the three horizontal pins were pounded into the bank so that they were exposed approximately 1 in. Baseline measurements were again taken. We felt that if a pin became greatly exposed, angler activity (stepping on the pin or intentionally tampering with it) would have biased the results by increasing the erosion measurements. Greatly exposed pins might also have increased accident potential as related to angler activity.

Bank angle, undercut bank, overhanging vegetation, stream depth and bank erosion were measured before and after the fishery. The change in each variable was calculated as:

$$\Delta = \text{prefishery value} - \text{postfishery value}. \tag{4}$$

Analysis of variance with a randomized block design was used to test for a significant relationship between angler traffic and the change in assessment values (controlling for habitat type). The model for the analysis is:

$$D_{ijk} = \mu + H_i + S_{j(i)} + \beta x_{ijk} + e_{ijk}, \tag{5}$$

where:

μ = overall mean change of the integrity variable;

H_i = effect of the i^{th} habitat type;

$S_{j(i)}$ = effect of the j^{th} site within the i^{th} habitat type;

βx_{ijk} = effect of angler traffic on the j^{th} site within the i^{th} habitat type; and

e_{ijkl} = error of the l^{th} replicate associated with the i^{th} habitat type, the j^{th} site.

Measurement error and the variance associated with angler traffic were ignored in this preliminary study.

NEARSHORE UPLAND AREAS

The nearshore upland areas of the habitat survey sites, described above, were evaluated at the same time the bank integrity data were collected, both before and after the sport fishery. The nearshore upland areas were assessed through the measurement of the following variables:

1. **Vegetation:**

   a) To sample vegetation proximal to the bank, a 150 ft transect was located along the shoreline with each end 5 ft onshore from OHW (Figure 3). For repeatability, these were straight transects, not following the irregularity of the bank. A 1 in 10 systematic sampling design was employed, (sample 1, skip 9). A 1 ft x 10 ft quadrat was used to sample the vegetation such that the midpoint of the long side of the quadrat intersected the transect line and was placed at the downstream side of the designated sample point. Vegetation was identified to the species level in most cases. Percent cover by species and cover class were estimated using the Daubenmire (1959) cover class method.

   b) To sample vegetation changes with departure from the riverbank, three transects were located perpendicular to the channel and at 50 ft intervals beginning at 25 ft from the upstream end of the habitat survey site (25 ft, 75 ft, 125 ft) (Figure 3). Each transect began at the riverbank and extended 75 ft onshore. A 1 in 20 systematic sampling design (sample 1, skip 17) was used. A 3 ft x 3 ft quadrat was centered on the transect line at the sample point. Vegetation was identified to the species level in most cases. Percent cover by species and cover class was estimated using the Daubenmire (1959) cover class method.

   Plant identification was conducted primarily by two technicians with knowledge of local flora. Guide books used for plant identification included: *The Flora of Southcentral Alaska* (Shaffer 1996), *Flora of Alaska and Neighboring Territories* (Hulten 1968), and *Wildflowers Along the Alaskan Highway* (Pratt 1996).

   The relationship between species distribution and angler traffic was examined using canonical correspondence analysis (CCA), an ordination technique developed by ter Braak (1985; 1986; 1987a, b, 1988a, b, c). For each habitat type a Monte Carlo permutation test (Hall and Titterington 1989) was used to test the hypothesis that species distribution is not related to angler traffic. The computer program CANOCO™[1] (ter Braak 1988a, c) was used to perform the analysis. Again, measurement error and the variance associated with angler traffic were ignored in this preliminary study.

2. **Soil Compaction** - A penetrometer was used to measure soil penetrability, interpreted as an indicator of soil compaction. Measurements were taken at depths of 1 in, 3 in, and 6 in since soil compaction by human foot traffic primarily occurs within the first 6 in of the surface (Kuss 1983, Dotzenko et al. 1967). Along the 150 ft vegetation transect, measurements were taken at 30 ft intervals starting 20 ft from the upstream end of the habitat survey site (20 ft, 50 ft, 80 ft, 110 ft, and 140 ft) (Figure 3).

These data were measured before and after the fishery with the change calculated as:

$$\Delta = \text{prefishery value - postfishery value.} \quad (6)$$

Since this project did not sample for soil type, it was not possible to look at change by habitat type—there could have been different soil types at each site which would have resulted in different resistance measurements based upon the composition of the soil. Therefore, change comparisons were made within sites by using a one-sample t-test to test the hypothesis:

H_o: $\Delta = 0$ against the alternative:

H_a: $\Delta < 0$.

The overall type I error was set at 0.10 and was adjusted to 0.009 for each individual test to control for experimentwise error.

3. **Trampling** - To assess the impact of trampling, photos were taken of four permanently marked plots at each habitat survey site. The plots (48 in x 30 in) were located along the 150 ft vegetation transect and began 30 ft, 60 ft, 90 ft and 120 ft from the upstream end of the transect (Figure 3). Permanent rebar stakes were inserted flush with the ground at the two corners of each plot which laid on the 150 ft vegetation transect (example: stakes at 30 ft and 34 ft). Two corners of a 48 in x 30 in quadrat were placed on the rebar stakes such that a long side of the quadrat fell on the transect line with the remainder of the quadrat extending 30 in toward the river. Photographs of the plot were taken using a Minolta®[1] 35 mm camera. While standing on a stepladder, a technician attempted to center the camera over the plot approximately 5 ft above ground level. Occasionally it was necessary to use an umbrella to canopy the plot to minimize shadowing effects. Sometimes an automatic flash was also used to further enhance lighting uniformity. Photos were taken as near to the beginning of the sport fishery and as soon afterwards as possible. Photos were cataloged by habitat survey site, plot, and date.

   Postseason the photos were scanned and the computer images analyzed using Adobe PhotoShop®[1] software following the protocol for photo imagery analysis outlined by Dietz and Steinlein (1996). Area by cover class, which included vegetation, litter (decomposing plant material), bare ground, and water, and percent cover class were estimated.

   A multivariate analysis of variance was used to test if angler traffic had a significant impact on mean percent change between prefishery and postfishery for each cover class. The following model was used:

$$\Delta_{ijkl} = \mu + \beta_i + \alpha_j + \gamma(\alpha)_{jk} + \beta\gamma(\alpha)_{jk} + \varepsilon_{ijkl,} \quad (7)$$

   where:

   Δ_{ijkl} = the change in percent cover (prefishery percent - postfishery percent),

   β_i = the effect of the i^{th} angler traffic,

   α_j = the effect of the j^{th} habitat type,

$\gamma(\alpha)_{jk}$	=	the effect of the k^{th} site in the j^{th} habitat type,
$\beta\gamma(\alpha)_{jk}$	=	the interaction between the i^{th} angler traffic and the k^{th} site in the j^{th} habitat type, and
ε_{ijkl}	=	the effect of the l^{th} photograph from the k^{th} site in the j^{th} habitat type.

OBSERVER MEASUREMENT ERROR

Measurement error was estimated for variables used to assess both bank integrity and nearshore upland areas. The methods and results are in Appendix B1.

RESULTS AND DISCUSSION

ANGLER DISTRIBUTION

For the 12 days on which angler counts were conducted from 8 July–10 August 1997, the riverwide count (total for all reaches) ranged from 150 anglers (8 August) to 1,515 anglers (20 July) (Table 2). Counts between 16 and 22 July were the highest observed and exceeded 1,000 anglers. (High angler counts may have occurred on days up to 27 July, the next count date after 22 July.) Angler participation in the fishery showed a 72% increase between 15 July and 16 July. A specific date marking reduced angler participation was not as easily discernible due to a 5-day separation in counts between 22 July and 27 July. The highest angler count in a specific river reach was 516 anglers, occurring in reach 4 on 16 July.

Of anglers counted, 60.5% were located on private lands and 39.5% were on public lands (Table 3, Figure 4). Only in reach 1 was angler land usage predominately public (99.8%). For reaches 2 and 4, angler land usage was closely split between public and private land ownership (52.8% and 49.9% public land usage, respectively). For reach 3, anglers tended to more often use private lands (60.4%).

To ascertain shifts in angler usage of public and private lands over time, a Chi-square analysis was conducted on the angler counts by reach (Table 3). Angler counts for 1995 were omitted from this analysis because we thought they were not representative of the fishery. Only 3 angler counts were conducted in 1995, compared to 8 counts in 1996 and 12 counts in 1997. The angler counts in 1996 and 1997 were designed to occur during all phases of the fishery (early, peak, and late) whereas the 1995 angler counts occurred on two peak dates and one late date. Also, in 1996 and 1997, the time of day for the angler counts was scheduled for peak periods of the angler fishing day to maximize counts. This was not the case for the 1995 angler counts. Results of the Chi-square analyses detected a significant difference in angler usage of public and private lands in reaches 1, 3, and 4 (all P values < 0.001).

The majority of anglers (86.9%) were shore anglers (fishing from banks), while only 8.4% of the anglers fished from islands and 4.8% fished from gravel bars (Figure 5). Of the bank anglers, 58.2% stood in the water while fishing and 28.5% stood on the bank. The remaining bank anglers (13.3%) fished from boardwalks or other structures. Both island and gravel bar anglers tended to stand in the water while fishing (over 80% for each group), with the remaining anglers from these groups tending to stand on the nearest exposed land (island or gravel bar).

Table 2.-Counts of anglers during the recreational fishery for late-run sockeye salmon, by river reach, Kenai River, 1995-1997.

Date	Reach 1	Reach 2	Reach 3	Reach 4	Total
1995[a]	255[b]	451	1,101	1,161	2,968
1996[b]	1,189	1,532	2,942	1,846	7,509
1997					
10-Jul	55	30	92	118	295
15-Jul	32	185	328	264	809
16-Jul	132	189	552	516	1,389
20-Jul	418	253	511	333	1,515
21-Jul	236	254	419	455	1,364
22-Jul	384	209	321	182	1,096
27-Jul	357	163	124	60	704
31-Jul	111	21	44	28	204
1-Aug	166	43	55	29	293
2-Aug	206	54	50	15	325
8-Aug	44	23	24	59	150
9-Aug	79	49	35	49	212
Total	2,220	1,473	2,555	2,108	8,356

[a] Unpublished data. D. Vincent-Lang, Alaska Department of Fish and Game, Division of Sport Fish, Anchorage, AK, personal communication.

[b] Revised data from Larson and McCracken (1998).

Summary

Peak participation in the sport fishery for late-run sockeye salmon occurred from mid July to the end of the month and, as documented in previous studies (King 1995, 1997), is strongly related to run timing for the return.

In 1997, angler usage of public and private lands tended more toward private land (60.5%) which was understandable considering that 62% of all Kenai River waterfront property is privately owned. Within each river reach, the percent of public and private land used by anglers is related to the percent of public and private waterfront property available (Figure 6). For example, in reach 1, 96% of the land is publicly owned and approximately 99% of counted anglers were located on public lands. In reach 3, approximately 24% of the land is publicly owned and approximately 40% of the counted anglers were located on public lands.

From 1996 to 1997 there was an 8.3% shift in angler use from private to public lands (Table 3). Although there was a significant difference detected in reach 1, the percent of anglers using public lands increased only 1% (from 98.8% to 99.8%), indicating nearly all land use by anglers

Table 3.-Angler counts by year, reach and property ownership, Kenai River, 1995-1997.

Reach	Year	Total Public	Total Private	Mean Public	Mean Private	Percent Public	Percent Private	$X^{2\,b}$	df	P
	1995[a]	233	0	77.7	0.0	100.0	0.0			
1	1996	1,175	14	146.9	1.8	98.8	1.2	12.668	1	<0.001
	1997	2,215	5	184.6	0.4	99.8	0.2			
	1995	240	211	80.0	70.3	53.2	46.8			
2	1996	810	722	101.3	90.3	52.9	47.1	0.001	1	0.976
	1997	778	695	64.8	57.9	52.8	47.2			
	1995	452	649	150.7	216.3	41.1	58.9			
3	1996	874	2,068	109.3	258.5	29.7	70.3	59.932	1	<0.001
	1997	1,013	1,542	84.4	128.5	39.6	60.4			
	1995	703	458	234.3	152.7	60.6	39.4			
4	1996	1,062	784	132.8	98.0	57.5	42.5	23.282	1	<0.001
	1997	1,051	1,057	87.6	88.1	49.9	50.1			
	1995	1,628	1,318	542.7	439.3	55.3	44.7			
All	1996	3,921	3,588	490.1	448.5	52.2	47.8	110.964	1	<0.001
	1997	5,057	3,299	421.4	274.9	60.5	39.5			

[a] For comparison, the number of anglers on public land in Reach 1 in 1995 was reduced by 22 because these anglers were counted between Jim's Landing and the inlet to Skilak Lake. This section of the river was not evaluated during 1996 and 1997.

[b] Chi square analyses did not include the 1995 counts. These counts were not representative of the fishery: only three counts conducted, with two done on peak dates.

in reach 1 is public. In reach 2, angler land use remained constant, with 53% public and 47% private. In reach 3, where most of the anglers are located (34.6%), there was a 10% increase between 1996 and 1997 in use of public lands by anglers. The reverse of this occurred in reach 4, with a decrease of 7.6% in use of public land by anglers. In reviewing the "bank fishing closures" implemented by the department in 1996 and continued in 1997 (Table 4), there was no change in bank closures between the two years: the sites and number of river miles of bank

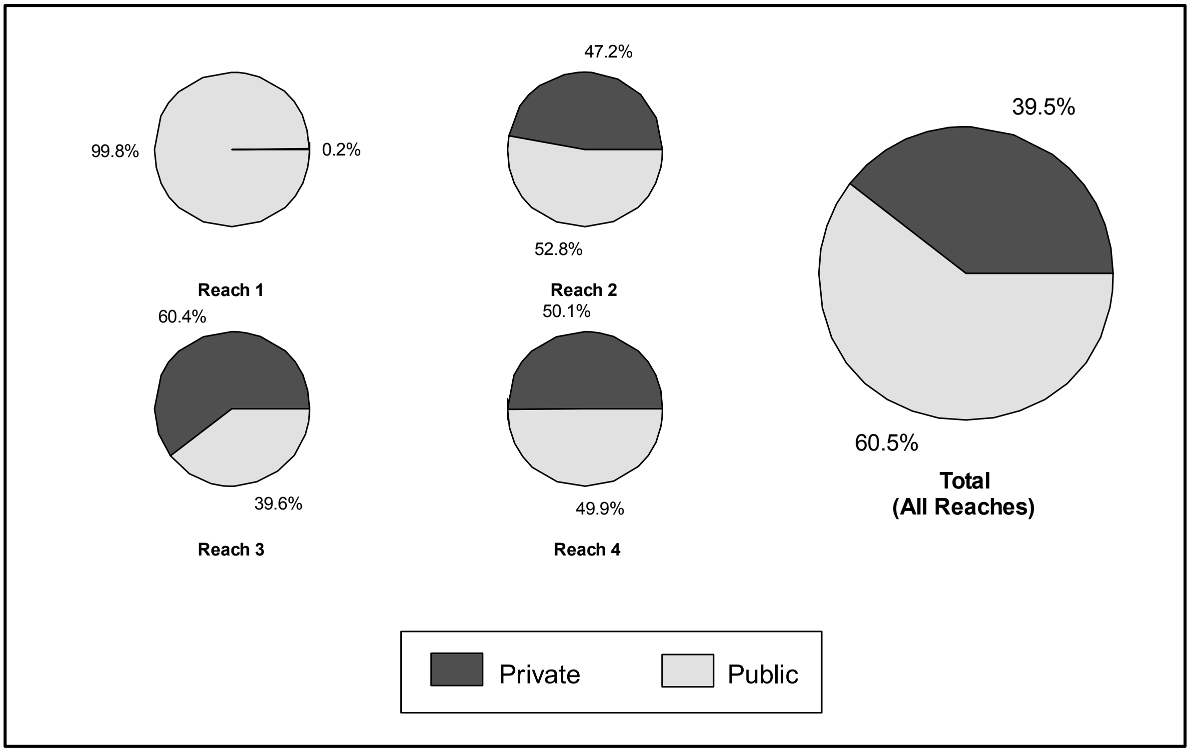


Figure 4.-Percent of anglers using private and public lands during the sport fishery for late-run sockeye salmon, Kenai River, 1997.

closed to angling remained the same. Therefore, the shift in land use by anglers in reaches 3 and 4 was unrelated to these bank closures.

Although some anglers fish from islands and gravel bars (13.2%), most anglers fish from the mainland banks (86.9%) (Figure 5). Of the few anglers fishing from islands and gravel bars, most accessed these locations by boat. Anglers fishing from shore tended to access their fishing locations on foot. Only 13.4% of the shore anglers actually fished from boardwalks and other structures which could minimize their impacts to riparian habitats. Shore anglers who stood in the water (58.2%) tended to reduce their overall impact to riparian habitats. But, how they access the river and whether they move from one fishing location to another by walking on top of the bank or in the water are the determinants of the level of riparian habitat impact. Those anglers who actually stand on the banks while fishing (28.5%) are more likely to cause impacts to riparian habitats throughout the entire time of their fishing trip.

ANGLER MOVEMENT

During the fishery, angler movement was estimated at each habitat survey site. At four sites no anglers were observed during the monitoring periods (Table 5). During the fishery, the total number of anglers monitored at each site ranged from 0 to 32, and the estimated mean angler movement for sites with anglers ranged from 1.8 to 54.1 feet per minute (Table 5). Of the eight sites where angler movement was measured, six of the sites had similar movement (nonparametric ANOVA, $P < 0.01$). One site, (SHC1), where the bank area was closed to

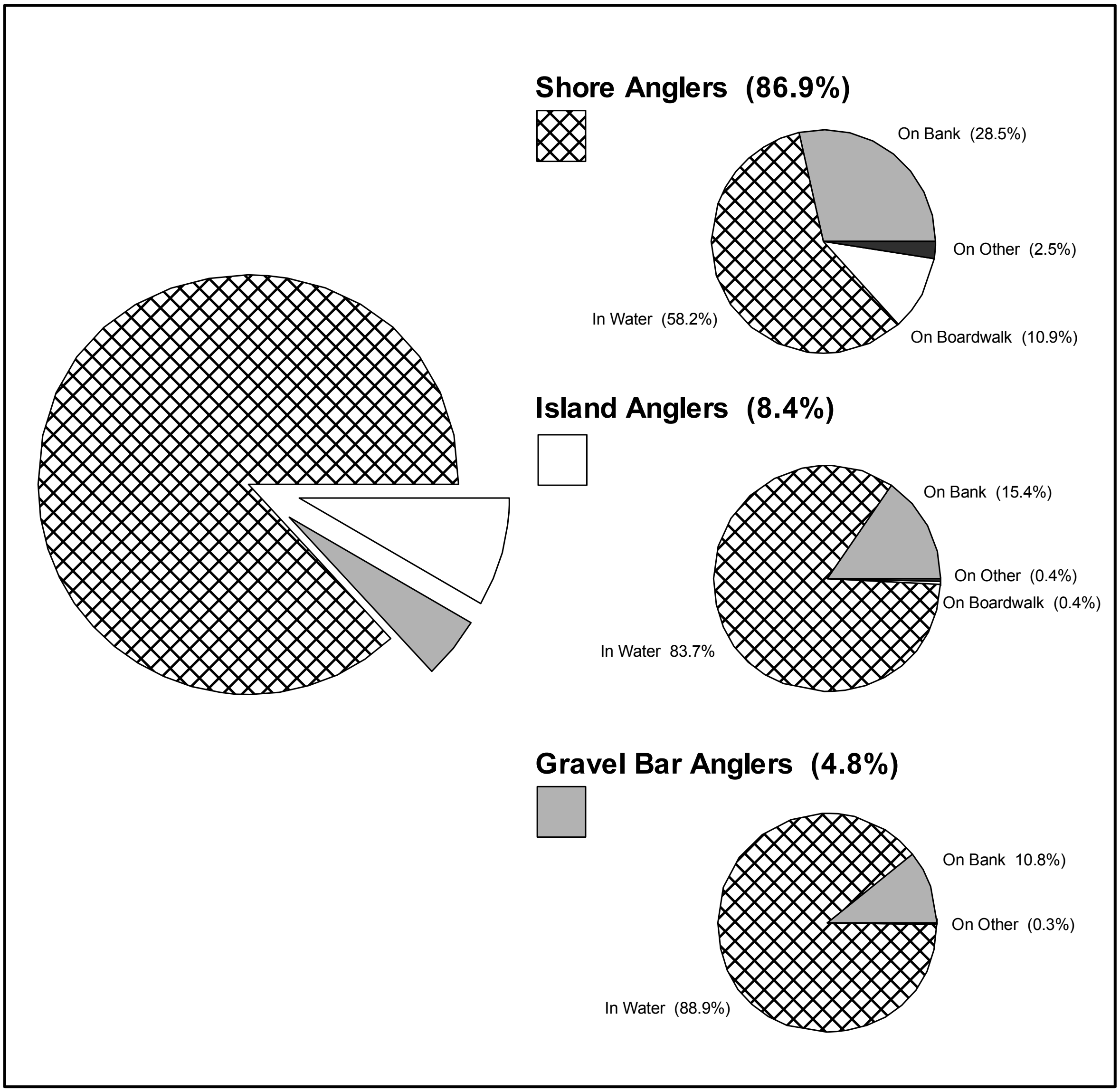


Figure 5.-Angler distribution by primary location and their structural use during the sport fishery for late-run sockeye salmon, Kenai River, 1997.

fishing, was very heavily utilized by shore anglers and had the highest movement. Although anglers did not actually fish from the bank at this site, they used the site as a corridor to access nearby gravel bars. The other site which had high angler movement was SHI4. This may have been related to the topography of the site. The channel adjacent to the bank was too deep for wading which necessitated that anglers move along the top of the bank. This site was also characterized by several embayments which forced anglers to walk interior to the site when accessing desired fishing locations. Both of these may have contributed to the increased distance traveled by anglers at this site.

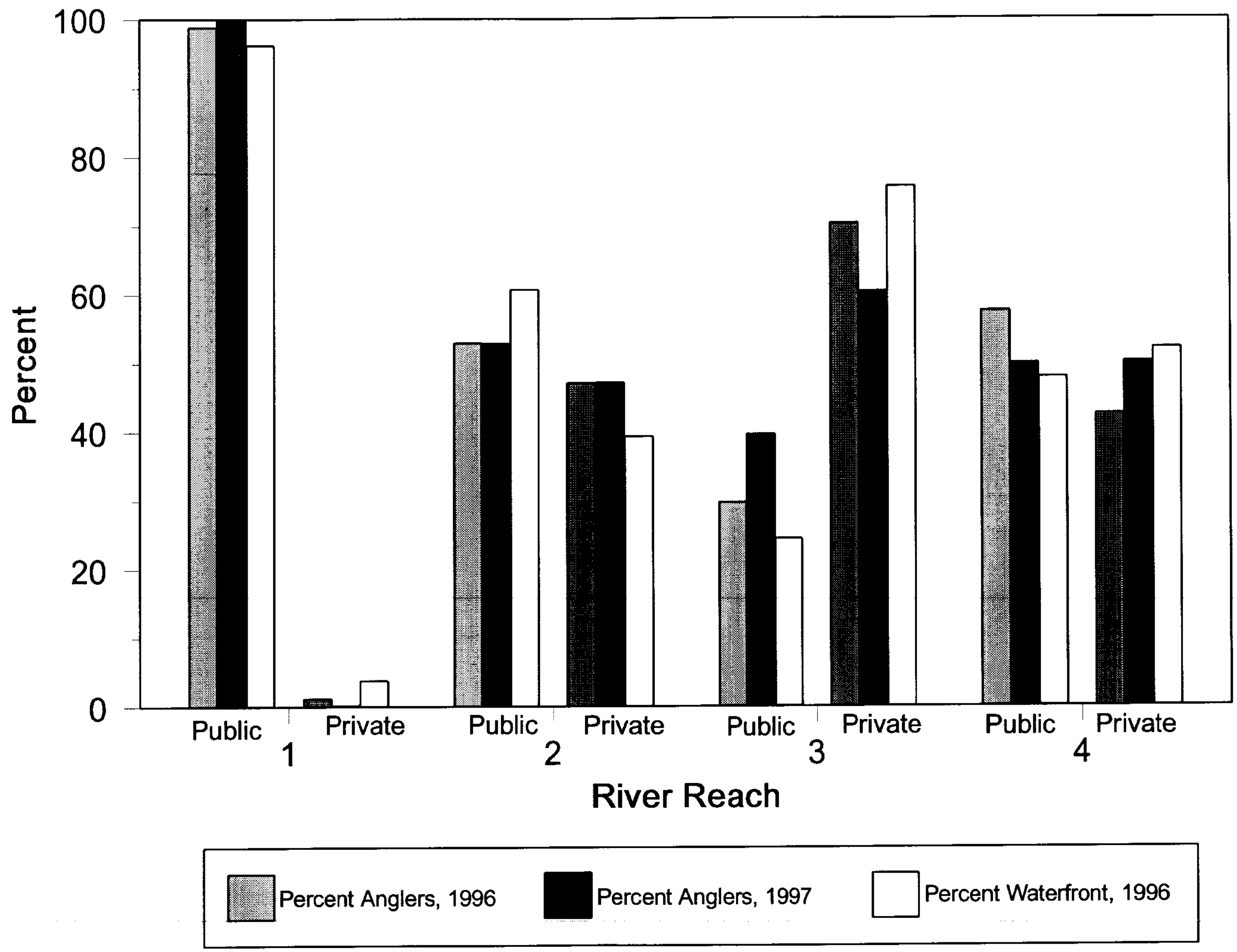


Figure 6.-Percent of anglers using public and private land (1996 and 1997) and percent of public and private waterfront land (1996), by river reach, Kenai River.

Table 4.-Miles of riverbank closed to angling, by river reach, Kenai River, 1996 and 1997.

Year	Reach 1	Reach 2	Reach 3	Reach 4	Total
1996	3.4	0.2	2.9	2.8	9.3
1997	3.4	0.2	2.9	2.8	9.3

Using angler counts (conducted by boat), angler traffic was estimated for each habitat survey site (Table 5). These ranged from 0.9 to 252.5 feet per minute for sites with movement estimates. Again, the corridor site had the highest estimate of angler traffic.

Summary

The distance traveled by anglers at each site is likely related to local topography. Site SHC1 had the highest mean angler movement (54.1 ft/min), probably due to the reason described above. Site SHI4, also described above, had the next highest mean angler movement (17.3 ft/min). Site SHI3 had the third highest angler movement (8.8 ft/min) and was characterized as having shrubs very near the bank in some areas, forcing anglers to walk interior to the site on a trail and then back out to the river. Open areas at this site were boggy which forced anglers to walk around the boggy area to access a desired fishing location. Each site seemed to be unique as to the depth of the channel near the bank, density of shrubs near the bank, and the presence of terraces, wetland areas, and embayments. All of these influenced angler behavior and how much anglers moved when fishing at the specific site.

Table 5.-Summary of angler movement, angler counts (conducted by boat), and angler traffic by habitat type for each habitat survey site, 1997.

		Angler Movement			Angler Count (conducted by boat)			Angler Traffic	
Habitat Type	Site	No. of Anglers	Mean (ft/min)	Var	No. of Anglers	Mean	Var	Mean (ft/min)	Var
Herb	HC1	0			0			0.0	
	HC2	0			0			0.0	
	HI1	18	5.9	4.0	34	2.8	25.8	16.6	836.2
	HI2	0			0			0.0	
	HI3	15	3.3	1.4	11	0.9	1.2	3.0	12.9
	HI4	25	1.8	0.3	40	3.3	27.5	6.0	86.1
Shrub/Herb	SHC1	17	54.1	29.5	56	4.7	50.1	252.5	145,780.4
	SHC2	0			0			0.0	
	SHI1	21	1.9	1.0	16	1.3	3.7	2.5	11.4
	SHI2	32	4.3	0.7	26	2.2	16.7	9.5	300.3
	SHI3	14	8.8	25.4	1	0.1	0.1	0.9	5.4
	SHI4	15	17.3	115.0	2	0.2	0.3	3.5	60.3

During analyses of the angler movement data, we concluded that these data may not be representative of the fishery occurring at the habitat survey sites. Particularly, of the angler counts conducted by boat, a count of zero occurred at each site on at least 5 of the 12 sample days (Appendix C1). Two sites (SHI3, SHI4) had counts of zero on 11 days. Personal knowledge of this fishery and the level of angler use at the habitat survey sites suggested that the count data were not representative of angler presence at these sites, counts being too low. Therefore, the estimates of angler traffic for the habitat survey sites are likely biased low.

BANK INTEGRITY

Results from the analysis of variance indicated no significant relationship between angler traffic and the change in bank angle (F = 2.37, P = 0.13, Figure 7). There was a significant difference between macrohabitat type and change in bank angle (F = 8.22, P = 0.02). At herbaceous habitat survey sites, the average change in bank angle was –10.2 degrees (SE = 6.9) while at shrub/herbaceous habitat survey sites the average change was 16.8 (SE = 5.9).

The analysis of variance detected no significant relationship between change in undercut bank and angler traffic (F = 0.49, P = 0.49) or between change in undercut bank and macrohabitat type (F = 0.46, P = 0.52, Figure 7). The average change was –1.0 (SE = 1.6) inches for herbaceous habitats and –3.1 (SE = 1.0) inches for shrub/herbaceous habitats.

For amount of overhanging vegetation, the analysis of variance detected no significant relationship with angler traffic (F = 0.76, P = 0.39) or macrohabitat type (F = 0.90, P = 0.37, Figure 7). The average change was 3.5 (SE = 3.5) inches for herbaceous habitats and –3.7 (SE = 2.9) inches for shrub/herbaceous habitats.

No significant relationship was detected between stream depth and angler traffic (F = 1.40, P = 0.24) or between stream depth and macrohabitat type (F = 2.00, P = 0.19, Figure 7). Stream depth increased at all habitat survey sites (average = 11.97, SE = 1.1). The increased stream depth is more related to seasonal fluctuations in water levels. The Kenai River, being a glacial stream, typically reaches its highest annual discharge in July and August. This would clearly explain higher stream depth measurements at habitat survey sites in August versus June. Increased stream depth at survey sites is not an angler related phenomenon.

Results from the bank erosion measurements showed bank changes ranged from a loss of 27.6 in to a gain of 1.5 in. Most habitat survey sites exhibited a change of less than 1 in between prefishery and postfishery measurements. Only the site located on the bank opposite of the Moose River confluence (HC2) had a large measurement of bank loss (over 17 inches for all three erosion pins at the 125 ft transect location). This site was closed to bank anglers. The high amount of erosion was probably more related to the confluence of the Moose River and its influences on this very sandy, herbaceous bank on the opposite shore, and possibly to boat wake activity associated with nearby recreational docking areas. There were habitat survey sites (SHI1, SHI2, HI3, HI4) that had large sections of bank loss, but the estimate of bank loss was an ocular measurement due to the loss of the erosion pins. At site SHI1 an estimated 2^+ ft wide and 25 ft long piece of bank had calved. Similarly at SHI2, a calved chunk was estimated at 2^+ ft wide and 15 ft long. At sites HI3 and HI4 four chunks of bank 2 ft in width and of varying lengths were estimated to have calved; one calved chunk contained two erosion pins.

Measurements for some erosion pins indicated an increase of bank. This is likely related to compaction of the bank from the surface with the initiation of a “rollover” as the bank begins the

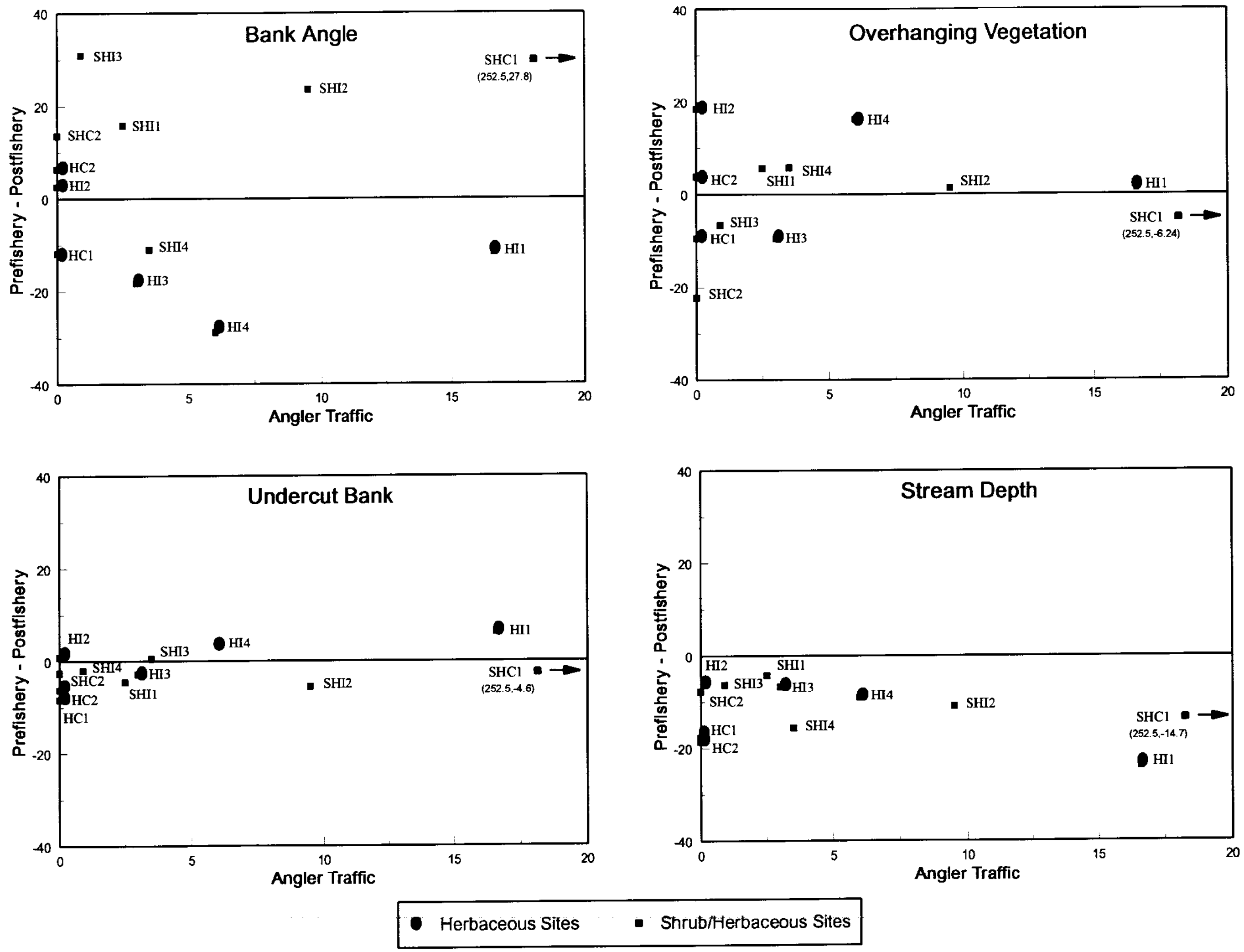


Figure 7.-Relationship of angler traffic to prefishery - postfishery measurement change for bank integrity variables (bank angle, overhanging vegetation, undercut bank, stream depth) by habitat type and site, Kenai River, 1997.

calving process. In some cases, the erosion pins, which were inserted horizontally in June, were observed to be in a downward pointing angle in August.

No statistical analysis to correlate these data with angler traffic data was done. During the project there were several problems with obtaining erosion pin measurements. Of the 87 erosion pins initially placed in June, only 56 (64%) were re-measured in August after the fishery. Some pins (12) were never re-located due to high water. Other pins (20) were fated as missing.

Angler behavior explains the fate of some pins and also questions the reliability of the measurements for other pins. Some erosion pins were found onshore in the vegetation, indicating human tampering. On one known occasion a pin had been used to tie off a boat. Some pins had been observed as being stepped and pulled on. So, for those pins with measurements, the reliability of the measurement was questionable.

Summary

The data did not support a relationship between bank integrity variables (bank angle, undercut, overhanging vegetation, and stream depth) with angler traffic. This was contrary to what was expected, but the explanation may be partly associated with problems with the angler count data. As discussed above in the Angler Movement section, we felt that these data were not representative of angler effort at each habitat survey site. Hence, the sensitivity for correlation of these data with the bank integrity data would be reduced.

The bank angle data showed an increase in bank angle at herbaceous sites and a decrease in bank angle at shrub/herbaceous sites between pre- and postfishery measurements. While not statistically significant, both habitat types exhibited increased undercut bank postfishery, but there was a greater average undercut at shrub/herbaceous habitat sites. This might suggest that the banks at shrub/herbaceous sites have a higher level of stability than do the herbaceous sites. The increased stability may be due to root structures of shrubby vegetation which help to stabilize soils. However, the nearshore area of the shrub/herbaceous sites was generally characterized by a 10 ft-15 ft wide zone of herbaceous vegetation at the bank. It is unlikely that this zone would offer any greater soil stabilization than the vegetation along the banks of the herbaceous sites. Possibly, these indicated trends in bank angle and undercut bank may be more circumstantial when considering dynamics of the river. The riverbanks are constantly in motion, i.e., in some stage of undercutting, rolling over, slumping, and calving. Results for bank angle and undercut bank measurements could be entirely different dependent upon sample time within the cycle.

Of the bank integrity variables collected, stream depth was concluded to be the least important and the least indicative of angler induced impacts. Changes in stream depth throughout the assessment period were largely due to normal increased discharge associated with peak flow periods for the Kenai River.

Although it was not possible to determine a statistical relationship between bank erosion and angler presence at the habitat survey sites, four of the eight sites selected as being impacted by anglers exhibited large losses of bank. The banks at these sites were characterized as being steep (less than 90 degree bank angle) and undercut; therefore, they were more prone to bank calving as compared to banks with a greater than 90 degree bank angle having no undercut. This is only anecdotal data and further research would be required to document a specific relationship between bank erosion and angler use at these sites.

NEARSHORE UPLAND AREAS

Vegetation Assessment

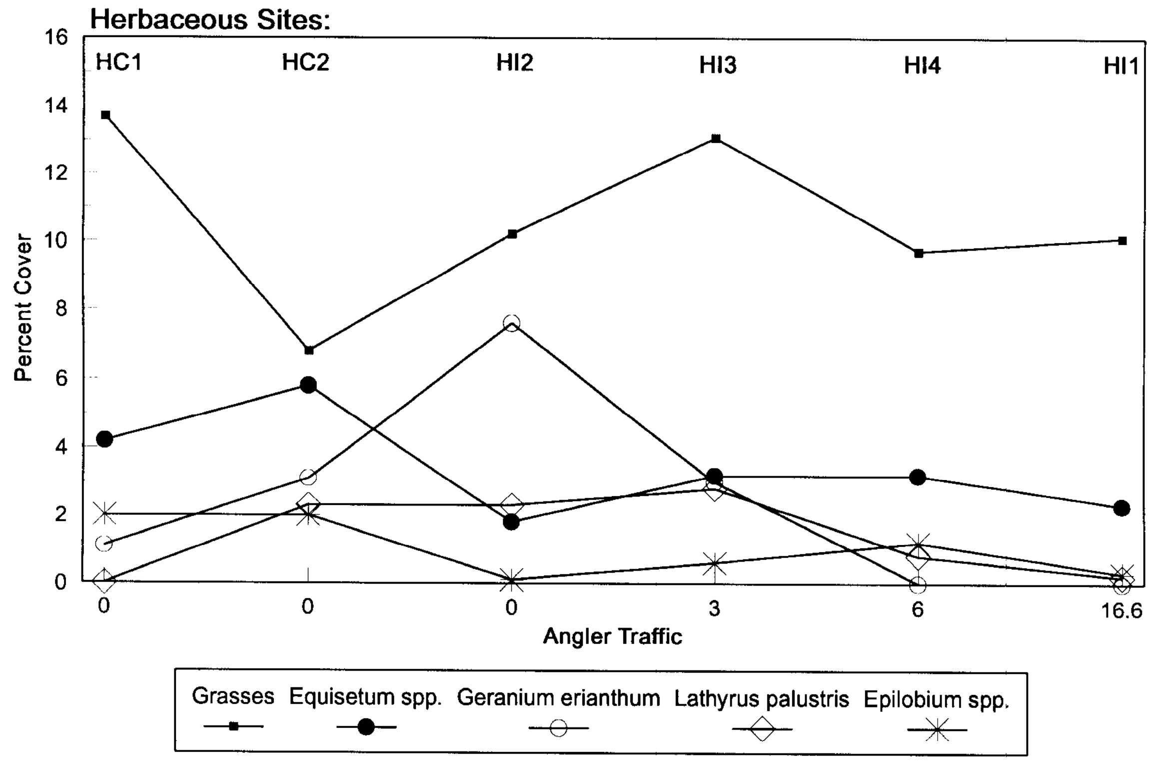
Vegetation and cover classes identified along the 75 ft and 150 ft transects are listed in Appendices C2 and C3. There were four plant categories that were present at nearly all habitat survey sites during prefishery and postfishery sampling: bryophytes (mosses and ferns), graminoids (grasses), *Epilobium* (fireweed), and *Equisetum* (horsetails).

Results of the canonical correspondence analyses, used to determine if there was a relationship between plant species composition and angler traffic, were negative for the 75 ft transects. For both habitat types, there were no significant differences detected in percent coverage as related to a 75 ft proximity to the river bank (Table 6).

For the 150 ft transects, a significant difference was detected for both habitat types (Table 6), indicating that there was a relationship between angler traffic and percent coverage by plant species. Figure 8 shows this relationship for a few plant species by habitat type. There is a slight trend toward greater percent coverage at sites with no angler impact. For the shrub/herbaceous habitats, site SHC1 received high angler use (angler traffic = 252.5), but was generally assessed to have higher percent cover for species plotted compared to other sites. Again, site SHC1 was used by anglers to access gravel bars, but anglers did not actually fish from the main bank. Angler impact at this site was mainly in the form of extensive trails, both perpendicular and parallel to the bank. In general, anglers were not observed to trample vegetation in the nearshore area except for a few locations where they entered the water to cross a small channel to access the nearby gravel bar. For this site, the impact to nearshore vegetation was not indicative of angler traffic.

Table 6.-Results of canonical correspondence analyses for the relationship of plant species distribution with angler traffic, Kenai River, 1997.

Transect Type	Habitat Type	Quadrat	F ratio	P
75 ft	Herb	1	1.31	0.10
		2	1.94	0.04
		3	1.24	0.28
		4	1.53	0.09
	Shrub/Herb	1	0.68	0.75
		2	1.42	0.10
		3	1.22	0.23
		4	1.03	0.42
150 ft	Herb		4.12	0.01
	Shrub/Herb		2.40	0.01



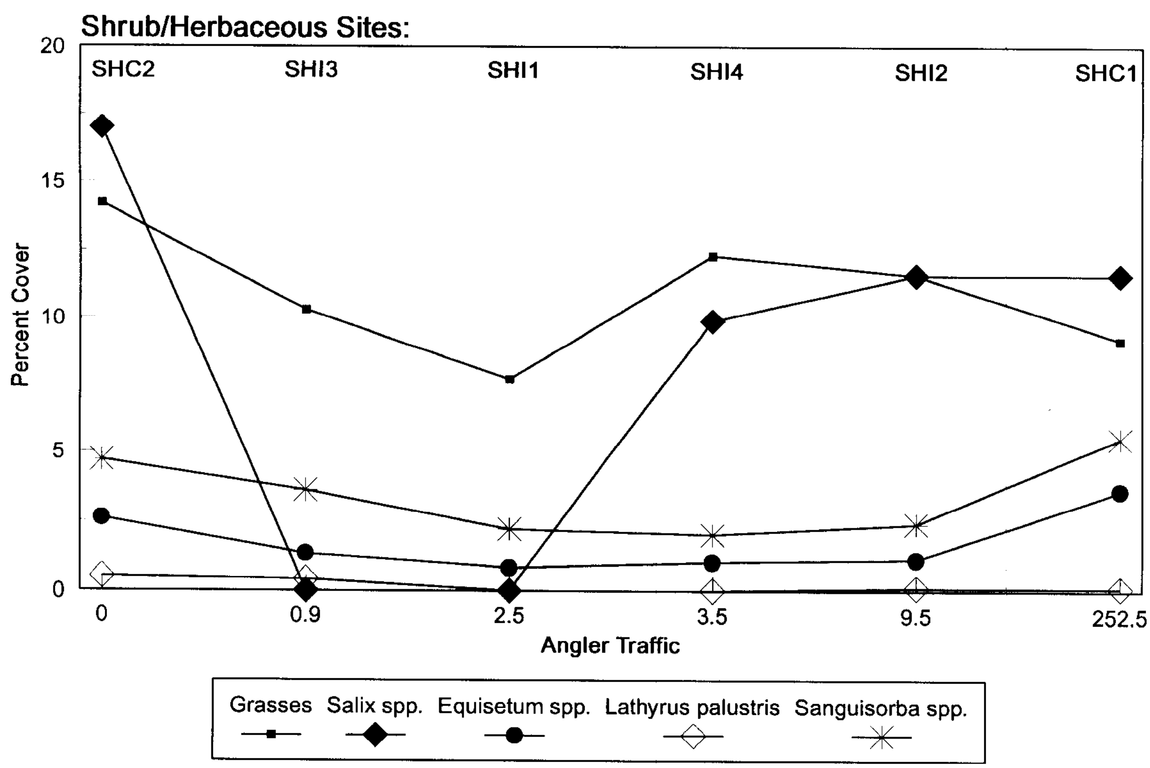


Figure 8.-Interaction of angler traffic with percent coverage of selected plant species by habitat type, Kenai River, 1997.

Soil Compaction

The range for change in soil penetrability measurements at a depth of 1 in was -59 to 102 psi with a mean of 0.91 psi; at a depth of 3 in, the range was -104 to 87 psi with a mean of -14.16 psi; and at a depth of 6 in, the range was -102 to 71 psi with a mean of 3.15 psi (Table 7). There were no significant relationships detected between angler traffic and soil penetrability measurements except at site HI3 at the 6 in depth (Figure 9).

Trampling

Trampling in the nearshore area was evaluated by examining photographs and assessing changes in percent cover for broad cover classes: vegetation, litter, bare ground, and water. Water was a cover class which was added during the assessment process. Due to natural bank curvatures with respect to the transect line, a few photo plots actually overhung the river, particularly with increased seasonal water levels.

The multivariate analysis of variance for angler traffic data with each cover class detected no significant changes in mean percent cover of bare ground or water (Table 8). There was significant interaction between habitat type and angler traffic for changes in mean percent vegetative cover and mean percent litter cover (Table 8). The analysis was then done for each habitat type. The herbaceous habitat type was more sensitive to anglers; angler traffic had significant effects on the changes in mean percent vegetative cover and mean percent litter cover (Table 8). Herbaceous sites with higher angler traffic values experienced a greater loss in mean vegetative cover and an increase in litter cover (Table 9, Figure 10). For shrub/herbaceous habitats, angler traffic had no significant effect on the changes in mean percent vegetative cover or in mean percent litter cover.

Figure 11 shows the prefishery minus postfishery changes in percent cover for vegetation, litter, and bare ground by habitat type and angler use. While not statistically significant, the general trend for low angler traffic sites was an increase in vegetative cover (a negative value in the graph) accompanied by a decrease (a positive value in the graph) in cover for litter and bare ground. This would be the anticipated pattern for sites with low angler traffic. Increased seasonal growth without trampling would tend to increase the vegetative canopy, thus having a sheltering effect and reduction in percent cover for litter and bare ground. For sites with more angler traffic, the anticipated trend, again not statistically significant, occurred: decreased percent cover of vegetation and increased cover for bare ground and litter. At sites with more angler use, trampling of vegetation would lead to decreased percent cover of vegetation. As the vegetation became trampled, that contributed to increased percent cover of litter. Continued trampling and runoff could reduce cover of litter to bare ground.

Summary

Results of the vegetation assessment using three 75 ft transects (perpendicular to the bank) and one 150 ft transect (parallel to the bank) were contradictory. The analyses detected significant angler impact in the nearshore area along the 150 ft transects for both habitat types, but did not detect any impacts or changes between quadrats sampled at different distances from the bank along the 75 ft transects. This is likely due to a smaller sampling rate for the 75 ft transects. For example, there were only three of these transects; therefore, there were only three quadrats (a total 27 ft^2) sampled in the nearshore area compared to 15 quadrats for the 150 ft transects (a total 150 ft^2). An improved design should eliminate this problem and improve results: (1) use 15 belt transects which are perpendicular to the bank and 25 ft long, (2) sample with a 1-foot square quadrat. Observation of this fishery indicated that anglers primarily use the first 15 ft

Table 7.-Summary statistics for soil penetrability measurements sampled along the 150 ft vegetation transect at habitat survey sites, Kenai River, 1997.

			Soil Penetrability (PSI)					
Depth	Habitat Type	Survey Site	N	Mean Change	SE	Angler Traffic	t[a]	P
1 in	H	HC1	5	-18	13.285	0	-1.355	0.123
	H	HC2	5	33	17.146	0	1.925	0.937
	H	HI1[b]				16.619		
	H	HI2	5	102	21.772	0	4.685	0.995
	H	HI3	5	-59	20.821	3.012	-2.834	0.024
	H	HI4	5	-45	24.290	5.993	-1.853	0.069
	S/H	SHC1	5	-9	37.862	252.549	-0.238	0.412
	S/H	SHC2	5	2	25.179	0	0.079	0.530
	S/H	SHI1	5	56	16.233	2.471	3.450	0.987
	S/H	SHI2	5	26	31.836	9.451	0.817	0.770
	S/H	SHI3	5	-38	19.404	0.877	-1.958	0.061
	S/H	SHI4	5	-40	31.781	3.467	-1.259	0.138
3 in	H	HC1	5	-12	16.859	0	-0.700	0.261
	H	HC2	5	-5	8.660	0	-0.577	0.297
	H	HI1	5	-3	18.547	16.619	-0.162	0.440
	H	HI2	5	2	25.476	0	0.079	0.529
	H	HI3	5	-104	35.157	3.012	-2.958	0.021
	H	HI4	5	-35	23.927	5.993	-1.463	0.109
	S/H	SHC1	5	-48	44.542	252.549	-1.078	0.171
	S/H	SHC2	5	0	20.000	0	0	0.500
	S/H	SHI1	5	87	29.223	2.471	2.977	0.980
	S/H	SHI2	5	17	13.928	9.451	1.221	0.855
	S/H	SHI3	5	-55	15.000	0.877	-3.667	0.011
	S/H	SHI4	5	-24	35.014	3.467	-0.685	0.265
6 in	H	HC1	5	2.6	11.281	0	0.230	0.585
	H	HC2	5	-15	19.812	0	-0.757	0.246
	H	HI1	5	46	22.045	16.619	2.087	0.947
	H	HI2	5	42	16.401	0	2.561	0.969
	H	HI3	5	-102	24.114	3.012	-4.230	0.007
	H	HI4	5	-22	24.423	5.993	-0.901	0.209
	S/H	SHC1	5	36	33.963	252.549	1.060	0.826
	S/H	SHC2	5	4	21.932	0	0.182	0.568
	S/H	SHI1	5	71	23.043	2.471	3.081	0.982
	S/H	SHI2	5	-15	22.858	9.451	-0.656	0.274
	S/H	SHI3	5	-13	12.104	0.877	-1.074	0.172
	S/H	SHI4	5	12	31.647	3.467	0.379	0.638

[a] t = one-sample t-test.

[b] Measurements at the 1 in depth were not taken at this site postfishery; hence, no change can be calculated.

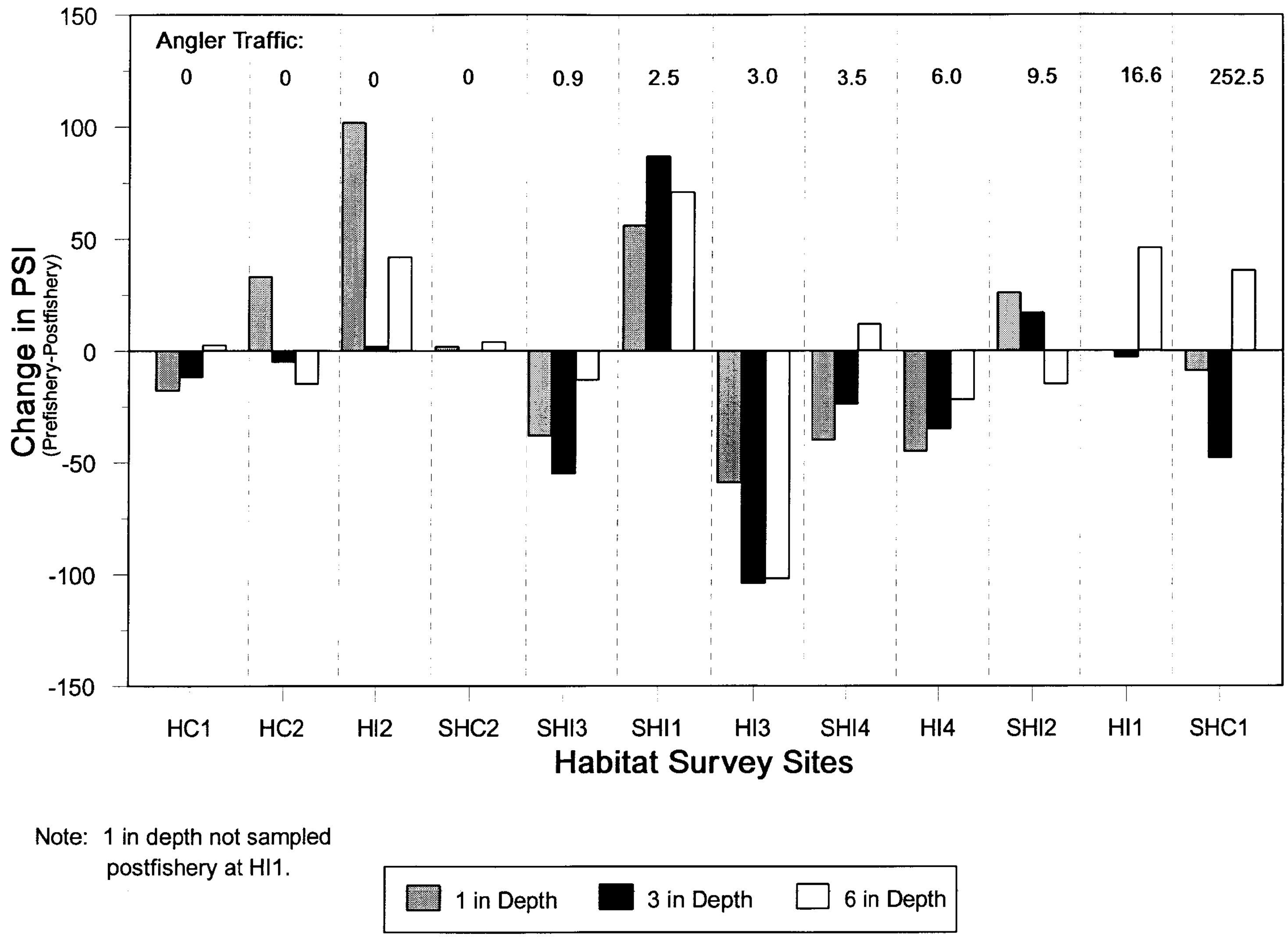


Figure 9.-Change in mean soil resistance (PSI) measurements at three soil depths for habitat survey sites, Kenai River, 1997.

Table 8.-Multivariate analysis of variance for change in percent cover by cover class from photo imagery analysis of permanent photo plots at habitat survey sites, Kenai River, 1997.

Change in Percent Vegetative Cover		Change in Percent Bare Ground Cover	
Source	P>F	Source	P>F
Weighted Angler Movement	0.61	Weighted Angler Movement	0.95
Habitat Type	0.05	Habitat Type	0.07
Interaction	<0.01	Interaction	0.08
Change in Percent Litter Cover		**Change in Percent Water Cover**	
Source	P>F	Source	P>F
Weighted Angler Movement	0.41	Weighted Angler Movement	0.77
Habitat Type	0.03	Habitat Type	0.16
Interaction	<0.01	Interaction	0.32

Table 9.-Multivariate analysis of variance for change in percent cover of vegetation and litter, by habitat type, for permanent photo plots at habitat survey sites, assessed by photo imagery analysis, Kenai River, 1997.

Herbaceous:				Shrub/Herbaceous:			
Change in Percent Vegetative Cover				Change in Percent Vegetative Cover			
Parameter	Estimate	SE	P>T	Parameter	Estimate	SE	P>T
intercept	1.93	50.6	0.76	intercept	27.84	6.97	<0.01
slope	3.97	0.69	<0.01	slope	-0.01	0.07	0.93
Change in Percent Litter Cover				Change in Percent Litter Cover			
Parameter	Estimate	SE	P>T	Parameter	Estimate	SE	P>T
intercept	50.2	2.89	0.10	intercept	-8.70	5.25	0.11
slope	-2.81	0.39	<0.01	slope	-0.02	0.05	0.73

from the bank so transects which extend beyond this distance would allow detection of vegetation change or impact with departure from the bank.

Soil compaction changes, as indicated by the soil penetrability measurements, were unrelated to angler presence at the habitat survey sites except for one site. At site HI3 a significant difference was detected at a depth of 6 in. Most soil compaction by foot traffic occurs within the first 3 in so change should be detected at this depth as well as 6 in. Since this was not the case, this relationship was likely a random event. Improvement of the sample design, to include increased sample rate, may better allow correlation with angler traffic data.

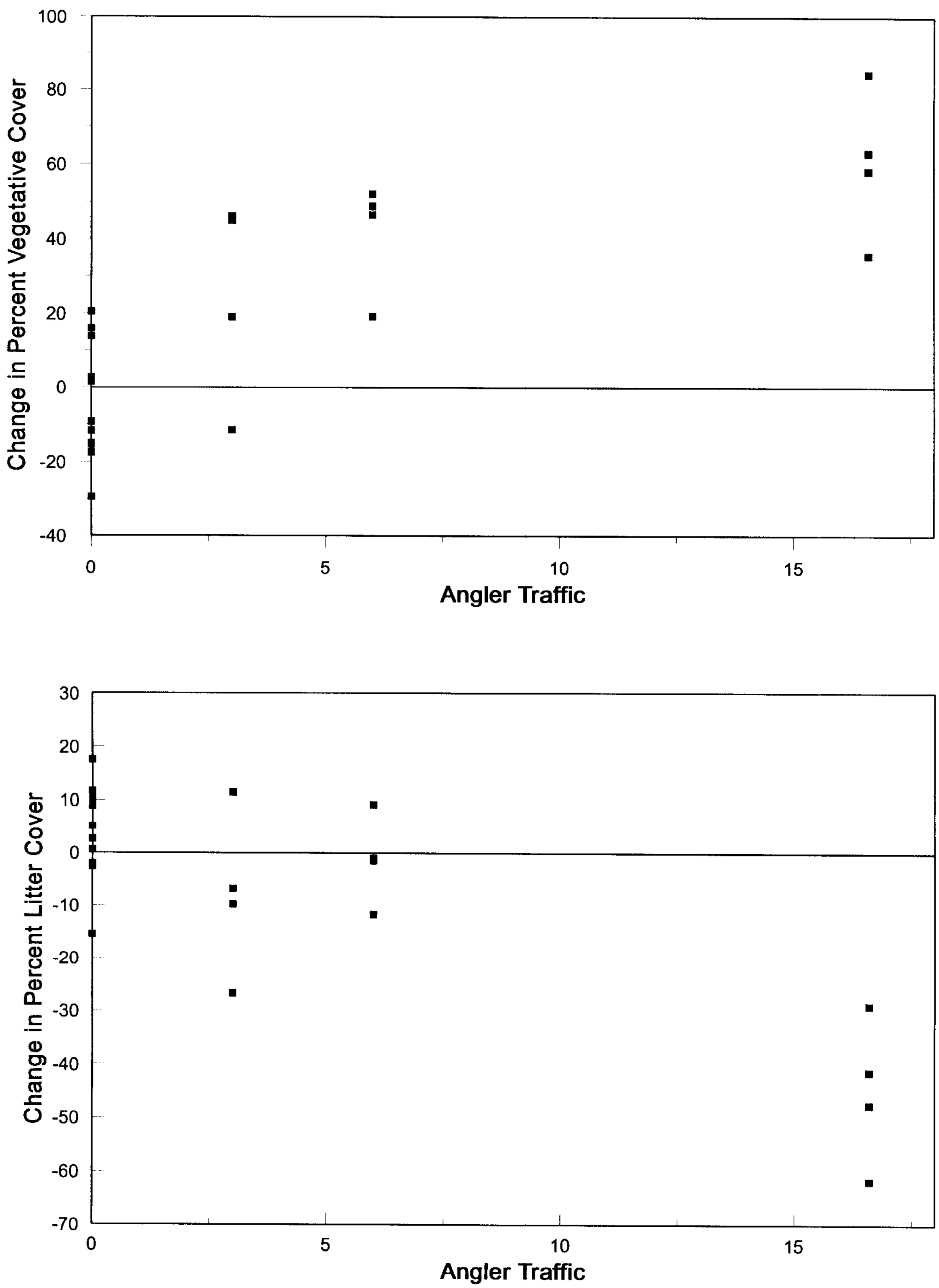
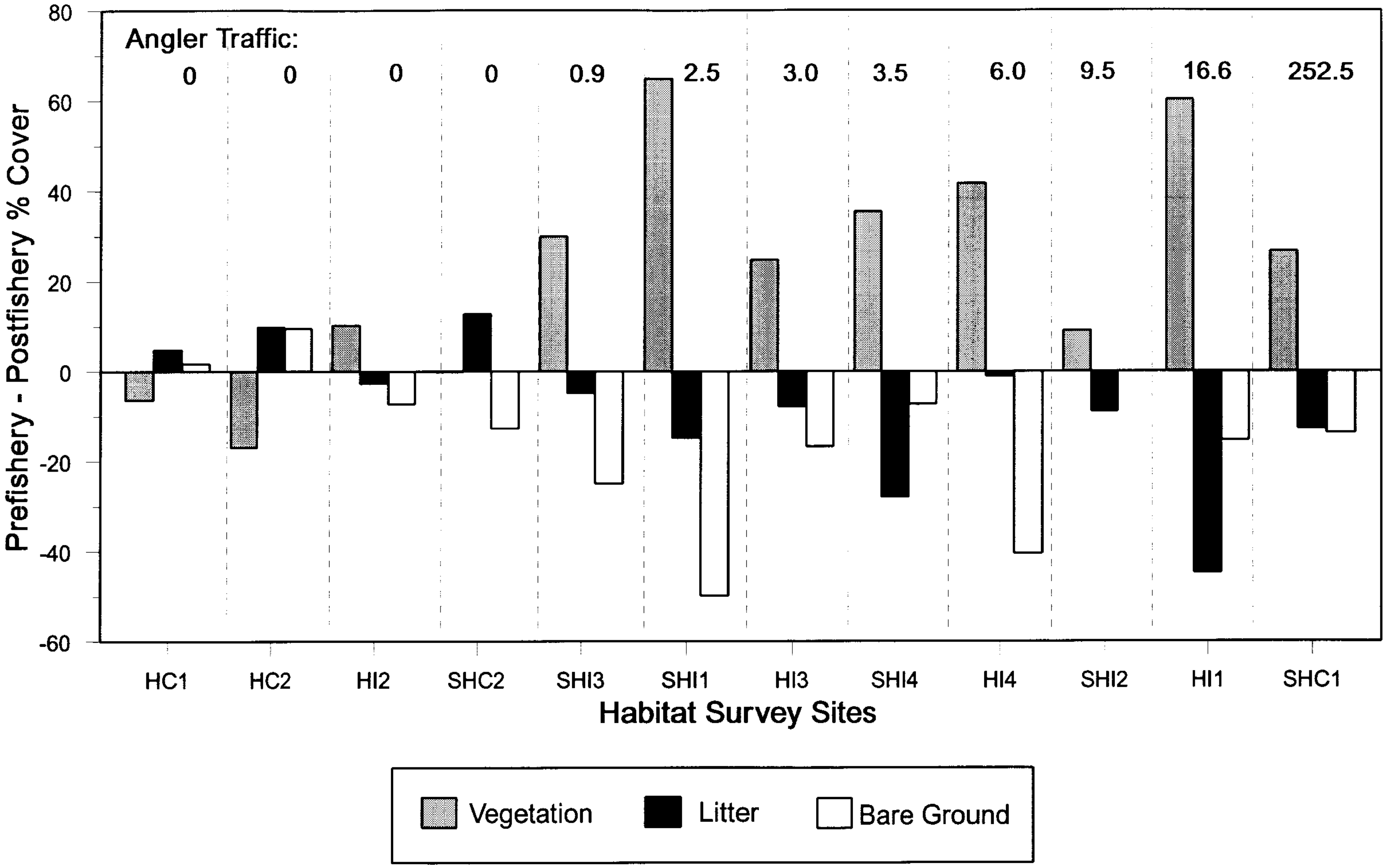


Figure 10.-Relationship of angler traffic with change in percent cover of vegetation and litter for permanent photo plots (assessed by photo imagery analysis) at herbaceous habitat survey sites, Kenai River, 1997.



Note: Percent cover of water was omitted from the graph since incidence at sites was minimal.

Figure 11.-Change in percent cover for permanent photo plots at habitat survey sites, analyzed using photo imagery analyses, Kenai River, 1997.

Of the two macrohabitat types assessed for trampling, herbaceous habitats were more sensitive to angler impacts than shrub/herbaceous habitats. Similar, though not statistically supported, impact "trends" (decreased vegetative cover and increased cover for litter and bare ground) existed for shrub/herbaceous sites; the analysis with angler traffic did not detect a significant relationship. The analysis may not have been able to detect a difference due to the questioned bias associated with the angler traffic data (discussed above in the Angler Movement section). Improved angler traffic data may better enable a more meaningful test.

RECOMMENDATIONS

Assessment of angler impacts to Kenai River riparian habitats has been ongoing since 1996. During this time, project personnel have explored and tested various methods to best assess angler impacts. The 1996 project used a broad based approach for an overall assessment of habitat values. This proved to have poor resolution for assessing the specific problem of angler impacts. This resulted in a redesign of the project for 1997 with the focus being on two specific habitat types (herbaceous and shrub/herbaceous) felt to be more sensitive to angler impacts. Through assessment of specific habitat variables at designated habitat sites, the project attempted to identify impacts to the riparian habitat which might be attributed to angler use.

Of the techniques employed in 1997, some have potential for monitoring and assessing angler impacts. The angler distribution counts, ongoing since 1995, continue to provide information which characterize angler behavior within this fishery. These counts provide good trend information regarding angler use of public and private lands, and their use of structures as a platform for fishing. Continuation of these angler counts will allow the department to monitor these trends as participation in the fishery changes and as a result of bank angling closures as the department continues to exercise its regulatory authority to protect critical and damaged habitats. Angler counts also allow determination of bank locations receiving high angler use, possibly needing evaluation to determine if the level of angler use is sufficient to warrant regulatory action. The number of angler counts conducted during the fishery seemed adequate to accomplish the above tasks.

The angler traffic data were used as a means to relate angler use to habitat changes at each habitat survey site. These data appeared to be biased low for some sites, based upon personal knowledge of the fishery. Due to the changing fish entry pattern into the river, there may be low angler participation at one time of the day and very high angler participation at another time of the day. Therefore, a single angler count at a habitat survey site is likely not representative of the total angler effort at that site for one day. To avoid this bias, it may be better to develop a method for estimating total angler effort at each habitat survey site. Improved angler effort estimates for each habitat survey site would allow better correlation of the level of angler use with habitat impacts.

The vegetation assessment was actually a twofold process using transects and permanent vegetation plots. The vegetation transects were very specific using quadrat sampling to speciate the local flora in the nearshore area (the 150 ft transect) and with departure from the bank (the three 75 ft transects). These vegetation transects were able to detect significant angler impact occurring in the nearshore area. Though effective, these methods are very time consuming and manpower intensive. Photography of the permanent vegetation plots has potential to reasonably and efficiently assess vegetative change in the nearshore area. For the purpose of assessing angler impact, in the sense of vegetative loss, it is probably not necessary to speciate the plant community at these sites. The process of photo imagery analysis allows a quicker and more objective analysis of broad scale vegetative change. For assessing angler impact to vegetation (trampling), the change in percent cover of vegetation, litter, and bare ground is sufficient. Continued monitoring and analysis of these vegetation plots will provide information as to plant recovery vs. permanent loss of vegetation.

Attempts to assess soil compaction by using soil resistance measurements as an indicator could be greatly improved. Soil compaction along with denuding of the vegetation accelerates bank erosion. To better assess this relationship, the sampling rate could be increased and samples could be taken within every permanent vegetation plot. This would allow very specific analysis of vegetative cover and soil resistance changes with angler effort at each site.

The results of the assessment of bank integrity variables (bank angle, undercut, overhanging vegetation, stream depth) proved to be very difficult to relate to shore anglers. Stream depth changes were determined to be seasonally related to Kenai River discharge and not anglers. Observation of the fishery indicated that overhanging vegetation in some areas was impacted by angler presence. Again, the problem may have been that the estimates of angler traffic were not representative of the true activity at the site. Also, the sample rate was likely not adequate to detect this change when correlated with angler traffic. Certainly, this method could be improved to further verify angler impacts.

Regarding bank angle and undercutting, bank anglers play a role in the "bank change cycle" but are certainly not responsible for the entire process. Natural erosion (wind, rain, ice scouring, current, etc.) as well as wave action from boat wakes contribute to bank undercutting. When the undercutting reaches a point in which soils become less stable, the bank will calve. This is not an angler related phenomenon; however, angler presence may accelerate this process. In other studies (Dotzenko et al. 1967, Kuss 1983), foot traffic has been shown to increase soil compaction. Pressure on the bank above a large undercut tends to cause the bank to rollover or calve sooner than normal. Assessment of bank angle and depth of undercut provides information characterizing a specific bank location, but does not directly relate to anglers as the cause.

The last bank integrity variable assessed was bank erosion. Although the methodology for this study failed due to anglers tampering with the erosion pins, measurement of bank erosion at angler impacted sites is certainly the "ultimate" measure of change along the river bank. All of the other habitat variables measured were an attempt to specifically characterize how anglers impact the riverbank. However, it is the combined effects of these impacts that contribute to increased bank erosion. Due to the level of human activity at the habitat survey sites, measurement of bank erosion must be designed and implemented such that it is non-obtrusive. To do this, it may be necessary to establish permanent markers far enough onshore such that these stakes would be excluded from the nearshore area used by anglers, thus reducing tampering. Observation from this field season indicates a need to closely space the stakes, possibly every 10 ft. Measurements would be taken from the stake to the bank; the 10-foot intervals being adequate to capture narrow band bank changes (small areas of calving). These measurements should be taken before and after the fishery.

Estimation of angler effort at the bank erosion monitoring sites would allow correlation of angler effort with bank erosion. Conclusions from these comparisons should be made with extreme caution. As mentioned above, the river is a very dynamic system and is in constant change. That change, as related to erosion, can be caused by many factors, bank anglers being only one.

Each bank erosion site should also be evaluated as to the level of boat wake activity in that section of the channel and the location of the site with respect to channel morphology (inside meander, outside meander, etc.). These two variables could greatly increase erosion rates occurring at a site and should be considered when drawing conclusions about increased erosion as related to angler use.

The primary goal of this habitat study has been to determine if bank anglers cause significant loss of riparian habitat. This has been a challenging task because of the dynamics of stream ecology, not to mention other human induced perturbations. Kenai River riparian habitats have certainly been altered due to shorebased angling. The question is how much change (loss?) of riparian habitat is directly attributed to bank anglers? Are bank angler impacts only a piece of a bigger problem related to habitat loss? Studies conducted by USGS (Dorava and Moore 1997) have already indicated high levels of bank erosion due to boat wakes. Bank loss in non-motorized reaches of the river was approximately 75% less than in high use motorized reaches and 33% less than in low use motorized reaches. Urbanization and structural development within the flood plain have also influenced changes in riparian habitat. Structures placed along the bank or directly in the river (such as rip-rap, gabions, jetties, various dock and deck structures) have contributed to loss of habitat. The increase in structures is due to landowners trying to access the river or reduce bank erosion. Recognition of processes negatively impacting riparian habitat and assessment of their respective level of impact would allow researchers and managers to better direct efforts to reduce habitat loss.

ACKNOWLEDGMENTS

We would like to express our gratitude to those individuals who assisted with data collection and analysis. Betsy McCracken was the crewleader for the field season, supervising project personnel and coordinating daily operations. She was also responsible for producing basemaps which graphically summarized angler count information. Betsy and all field personnel (Larry Lewis, Peter Reynoldson, Susan McKee, Pam Russell and Sanne Berrig) contributed greatly to the overall success of the project with their daily contributions in collecting habitat data, conducting shore angler counts, entering data, and cataloging site photos. The support and guidance provided by Dave Nelson was greatly appreciated. We also thank Doug Vincent-Lang for technical guidance to the development of the project.

LITERATURE CITED

Armour, L. A., R. J. Fisher, and J. W. Terrell. 1984. Comparison of the use of the Habitat Evaluation Procedures (HEP) and the instream flow incremental methodology (IFIM) in aquatic analyses. Western Energy and Land Use Team, USFWS, Fort Collins, CO.

Brinson, M. M., F. R. Hauer, L. C. Lee, W. L. Nutter, R. D. Rheinhardt, R. D. Smith, and D. Whigham. 1995. A guidebook for application of hydrogeomorphic assessments to riverine wetlands. Technical Report WRP-DE-11, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Daubenmire, R. F. 1959. Canopy coverage method of vegetation analysis. Northwest Science 33:43-64.

Dietz, H. and T. Steinlein. 1996. Journal of Vegetation Science 7:131-136.

Dorava, J. M., and G. W. Moore. 1997. Effects of boatwakes on streambank erosion, Kenai River, Alaska. U.S. Geological Survey Water-Resources Investigations Report 97-4105.

LITERATURE CITED (Continued)

Dotzenko, A. D., N. T. Papamichos, D. S. Romine. 1967. Effect of recreational use on soil and moisture conditions in Rocky Mountain National Park. Journal of Soil and Water Conservation 22:196–197.

Goodman, L. A. 1960. On the exact variance of products. Journal American Statistical Association. 55:708-713.

Goudie, A. 1981. Geomorphological techniques. George Allen and Unwin Ltd., London.

Hall, P. and D. M. Titterington. 1989. The effect of simulation order on level accuracy and power of Monte Carlo tests. J. R. Statist. Soc. B. 51:459-467.

Howe, A. L., G. Fidler, C. Olnes, A. E. Bingham, and M. J. Mills. 1997. Harvest, catch, and participation in Alaska sport fisheries during 1996. Alaska Department of Fish and Game, Fishery Data Series No. 97-29, Anchorage.

Hulten, Eric. 1968. Flora of Alaska and neighboring territories, a manual of vascular plants. Stanford University Press, California.

King, M. A. 1995. Fishery surveys during the recreational fishery for late-run sockeye salmon to the Kenai River, 1994. Alaska Department of Fish and Game, Fishery Data Series No. 95-28, Anchorage.

King, M. A. 1997. Fishery surveys during the recreational fishery for late-run sockeye salmon to the Kenai River, 1995. Alaska Department of Fish and Game, Fishery Data Series No. 97-4, Anchorage.

Kuss, F. R. 1983. Hiking boot impacts on woodland trails. Journal of Soil and Water Conservation 38:119-121.

Larson, Larry L., and Betsy W. McCracken. 1998. Assessment of angler impacts to Kenai River riparian habitats during 1996. Alaska Department of Fish and Game, Fishery Data Series No. 98-10, Anchorage.

Liepitz, G. 1994. An assessment of the cumulative impacts of development and human uses on fish habitat in the Kenai River. Alaska Department of Fish and Game, Habitat Division, Technical Report No. 94-6, Anchorage.

Platts, W. S., W. F. Megahan, G. W. Minshall. 1983. Methods for evaluating stream, riparian, and biotic conditions. Gen. Tech. Rep. INT-138: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, Ogden, UT.

Pratt, Verna E. 1996. Wildflowers along the Alaska highway. Alaskakrafts, Inc. Anchorage, AK.

Shaffer, B. J. 1996. The flora of southcentral Alaska, second edition. Kenai Peninsula College, Kenai, AK.

ter Braak, C. J. F. 1985. Correspondence analysis of incidence and abundance data: properties in terms of a unimodal response model. Biometrics 41:859-873.

ter Braak, C. J. F. 1986. Canonical correspondence analysis: a new eigenvector technique for multivariate direct gradient analysis. Ecology 67:1167-79.

ter Braak, C. J. F. 1987a. Ordination. In R. H. G. Jongman, C. J. F. ter Braak, and O. F. R. van Tongeren, editors. Data analysis in community and landscape ecology. PUDOC, Wageningen, 91-173.

ter Braak, C. J. F. 1987b. The analysis of vegetation-environment relationships by canonical correspondence analysis. Vegetatio 64:69-77.

ter Braak, C. J. F. 1988a. CANOCO-a FORTRAN program for canonical community ordination by [partial] [detrended] [canonical] correspondence analysis (version 2.0). TNO Institute of Applied Computer Science, Wageningen.

ter Braak, C. J. F. 1988b. CANOCO-an extension of DECORANA to analyse species-environment relationships. Vegetatio 75:159-60.

ter Braak, C. J. F. 1988c. Partial canonical correspondence analysis. In H. H. Bock, editor. Classification and related methods of data analysis. Elsevier, North Holland, 551-8.

LITERATURE CITED (Continued)

Thorne, C. R. 1981. Field measurements of rates of bank erosion and bank material strength. In Erosion and Sediment Transport Measurement, Proceedings of the Florence Symposium, June 1981: International Association of Scientific Hydrology, Publication No. 133.

Viereck, Leslie A., C. T. Dyrness, and A. R. Batten. 1982. 1982 Revision of preliminary classification for vegetation of Alaska. USDA Forest Service, Institute of Northern Forestry, Pacific Northwest Forest and Range Experiment, Fairbanks.

APPENDIX A: KENAI RIVER MANAGEMENT PLANS

Appendix A1.-Kenai River Late Run Sockeye Salmon Management Plan.

5 AAC 21.360. KENAI RIVER LATE RUN SOCKEYE SALMON MANAGEMENT PLAN.

(a) The purpose of this management plan is to achieve the biological escapement goal, as determined by the department, of late run sockeye salmon into the Kenai River system and to provide management guidelines to the department.

(b) The department shall manage the Cook Inlet commercial salmon gillnet fisheries to achieve a sonar count of late run sockeye salmon, as estimated by the Kenai River sonar counter at river mile 19, as follows:

(1) 550,000 - 800,000 sockeye salmon in 1996;

(2) 550,000 - 825,000 sockeye salmon in 1997;

(3) 550,000 - 850,000 sockeye salmon in 1998;

(4) the sonar counts established in (1) - (3) of this subsection may be reduced by the Board of Fisheries (board) if noncommercial fishing, after consideration of mitigation efforts, results in a net loss of habitat units on the Kenai River, as determined by the board based on the department's observations and on the use of the habitat evaluation procedures described in Technical Report No. 94-6, dated July 1994 and titled *An Assessment of the Cumulative Impacts of Development and Human Uses on the Kenai River*, hereby incorporated as reference.

Appendix A2.-Riparian Habitat Fishery Management Plan.

5 AAC 56.065. RIPARIAN HABITAT FISHERY MANAGEMENT PLAN.

(a) The Board of Fisheries (board) finds that freshwater fisheries in upper Cook Inlet, including the Kenai Peninsula Area, subject to access limitations of federal, state, and local landowners, are a recognized use of the fishery resources of upper Cook Inlet. The board also finds that, in some situations, freshwater fisheries are negatively impacting riparian habitats of upper Cook Inlet.

b) The board recognizes the importance of maintaining the structural and functional integrity of upper Cook Inlet riparian habitats. Given this, the board will consider, as part of its deliberations, avoidable impacts to upper Cook Inlet riparian habitats related to recreational fishing.

(c) If the commissioner determines that freshwater fisheries are likely to result in riparian habitat loss that could negatively affect the fishery resources of upper Cook Inlet, the commissioner may close, by emergency order, those riparian areas to fishing. This authority extends only to riparian areas in which there is a state, federal, or municipal property interest. The commissioner may reopen, by emergency order, those riparian areas to fishing if the commissioner determines that such openings will not compromise the integrity of the riparian habitats the emergency order is designed to protect. During seasons in areas opened by emergency order, fishing is only open at times selected by the commissioner at the commissioner's discretion, and fishing is only open from the following, selected at the commissioner's discretion:

(1) boats;

(2) boardwalks or similar structures;

(3) docks;

(4) gravel bars;

(5) natural formations identified by the commissioner; or

(6) other areas identified by the commissioner as areas where use for fishing will not compromise the integrity of the habitat the closure is designed to protect.

(d) *(Note: This section lists 23 bank locations along the Kenai River that are closed to fishing.)*

(e) For purposes of this section, “riparian habitat” means all areas within 10 feet in either direction from the Kenai River waterline.

APPENDIX B: OBSERVER MEASUREMENT ERROR ANALYSES

Appendix B1.-Observer measurement error analyses.

Measurement of environmental conditions is very difficult due to bias associated with observer errors which are compounded by normal fluctuations in physical and biological conditions. In *Methods for Evaluating Stream, Riparian, and Biotic Conditions* (1983), Platts et al. discuss the many problems associated with precision and accuracy when collecting environmental data, to include repeatability of sampling within and between observers. The inability to repeat a procedure which defines a measurement can lower precision; such as, when measuring bank undercut, an observer may not consistently locate the reference points which define the measurement, thus obtaining a different measurement when the bank may not have changed at all. In evaluating the precision associated with collecting habitat measurements, Platts et al. rated measurements based upon their confidence intervals: (1) poor = confidence interval over ±21%, (2) fair = confidence interval ±11%-20%, (3) good = confidence interval ±5%-10%, and (4) excellent = confidence interval less than 5%.

Subjective observations most often provide low precision. Things which can lower precision include: using different observers over time, observers changing their thinking from year to year, the ability of the methods to measure the attributes, weather conditions at time of measurement, size of stream, amount and type of experience and training, and degree of stream bank stability (Platts et al. 1983). When conducting their research, Platts et al. (1983) used personnel with advanced degrees in fisheries or related fields, provided extensive training, and used good to excellent equipment. In our Kenai River habitat study, personnel had mixed educational backgrounds, were provided short training which evolved with the field season, and used good equipment.

METHODS

BANK INTEGRITY

Observer variability was measured on four bank integrity variables:

1. Bank Angle.
2. Undercut Bank.
3. Stream depth.
4. Overhanging Vegetation.

Four observers measured all variables on four test plots, two of each habitat type. A second measurement was taken on all four plots after all initial measurements were recorded. Between observers and within observer measurement error was estimated for each variable.

The measurement error between observers was estimated for each variable as:

$$BR = \frac{\sum_i \left(\frac{\sum_j \left(\frac{\left| R_{ij} - \overline{R}_j \right|}{\overline{R}_j} * 100 \right)}{n_j} \right)}{n_i}. \qquad (a)$$

Measurement error within an observer was measured for each variable as:

$$WR = \frac{\sum_i \sum_j \left(\frac{\sum_k \left(\frac{\left| R_{ijk} - \overline{R}_{ij} \right|}{\overline{R}_{ij}} * 100 \right)}{n_k} \right)}{n_i n_j}, \qquad \text{(b)}$$

where:

BR	=	between observer variability,
R_{ij}	=	measurement by observer i at site j,
$\overline{R}_j$	=	average measurement by i at site j,
n_j	=	number of measurements at site j,
n_i	=	number of observers,
WR	=	within observer variability,
R_{ijk}	=	measurement by observer i at site j on trial k,
$\overline{R}_{ij}$	=	average measurement by observer i at site j, and
n_k	=	number of trails by observer i at site j.

PERCENT COVER

Vegetation Assessment (Species composition)

To measure the variability in the determination of species composition, two plots from each habitat type were chosen and three observers evaluated the plot twice (first determination was completed before the second was started). The measurement error in the determination of species composition was estimated using formulas (a) and (b).

Trampling

To measure the variability in the determination of trampling and percent cover, the evaluator randomly selected 16 (8 from each habitat type) assessment study photographs and assessed these for trampling and percent cover in random order, re-randomized and evaluated a second then a third time. The variability in the determination of area by cover class and trampling was determined using formula (a).

SOIL COMPACTION

To measure the variability in the determination of soil compaction, two sites from each habitat type were chosen and four observers took measurements at nine depths, both before and after the fishery. The measurement error in the determination of soil compaction was estimated using formula (a).

RESULTS AND DISCUSSION

BANK INTEGRITY

Between observer variability was estimated for each variable to be:

	Between Observer Measurement Error (%)				
	Observer 1	Observer 2	Observer 3	Observer 4	**Average**
Bank Angle	19	18	26	31	24%
Overhanging Vegetation	20	18	27	27	23%
Stream Depth	16	14	16	15	15%
Undercut Bank	21	23	14	39	24%

Within observer variability was estimated for each variable to be:

	Within Observer Measurement Error (%)				
	Observer 1	Observer 2	Observer 3	Observer 4	Average
Bank Angle	37	10	26	19	23%
Overhanging Vegetation	45	40	43	41	42%
Stream Depth	28	13	3	6	12%
Undercut Bank	22	7	11	23	16%

Both within and between observer variability were high for all categories and would have biased the precision of the bank integrity data. An increased training period to better define methods might improve these measurements.

PERCENT COVER

Vegetation Assessment (Species Composition)

Between observer variability was estimated for each species to be:

	Between Observer Measurement Error (%)		
Cover Type/Species	Observer 1	Observer 2	Observer 3
Rhianthus minor	100	200	100
Compositae (remains)	200	100	100
Unknown #1 (Peter)	100	150	150
Bryophytes (Mosses/Lichens)	100	100	200
Unknown #1 (Sanne)	200	100	100
Leslia paniculata	31	31	63
Caryophyllaceae	100	100	200
Mertensia paniculata	63	63	125
Ribes laxiflorum	125	100	75
Hordeum jubatum	200	100	100
Triantalis europea	50	25	25
Polemonium acutiflorum	0	0	0

-continued-

Cover Type/Species	Between Observer Measurement Error (%) Observer 1	Observer 2	Observer 3
Taraxacum officinalis	0	0	0
Lathyrus palustris	17	33	17
Geranium erianthum	66	53	94
Others	100	93	60
Epilobium spp.	56	43	45
Stellaria spp.	93	153	100
Rubus arcticus	33	39	39
Barbarea orthoceras	0	0	0
Salix sp.	33	33	66
Achillea borealis	10	19	10
Potentilla palustris	12	24	12
Galeum boreale	67	49	38
Sanguisorba stipulata	26	41	36
Equisetum spp.	26	50	45
Rosa acicularis	28	23	17
Calamagrostis spp.	55	30	43
Bare ground	49	19	34
Litter	25	22	19
AVERAGE	**65**	**60**	**64**

Within observer variability was estimated for each variable to be:

Cover Type/Species	Within Observer Measurement Error (%) Observer 1	Observer 2	Observer 3
Bryophytes (Mosses/Lichens)			71
Caryophyllaceae			0
Rhianthus minor		0	
Unknown #1 (Peter)		50	50
Unknown #1 (Sanne)			
Ribes laxiflorum			50
Triantalis europea		0	0
Achillea borealis		0	32
Barbarea orthoceras		0	0
Leslia paniculata		0	71
Mertensia paniculata		0	0
Polemonium acutiflorum		0	0
Taraxacum officinalis		0	0
Stellaria spp.	0	0	
Hordeum jubatum	0		

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Cover Type/Species	Within Observer Measurement Error (%) Observer 1	Observer 2	Observer 3
Lathyrus palustris		0	25
Geranium erianthum		25	36
Salix sp.	0	0	56
Others		0	40
Potentilla palustris	0	0	0
Rosa acicularis		16	0
Sanguisorba stipulata		51	15
Rubus arcticus		0	35
Galeum boreale	0	0	35
Epilobium spp.	50	40	0
Equisetum spp.	0	0	0
Calamagrostis spp.	0	14	13
Bare ground	0	0	18
Litter	0	7	7
AVERAGE	5	8	22

Between observer variability averages were high, yet relatively consistent (60-65). Within observer variability averages were very good for Observers 1 and 2, but slightly high for Observer 3. Observers 1 and 2 were the two technicians assigned to regularly speciate plants and they were very consistent. Observer 3 became familiar with plant identification during the field season and assisted the other two observers, but seldom conducted plant assessment alone.

Trampling

Within observer variability was estimated for each variable to be:

Cover Class	Average Measurement Error (%)
Vegetation	7
Litter	27
Bare Ground	45
Water	0

During photo imagery analysis, pixels were assigned to each cover class in a specified order. The protocol recommended assessment of vegetation first and bare ground last. Once the number of pixels for vegetation, litter, and water were assigned, bare ground was calculated by subtracting the sum of those from the total number of pixels for the photo. This method was shown to always bias high the percent cover for bare ground and likely made it the more variable since it was dependent upon pixel assignment to the other cover classes. Measurement error for water and vegetation coverage was very good due to the ease in discerning these cover types. Separating litter from bare ground was highly variable when using color enhancement. This step was much more subjective. In the photo imagery process described by Dietz et al. (1996), litter and bare ground were lumped together. To assess effects of trampling, it was necessary to separate the two cover classes. Since litter was the next to last cover class when color enhancing, it had the next highest measurement error. Although percent cover of litter and bare ground may have high variabilities, these were relative to the error associated with percent cover of vegetation and water.

SOIL COMPACTION

Between observer variability was estimated for each variable to be:

	Between Observer Measurement Error (%)				
Depth	Observer 1	Observer 2	Observer 3	Observer 4	Average
1	5	4	8	7	6%
3	11	4	6	10	8%
6	5	4	6	7	6%
9	4	7	10	6	7%
12	7	6	6	5	6%
15	4	3	4	5	4%
18	2	2	3	2	2%
21	5	2	5	6	4%
24	4	7	4	8	5%
				Average	5%

Measurement error for soil penetrability readings was very acceptable. The low error between observers is likely attributed to the lack of restriction on placement of the penetrometer and the ability to read measurements directly from a calibrated dial—the entire process being less subjective.

APPENDIX C: SUPPORTING STATISTICS

Appendix C1.-Counts of anglers conducted by boat during the sport fishery for late-run sockeye salmon, at habitat survey sites, Kenai River, 1997.

	Shrub/Herbaceous Sites						Herbaceous Sites					
Date	SHC1	SHC2	SHI1	SHI2	SHI3	SHI4	HC1	HC2	HI1	HI2	HI3	HI4
7/10/97	3	0	0	0	0	2	0	0	3	0	0	0
7/15/97	3	0	0	0	0	0	0	0	0	0	2	2
7/16/97	18	0	4	5	0	0	0	0	15	0	3	8
7/20/97	0	0	0	0	0	0	0	0	0	0	0	3
7/21/97	19	0	6	14	0	0	0	0	11	0	2	18
7/22/97	0	0	2	3	0	0	0	0	5	0	1	5
7/27/97	0	0	2	1	1	0	0	0	0	0	2	3
7/31/97	10	0	0	0	0	0	0	0	0	0	0	1
8/1/97	0	0	0	0	0	0	0	0	0	0	0	0
8/2/97	0	0	0	0	0	0	0	0	0	0	0	0
8/8/97	3	0	1	0	0	0	0	0	0	0	1	0
8/9/97	0	0	1	3	0	0	0	0	0	0	0	0
Total Anglers	56	0	16	26	1	2	0	0	34	0	11	40

Appendix C2.-Plant species and cover classes identified along 75 ft vegetation transect at habitat survey sites by sample period, Kenai River, 1997.

	Shrub/Herbaceous Sites												Herbaceous Sites											
	SHI1		SHI2		SHI3		SHI4		SHC1		SHC2		HC1		HI2		HI3		HI4		HC1		HC2	
Cover Type/Species	Pre[a]	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Bare ground	+	+	+	+	+	+	+	+	+	+	+	0	+	+	+	+	+	+	+	+	+	+	+	+
Bareground (Sloping bank)	+	+	+	+	+	+	+	0	0	0	0	0	0	+	+	0	+	+	0	+	0	0	0	+
Litter	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	0	+	+	+	+	+
Water	0	0	0	0	0	+	0	+	0	0	0	+	0	+	+	+	0	0	0	+	0	+	+	+
Bryophytes (Mosses/Lichens)	+	+	+	+	+	+	+	+	+	+	0	+	+	+	+	+	+	+	+	+	0	+	+	+
Grasses:																								
Calamagrostis spp.	0	+	0	+	0	+	0	+	+	+	+	+	0	+	+	+	+	+	+	+	+	+	+	+
Carex spp.	0	+	0	0	0	+	0	+	+	+	0	+	0	0	+	+	0	0	0	0	0	0	0	0
Others	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	0
Trees:																								
Betula papyrifera	0	0	0	0	0	0	0	0	+	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Picea glauca	0	0	0	0	0	0	0	+	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Shrubs:																								
Alnus crispa sinuata	+	+	0	0	+	+	0	+	+	+	+	+	+	+	0	+	0	0	0	0	0	0	0	0
Betula nana	0	0	0	0	0	+	0	0	0	0	0	0	0	0	0	0	0	0	0	+	0	0	0	0
Cornus canadensis	0	0	+	+	0	+	0	0	0	0	0	+	+	+	0	0	0	0	0	0	0	0	0	0
Ribes hudsonianum	0	0	0	0	0	0	0	+	+	+	0	0	+	+	0	0	0	0	0	0	0	0	0	0
Ribes lacustre	0	0	0	0	0	0	0	0	0	0	0	0	+	0	0	0	0	0	0	0	0	0	0	0
Ribes laxiflorum	+	0	+	+	0	0	+	+	0	0	0	0	+	+	+	0	+	0	0	0	0	0	0	0
Ribes spp.	0	+	0	0	0	0	0	0	0	+	0	+	0	0	0	0	0	0	0	0	0	0	0	0
Rosa acicularis	+	+	+	+	0	0	0	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Rubus arcticus	+	+	+	+	+	+	+	0	+	+	+	+	+	+	+	+	0	+	+	+	+	+	+	+
Rubus chamaemorus	0	0	0	+	0	0	0	0	0	0	+	+	+	0	0	0	0	0	0	0	0	0	0	0
Rubus idaeus	0	0	+	+	0	0	0	+	0	0	0	0	+	+	+	+	+	+	+	+	0	0	+	+
Rubus spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	+	0	0	0	0	0	0	0	0	0	0
Salix sp.	0	0	+	+	+	+	+	+	+	+	+	+	+	+	0	0	+	+	+	+	+	+	0	0
Spirea beauverdiana	0	+	0	0	+	0	0	0	+	+	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Vaccinium ovalifolium	0	0	0	0	0	+	0	0	0	0	+	0	0	0	0	0	0	0	0	0	0	0	0	0
Vaccinium uliginosum	0	0	0	0	0	0	0	0	0	+	+	+	0	0	0	0	0	0	0	0	0	0	0	0
Vaccinium vitis-idaea	0	0	0	0	0	0	0	0	0	0	0	+	0	0	0	0	0	0	0	0	0	0	0	0
Viburnum edule	0	0	0	+	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

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	Shrub/Herbaceous Sites												Herbaceous Sites											
	SHI1		SHI2		SHI3		SHI4		SHC1		SHC2		HC1		HI2		HI3		HI4		HC1		HC2	
Cover Type/Species	Pre[1]	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Forbs:																								
Achillea borealis	0	0	0	0	0	0	0	0	0	0	0	+	0	0	+	+	+	+	0	0	0	+	+	+
Aconitum delphinifolium	0	0	0	0	0	0	0	0	0	0	0	+	0	0	0	+	0	0	0	0	0	0	0	+
Angelica genuflexa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	+	+	0	0	0	0	0	0	0	0
Artemesia tilesii	0	0	0	0	0	0	0	0	0	0	0	0	0	+	0	0	0	+	0	+	0	0	0	+
Barbarea orthoceras	+	+	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Caltha natan	0	0	0	0	0	0	0	+	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Caryophyllaceae	+	+	+	+	+	+	+	0	+	+	+	0	0	+	+	0	+	+	+	+	0	+	+	+
Claytonia spp.	0	0	0	0	+	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cruciferae	0	0	0	0	0	0	0	0	0	+	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Draba aurea	0	0	0	0	0	0	0	0	0	0	0	0	0	0	+	+	+	+	+	+	+	0	0	0
Epilobeum angustifolium	+	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Epilobium latifolium	0	0	0	0	0	0	+	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Epilobium leptocarpum	0	0	0	0	0	0	0	+	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Epilobium spp.	0	0	+	+	0	0	+	+	+	+	0	+	+	+	+	+	+	+	+	+	+	+	+	+
Equisetum spp.	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Fritallaria camschatcensis	0	0	0	0	0	0	+	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Galeum boreale	+	+	+	+	0	0	0	0	0	0	+	+	0	0	+	+	0	0	+	+	+	+	0	0
Geranium erianthum	0	0	0	0	0	0	+	+	0	0	+	+	0	0	+	+	+	+	0	0	0	0	+	+
Geum macrophyllum	+	0	0	0	0	0	0	0	+	0	+	0	0	0	+	+	+	+	+	+	+	0	0	0
Gymnocarpium dryopteris	+	+	+	+	0	0	0	0	0	0	0	0	0	0	+	0	0	0	0	0	0	0	0	0
Impatiens noli-tangere	0	0	0	0	0	0	+	+	0	0	0	0	+	+	0	0	0	0	0	0	0	0	0	0
Lathyrus maritimus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	+	0
Lathyrus palustris	+	0	+	+	+	0	+	+	+	0	+	+	+	0	+	+	+	+	+	+	+	+	+	+
Lupinus polyphyllus	0	0	0	0	0	+	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	+	+
Mertensia paniculata	+	+	0	0	0	0	+	0	+	+	0	0	+	+	+	+	+	+	+	+	+	+	+	+
Mimulus guttatus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	+	0	+	0	+	0	+
Moehringia lateriflora	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	+	0	+	0	0	0	0	0
Montia fontana	0	0	0	0	+	0	0	0	0	0	0	0	0	0	0	+	0	0	0	0	0	0	0	0
Parnassis palustris	0	0	0	0	0	0	0	0	0	0	+	0	0	0	0	0	0	0	0	0	0	0	0	0
Petasites frigidus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	+	+	+	+	0	0	+	+

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	Shrub/Herbaceous Sites												Herbaceous Sites											
	SHI1		SHI2		SHI3		SHI4		SHC1		SHC2		HC1		HI2		HI3		HI4		HC1		HC2	
Cover Type/Species	Pre[1]	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Plantago major	0	0	0	0	0	0	0	0	+	0	+	0	0	0	0	0	0	0	0	0	0	0	0	0
Plantago spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	+	0	0	0
Platanthera obtusata	0	0	0	0	+	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Platanthera saccata	0	0	0	0	0	0	0	0	0	0	+	0	0	0	0	0	0	0	0	0	0	0	0	0
Platanthera spp.	0	0	0	0	0	+	0	+	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Polemonium acutiflorum	+	+	0	0	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Polygonum viviparum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	+	0	0	0	0	0	0	0	0	0
Potentilla norvegica	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	+	0	0	0	0	0
Potentilla palustris	0	0	0	0	0	+	0	+	0	+	0	+	0	+	0	+	0	0	0	0	0	+	0	0
Pyrola secunda	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	+	0	0	0	0	0
Pyrola spp.	0	0	0	0	0	0	0	0	+	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rhinanthus minor	0	0	0	0	0	+	0	0	0	0	+	+	+	0	+	+	+	0	0	+	0	0	+	0
Sanguisorba spp.	0	+	+	+	0	0	+	+	+	+	0	+	0	0	0	+	0	0	0	0	0	+	0	0
Sanguisorba stipulata	+	0	0	0	0	0	0	0	0	0	+	0	0	0	+	0	0	0	0	0	+	0	0	0
Solidago multiradiata	0	0	0	+	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	+	+	0	0
Stellaria spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	+	+	0	+	0	0	0	0
Swertia perennis	0	0	0	0	0	+	0	0	0	0	+	+	0	0	0	0	0	0	+	0	0	+	0	0
Taraxacum officinale	+	+	+	+	+	+	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	+	+	+
Thalictrum sparsiflorum	+	+	+	+	0	+	+	0	0	0	+	0	0	+	+	+	0	0	0	0	0	0	+	0
Thalictrum spp.	0	0	0	0	0	0	0	0	0	+	0	0	+	0	0	0	0	0	0	0	0	0	0	0
Triantalis europea	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	0	0	0	0	+	+	+	+
Valeriana capitata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	+	0	0	0	0	0
Veronica americana	0	0	0	+	0	+	+	0	0	0	0	0	0	0	0	0	0	0	+	0	0	0	0	0
Viola epipsila	0	0	+	0	+	0	+	+	+	+	+	+	+	0	+	+	0	0	0	0	+	+	0	0
Viola glabella	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	+	0	0	0	0	0	0	0	0

[a] Pre = vegetation sampling occurring prior to the sport fishery for late-run sockeye salmon.

Post = vegetation sampling after the sport fishery for late-run sockeye salmon.

+ means present.

0 means absent.

Appendix C3.-Plant species and cover classes identified along 150 ft vegetation transect at habitat survey sites by sample period, Kenai River, 1997.

	Shrub/Herbaceous Sites												Herbaceous Sites											
	SHI1		SHI2		SHI3		SHI4		SHC1		SHC2		HC1		HI2		HI3		HI4		HC1		HC2	
Cover Type/Species	Pre[a]	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Bare ground	+	+	+	+	+	+	+	+	+	0	0	0	0	+	+	0	+	+	0	+	+	+	+	+
Bare ground (Sloping bank)	+	+	+	+	+	+	+	0	+	0	0	0	0	+	+	0	+	+	0	0	+	+	+	+
Litter	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Water	0	+	0	0	0	+	0	+	0	+	0	+	0	+	0	0	0	0	0	0	0	+	0	+
Bryophytes (Mosses/Lichens)	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	0	+	0	+	+	+
Grasses:																								
Calamagrostis spp.	0	+	0	+	0	+	0	+	0	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Carex spp.	0	0	0	+	0	0	0	+	0	+	0	0	+	+	0	+	0	0	0	0	0	+	0	0
Others	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Trees:																								
Betula papyrifera	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	+
Picea glauca	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	+
Shrubs:																								
Alnus crispa sinuata	+	0	0	0	+	+	0	+	+	+	0	0	0	+	0	+	0	0	0	0	0	+	+	+
Betula nana	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cornus canadensis	0	0	0	0	0	0	0	0	0	+	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ribes hudsonianum	0	0	0	0	0	0	0	0	0	0	0	0	0	+	0	0	0	0	0	0	0	0	0	0
Ribes laxiflorum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	+	0	+	+	+	+	0	0	0	0
Ribes spp.	0	+	0	+	0	0	0	0	0	0	0	0	0	0	0	0	0	+	0	+	0	0	0	+
Rosa acicularis	+	+	0	+	0	+	0	+	0	+	0	+	0	+	+	+	+	+	+	+	0	0	+	+
Rubus arcticus	+	0	+	0	+	0	+	0	+	0	+	0	+	0	+	0	+	0	0	0	+	0	+	0
Rubus chamaemorus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	+	0	+	+	0	+	0	0	0	+
Rubus idaeus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	+	0	+	0	+	+	0	0	+	0
Rubus spp.	0	0	0	+	0	0	0	+	0	+	0	+	0	0	+	+	+	+	0	+	0	0	0	+
Salix sp.	0	0	+	0	+	0	+	0	+	+	+	0	+	0	+	0	+	+	+	0	0	0	+	0
Spirea beauverdiana	+	0	0	0	0	0	0	0	+	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Vaccinium uliginosum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	+	0	0	0	0	0	0
Viburnum edule	0	0	0	0	0	0	0	0	0	0	0	0	0	0	+	0	+	0	0	0	0	0	0	0

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	Shrub/Herbaceous Sites												Herbaceous Sites											
	SHI1		SHI2		SHI3		SHI4		SHC1		SHC2		HC1		HI2		HI3		HI4		HC1		HC2	
Cover Type/Species	Pre[1]	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Forbs:																								
Achillea borealis	0	0	0	0	0	0	0	0	0	0	+	0	+	0	+	+	+	0	+	0	+	0	+	0
Angelica genuflexa	0	0	0	0	0	0	0	0	0	0	0	0	+	0	0	0	0	0	0	0	0	0	0	0
Arabis lyrata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	+	0	0	0
Artemesia arctica	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	+	0	+	+	+	0	+
Artemesia spp.	0	+	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Artemesia Tilesii	0	0	0	0	0	0	0	+	0	0	0	0	0	0	+	0	+	0	+	0	0	0	+	0
Barbarea orthoceras	+	0	+	0	0	0	0	0	0	0	0	0	+	0	+	0	+	0	0	0	0	0	0	0
Caltha palustris	0	+	0	+	0	+	+	+	0	+	0	0	0	+	0	+	0	+	0	+	0	+	0	+
Capsella rubella	0	0	0	0	0	0	0	0	0	0	0	0	0	0	+	0	+	0	+	0	0	0	0	0
Cardamine pratensis	0	0	0	0	0	0	+	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Caryophyllaceae	+	0	+	0	+	0	+	0	+	0	0	0	0	0	+	0	+	0	0	0	0	0	+	0
Cerastium arvense	0	0	0	0	0	0	0	0	0	0	0	0	0	0	+	0	+	0	0	0	0	0	0	+
Claytonia sibirica	0	0	0	0	0	+	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Claytonia spp.	0	0	0	0	0	0	+	0	0	0	0	0	0	0	0	0	0	+	0	+	0	0	0	0
Conioselinum chinense	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	+	0
Cruciferae	0	0	0	0	+	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Draba aurea	0	0	0	0	+	+	0	+	0	0	0	+	+	+	+	+	+	+	+	+	+	+	0	+
Epilobeum angustifolium	0	+	0	+	0	+	0	+	0	+	0	+	0	+	0	+	0	+	0	+	0	+	0	+
Epilobium leptocarpum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	+	0	0
Epilobium spp.	+	0	0	+	0	0	+	0	0	0	+	+	+	+	+	+	+	+	+	+	+	+	+	0
Equisetum spp.	+	0	+	0	+	0	+	+	+	0	+	+	+	+	+	+	+	+	+	0	+	+	+	+
Fritallaria camschatcensis	0	+	0	+	+	0	+	0	0	0	0	0	+	0	0	+	0	+	0	+	0	0	+	0
Galium boreale	+	0	+	0	0	0	0	0	0	0	+	0	+	0	+	0	+	0	+	0	+	0	0	0
Geranium erianthum	0	0	0	0	0	0	+	0	0	0	+	0	+	0	+	0	+	0	0	0	0	0	+	0
Geum macrophyllum	+	0	0	0	0	0	+	0	+	0	+	+	+	0	+	0	+	0	+	0	0	0	0	0
Gymnocarpium dryopteris	0	0	0	+	0	+	0	+	0	+	0	+	0	+	0	+	0	+	0	+	0	0	0	+
Impatiens noli-tangere	0	0	0	0	0	0	+	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Iris setosa	0	0	0	0	0	0	0	0	0	0	+	0	0	0	0	+	0	+	0	+	0	+	0	+
Lathyrus maritimus	0	0	0	0	0	0	0	+	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lathyrus palustris	0	0	0	0	+	0	+	0	0	0	+	0	+	0	+	0	+	+	+	+	+	0	+	+
Martricaria matricarioides	0	0	0	0	+	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mertensia paniculata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	+	0	+	0	+	0	+	0	+	0
Mimulus guttatus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	+	0	+	0	0	0	+
Moehringia lateriflora	0	0	0	0	0	0	0	+	0	0	0	0	0	0	+	0	+	0	+	0	0	0	0	0

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	Shrub/Herbaceous Sites												Herbaceous Sites											
	SHI1		SHI2		SHI3		SHI4		SHC1		SHC2		HC1		HI2		HI3		HI4		HC1		HC2	
Cover Type/Species	Pre[1]	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Montia fontana	0	0	0	+	0	+	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Papaver nudicaule	0	0	0	0	0	0	0	0	0	0	0	0	+	0	0	0	0	0	0	0	0	0	0	0
Parnassis palustris	0	0	0	0	0	+	0	+	0	+	0	+	0	+	0	+	0	+	0	+	0	0	0	+
Petasites frigidus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	+	+	+	0	+	0	0	0	+	0
Plantago major	0	0	0	0	+	0	0	0	+	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Plantago spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	+	0	0	0	0	0	0
Platanthera obtusata	0	+	0	+	+	+	0	+	+	+	0	+	0	+	0	+	0	0	0	0	0	+	0	0
Platanthera saccata	0	0	0	0	0	0	0	0	0	0	+	0	0	0	0	0	0	0	0	0	0	0	0	0
Polemonium acutiflorum	+	0	+	0	+	0	+	0	+	0	+	+	+	0	+	0	+	0	+	0	0	0	+	+
Polygonum viviparum	0	0	0	0	0	0	0	0	0	0	+	0	+	0	0	0	0	0	0	0	0	0	0	0
Portulaceae	0	0	0	0	0	0	+	0	0	0	0	0	0	+	0	0	0	0	0	0	0	+	0	0
Potentilla norvegica	0	+	0	+	0	+	0	+	0	+	0	+	0	+	+	+	+	0	+	0	0	+	0	0
Potentilla palustris	+	0	+	0	+	0	+	0	+	0	+	0	+	0	0	0	0	0	0	0	0	0	0	0
Pyrola spp.	0	0	0	0	0	0	0	0	+	0	0	0	0	0	0	0	0	0	0	0	0	+	0	0
Rhinanthus minor	0	0	0	0	+	0	0	0	0	0	0	0	+	0	+	0	+	0	0	0	0	0	+	0
Rorippa islandica	0	0	0	0	0	0	0	0	0	+	0	0	0	0	0	0	0	0	+	0	0	0	0	0
Rorippa spp.	0	+	0	+	0	0	0	0	0	0	+	0	0	0	0	0	0	+	0	+	+	+	0	0
Sanguisorba spp.	+	0	+	+	+	+	+	0	+	0	+	0	0	0	0	+	0	0	0	0	0	+	0	0
Sanguisorba stipulata	0	0	+	0	+	0	0	0	0	0	0	0	+	0	0	0	0	0	0	0	+	0	0	0
Senecio vulgaris	0	+	0	+	0	+	0	+	0	+	0	+	0	+	0	+	0	0	0	0	+	0	0	+
Solidago multiradiata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	+	0	0	0
Stellaria spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	+	0	+	0	+	0	0	0	0	0
Swertia perennis	0	0	0	+	0	+	0	+	0	+	0	+	0	+	0	+	0	+	0	+	0	0	0	0
Taraxacum officinale	+	0	+	0	+	0	0	0	0	0	0	0	+	0	+	0	+	0	+	0	0	0	0	0
Thalictrum sparsiflorum	0	0	0	0	+	0	0	0	0	0	0	0	+	0	0	0	0	0	0	0	0	0	+	0
Thalictrum spp.	0	+	+	+	0	+	0	+	0	+	0	+	0	+	0	+	0	+	0	0	0	+	0	0
Triantalis europea	+	0	+	0	+	0	+	0	+	0	+	0	+	0	+	0	+	0	0	0	0	0	+	0
Veronica americana	0	0	0	0	+	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Viola epipsila	0	0	+	0	+	0	+	0	+	0	+	0	+	0	0	0	0	0	0	0	0	0	0	0

[a] Pre = vegetation sampling occurring prior to the sport fishery for late-run sockeye salmon.

Post = vegetation sampling after the sport fishery for late-run sockeye salmon.

+ means present.

0 means absent.

Appendix C4.-Change in mean percent cover of habitat variables for onshore and offshore zone plots, Kenai River, 1997.

Shrub/Herbaceous Sites:	SHI1		SHI2		SHI3		SHI4		SHC1		SHC2	
Variable	Offshore	Onshore	Offshore	Onshore	Offshore	Onshore	Offshore	Onshore	Offshore	Onshore	Offshore	Onshore
Deciduous trees	0.0	5.0	0.0	0.0	0.0	0.0	0.3	0.3	0.0	0.0	0.0	0.0
Deciduous shrubs	-1.0	-9.0	2.0	7.5	0.5	-14.5	1.0	19.0	0.0	-18.5	0.0	14.0
All trees/shrubs	2.0	0.0	2.5	16.5	3.5	-14.5	2.0	9.5	0.0	-18.5	0.0	14.0
FWD[a]	0.5	-0.5	-0.5	-1.0	-1.0	-5.5	0.5	6.0	0.0	-6.5	0.0	0.5
Bare ground	0.0	0.0	0.0	16.5	0.0	2.0	0.0	9.5	0.0	-11.0	0.0	1.0

Herbaceous Sites:	HI1		HI2		HI3		HI4		HC1		HC2	
Variable	Offshore	Onshore	Offshore	Onshore	Offshore	Onshore	Offshore	Onshore	Offshore	Onshore	Offshore	Onshore
Deciduous trees	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Deciduous shrubs	0.0	-1.5	0.0	7.0	7.0	9.5	-0.4	22.5	0.0	-1.0	1.5	0.0
All trees/shrubs	0.0	3.5	0.0	7.0	7.0	9.5	1.0	22.5	0.0	-1.0	1.5	-9.5
FWD[a]	1.5	-3.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	12.0	6.0
Bare ground	0.0	4.5	0.0	6.0	0.0	4.5	0.0	-2.5	0.0	13.5	0.0	6.0

[a] FWD = fine woody debris.

APPENDIX D: RESULTS OF HYDROGEOMORPHIC ASSESSMENT- A TASK

Appendix D1.-Results of hydrogeomorphic assessment - a task.

INTRODUCTION

Hydrogeomorphic (HGM) assessment is a rapid assessment modeling technique developed for evaluating wetlands (Brinson et al. 1995). Numerous data are collected which contribute to the successful functioning of wetlands within a watershed. The HGM modeling program is applicable to this habitat study because bank types used by sockeye salmon anglers are primarily riverine and slope (proximal riverine) wetlands. To use HGM, reference standard sites (pristine areas representative of the wetland) are selected, evaluated, and rated (modeled) to form a standard of comparison for other sites. The modeling equations are modified to reflect characteristics of the watershed being assessed. Once the reference standard sites have been established then other areas are selected for evaluation and compared to the reference standard sites to detect change. If a change is detected then further data analysis (beyond the provisions of HGM) may reveal variables (data sets) which are responsible for the change.

It should be noted that the HGM approach for assessing wetlands is a relatively new program and that its application to this study was dependent upon new research to be conducted in the Kenai River watershed by a team of HGM-trained scientists during July 1997. Data collected during that time would allow modification of the model to better characterize wetlands representative of the Kenai River drainage. Specifically, the model had to be tailored to the mainstem Kenai River in order for application to be made to this angler impact study. Data collected in this project was based upon an assessment of the vegetation and bank characteristics such that it could be analyzed independently or in the HGM models to appropriately answer project objectives. Some data were more HGM specific and considered a "task" rather than a project objective, but all variables measured could have been potentially related to angler impacts.

During July 1997 the HGM assessment team opted to evaluate the slope wetlands and tributaries of the Kenai River drainage. Therefore, no model was developed for the mainstem Kenai River and all data collected by this angler impact study were analyzed independent of HGM modeling. Presented in this appendix is a brief summary of methods and results related to project tasks, i.e. HGM related variables.

METHODS

HGM tasks were completed at the same habitat survey sites described in the Methods section of this report. As in the report, analyses of these data were based upon a comparison of pre- and postfishery measurements to detect change.

Coarse Woody Debris (CWD): One set of variables collected was for sources of CWD, known to provide cover to juvenile fish. The midpoint of the bank side of the habitat survey site was located at OHW. At that point a 100 ft transect was determined upstream and downstream (200 ft total) along the OHW line. The following data were collected:

1. For each 100 ft transect, a count of nurse logs (downed logs with new plant growth) below OHW was conducted. The length and diameter at the midpoint for each piece were recorded.
2. For each 100 ft transect, the number of live trees ($\geq$3 in DBH- diameter breast height measured at 4.5 ft from ground level) within 10 ft either side of the transect was recorded.

3. Using the 200 ft transect, the location (0-200 ft) along the transect of any logjams (having more than two members with diameter > 3 in) was recorded. For the largest three members of each logjam, the length, diameter at the midpoint, and the presence of nurselogs and rootwads were recorded.

The upchannel source of CWD was evaluated using the same origin as the above transects and extending 200 ft upstream along the OHW line. From this point, two 50 ft sections were sampled: the first section being the initial 50 ft along OHW; then skip 100 ft and sample the next 50 ft. The number of pieces of CWD (> 3 in in diameter and > 10 ft in length) below OHW in these two sections were counted and recorded.

Vegetation Assessment: Vegetation assessment was conducted above OHW. Two nonoverlapping Point Center Quarter (PCQ) plots (circles with r = 37.2 ft) were established in each survey site. Density and basal area measurements were taken in each plot for trees (≥ 3 in DBH), saplings (< 3 in DBH), and snags (standing dead trees ≥ 3 in DBH). (Note: Because of the few members in these plots, all members were measured, negating the use of a boundless quartered plot.) Each tree (sapling) was speciated and its DBH recorded. Snags were not speciated, but the height was estimated. Coarse wood, on the ground, was evaluated through a count of all pieces and then recording the total length, and diameter at the midpoint for each piece.

The remaining set of data collected concerned the nearshore vegetation and its related contribution to juvenile fish habitat. Five adjacent zone plots (20 ft wide x 30 ft long) were located onshore along the OHW line with another five zone plots, mirror images to the first five, located offshore. An assessment of vegetation was estimated in each of the 10 zone plots:

1. Percent canopy cover of deciduous trees ≥ 3 in DBH.
2. Percent canopy cover of deciduous shrubs (includes saplings < 3 in DBH).
3. Percent canopy cover of all trees (deciduous, coniferous) and shrubs.
4. Percent cover of fine woody debris (< 3 in diameter).

RESULTS AND DISCUSSION

Coarse Woody Debris: The number of pieces of CWD counted along all transects was small. For all habitat survey sites, up channel and in channel sources of CWD ranged from 0-9 pieces prior to the fishery and from 0-2 pieces after the fishery. The decrease in number of pieces over time was likely due to increasing seasonal water levels which transported the CWD downstream. These pieces were probably deposited at these sites in the fall during receding water levels. It is unlikely that activities of shorebased anglers are in a large part related to the decrease in presence of CWD at these habitat survey sites.

The bank source contribution of CWD was also small. The number of live trees in the nearshore area ranged from 0-5 prior to the fishery and from 0-3 after the fishery. The two macrohabitat types surveyed were specifically selected to be low density treed sites (herbaceous and shrub/herbaceous) which would explain the low counts. The decrease in count over time at some sites is likely more related to observer error when counting trees which might be marginal to the count area along the transect.

Logjams were a non-issue at the habitat survey sites. Only one site had a jam and that jam was present both pre- and postfishery.

Site selection and knowledge of the geologic development of the Kenai River would explain the small contribution of CWD to the habitat survey sites. Again these sites were selected on the basis of having relatively few trees present so CWD would have to come from other sources. The sites were located in reaches of the Kenai River which are deeply entrenched and characterized with high current velocity by midsummer, as associated with glacial melt and rainfall. CWD that does enter the river from riparian areas is often rapidly transported downstream. Therefore, in these reaches of the river and for these macrohabitat types, CWD is not an important variable to measure when evaluating shorebased angler impacts to the riparian zone.

Vegetation Assessment: Density and basal area were calculated for trees and saplings at each habitat survey site. Of the six herbaceous sites, only two sites had trees present and no sites had saplings present. For the sites with trees, the density ranged from 15-25 trees/acre before the fishery and 10-35 trees/acre after the fishery. The change in tree density is likely due to observer error: the PCQ was a tenth acre plot, so an error of 1 tree in counting equated to a 10 tree density error. Of the shrub/herbaceous sites, there was one site without trees and three without saplings. Treed sites had a density of 5-95 trees/acre before the fishery and 5-85 trees/acre after the fishery. Again, the slight change in density is likely due to observer error. For shrub/herbaceous sites with saplings, the prefishery density ranged from 15-80 trees/acre and the postfishery density ranged from 0-40 trees/acre. Of the three shrub/herbaceous sites with saplings, two showed a decrease in density. This could be observer error or, possibly, shorebased anglers did actually trample/remove some saplings.

For herbaceous sites, there was an increase in basal area for trees ranging from 0.5-6 sq ft per acre. For shrub/herbaceous sites, the change in basal area ranged from –6.5-9.5 sq ft per acre. A slight increase in basal area over time would be expected with the low tree densities associated with these sites, but the change in basal area is probably more related to density counting errors affecting the basal area calculations.

The primary function of assessing vegetation in the zone plots was to look at woody vegetation contribution to bank stabilization and fish habitat. The offshore zone plots were designed to assess riparian contribution to juvenile fish habitat through shade, bank stability, and fine woody debris (FWD). The onshore zone plots were designed to assess vegetation contribution to bank stability as well as FWD for nutrient contributions. For this research project, the primary concern was if anglers affected these variables' contribution to juvenile fish habitat, measured by change over the course of the fishery. For both onshore and offshore zone plots the percent cover of deciduous trees changed by < 5%, with most sites exhibiting no change (Appendix C4). Considering observation error, there was little change in percent cover by deciduous trees from June to August and, therefore, no measurable impact by anglers. Change in percent cover of deciduous shrubs, in both onshore and offshore plots at habitat survey sites, ranged from –20% to +20%. The change in percent cover did not appear to be related to habitat type or level of angler use, i.e., increase or decrease in percent cover of deciduous shrubs occurred randomly within habitat types and at sites with no angler use versus high angler use. Change in percent cover for all trees and shrubs (deciduous and coniferous) ranged from –18% to +22% for onshore and offshore plots at all sites. For the offshore plots, the change did not appear to be related to habitat type or level of angler use at the habitat survey sites, another random event. However, for the onshore plots, the change may have been related to the level of angler use (generally increased cover at control sites and decreased cover at impacted sites). Change in percent cover of FWD was minimal (-5% to 6%) for both onshore and offshore plots at all habitat survey sites. The detected change is likely due to observation error and is unrelated to habitat type or level of angler use. Percent cover of bare ground was only assessed for onshore plots and the detected change ranged from -11% to 16%. Without having assessed the percent cover of litter in these plots, it would be difficult to draw conclusions about the percent cover of bare ground as related to angler use at the habitat survey site. For example, at non-impacted sites, bare ground should decrease over time due to an increased canopy cover throughout the growing season. However, angler activity might also decrease the amount of bare ground by trampling vegetation and increasing litter thereby reducing the percent cover of bare ground. Continued high levels of trampling might reduce the percent cover of litter and increase that of bare ground. Percent cover of litter should be added to the assessment of zone plots to better interpret angler effects concerning percent cover of bare ground.

RECOMMENDATIONS

For the 12 habitat survey sites, all located downstream of Skilak Lake, the presence of CWD was minimal. Although CWD is known to be important for good juvenile salmonid rearing habitat, the herbaceous and shrub/herbaceous macrohabitat types assessed in this study were not characterized by concentrations of CWD. This is likely related to the deeply entrenched nature of the Kenai River downstream of Skilak Lake. Therefore, assessment of CWD in future studies of juvenile salmonid rearing habitat at these macrohabitat types could be omitted.

Herbaceous and shrub/herbaceous macrohabitats have been characterized as having low tree densities and basal areas. Because of the low tree density and greater tree distance from the bank, shore anglers minimally impact trees present in these macrohabitats. Angler impact assessments for these variables would not be necessary at herbaceous and shrub/herbaceous macrohabitats. However, at more heavily treed macrohabitats, angler impacts may occur on seedlings and saplings; therefore, tree density and basal area measurements should be assessed.

The onshore and offshore zone plots have potential as a tool for evaluating nearshore riparian habitat contribution to juvenile fish habitat because the plots assessed variables contributing to good fish habitat and bank stability. For the purpose of this study, change detection could be made for each variable (percent cover for deciduous trees, shrubs, all trees and shrubs, FWD, and bare ground) and related to level of angler use. Adding percent cover classes for bare ground and herbaceous vegetation would give a complete picture within each zone plot and allow better correlation with levels of angler use. Due to the low percent cover of FWD, this variable could be omitted for these macrohabitats.