Fishery Data Series No. 15-33

Assessment of Shore Angling Impacts to Kenai River Riparian Habitats, 2000

by

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and

Patricia A. Hansen

October 2015

Alaska Department of Fish and Game **Divisions of Sport Fish and Commercial Fisheries**

Symbols and Abbreviations

The following symbols and abbreviations, and others approved for the Système International d'Unités (SI), are used without definition in the following reports by the Divisions of Sport Fish and of Commercial Fisheries: Fishery Manuscripts, Fishery Data Series Reports, Fishery Management Reports, and Special Publications. All others, including deviations from definitions listed below, are noted in the text at first mention, as well as in the titles or footnotes of tables, and in figure or figure captions.

Weights and measures (metric)

centimeter	cm
deciliter	dL
gram	g
hectare	ha
kilogram	kg
kilometer	km
liter	L
meter	m
milliliter	mL
millimeter	mm

Weights and measures (English)

cubic feet per second	ft^3/s
foot	ft
gallon	gal
inch	in
mile	mi
nautical mile	nmi
ounce	oz
pound	lb
quart	qt
yard	yd

Time and temperature

day	d
degrees Celsius	°C
degrees Fahrenheit	°F
degrees kelvin	K
hour	h
minute	min
second	s

Physics and chemistry

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

General

Alaska Administrative Code	AAC
all commonly accepted abbreviations	e.g., Mr., Mrs., AM, PM, etc.
all commonly accepted professional titles	e.g., Dr., Ph.D., R.N., etc.
at	@
compass directions:	
east	E
north	N
south	S
west	W
copyright	©
corporate suffixes:	
Company	Co.
Corporation	Corp.
Incorporated	Inc.
Limited	Ltd.
District of Columbia	D.C.
et alii (and others)	et al.
et cetera (and so forth)	etc.
exempli gratia (for example)	e.g.
Federal Information Code	FIC
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
registered trademark	®
trademark	™
United States (adjective)	U.S.
United States of America (noun)	USA
U.S.C.	United States Code
U.S. state	use two-letter abbreviations (e.g., AK, WA)

Mathematics, statistics

all standard mathematical signs, symbols and abbreviations	
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	CI
correlation coefficient (multiple)	R
correlation coefficient (simple)	r
covariance	cov
degree (angular)	°
degrees of freedom	df
expected value	*E*
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.
minute (angular)	'
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
variance	
population	Var
sample	var

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ABSTRACT

Impacts of shore anglers to Kenai River riparian habitats were assessed in 3 river reaches during the 2000 fishing season. A total of 10,114 shore anglers were counted, 48.2% on private land and 51.8% on public land. Over 90% of anglers fished from mainland banks rather than islands or gravel bars. Of those using mainland banks, 19.3% used boardwalks or other structures, 51.5% stood in the water, and 29.2% stood on the bank. At bank measurement survey sites (n = 172), there were no significant effects on annual bank change (June 1999 to June 2000) for boat activity, stream meander, or habitat type. Cumulative change (June 1998 to June 2000) was significant for boat activity, with a mean loss of 0.26 m. At angler-effort survey sites (n = 42), annual bank change was significantly affected by site position relative to stream meander and 1999 angler effort but not habitat type or boat activity. Increased bank loss occurred at sites located on the outside of a meander and those having high levels of angler effort. Cumulative bank change showed no significant effects of habitat type, boat activity, or stream meander, but a significant effect of cumulative angler effort (1997 and 1998); bank loss increased with increased angler effort. At vegetation analysis sites (n = 12), inseason angler effort had a significant effect on mean percent change in cover of vegetation, litter, and bare ground, but not water; vegetation cover decreased and litter and bare ground increased with increased effort. Angler effort in 1999 had no significant effect on annual vegetation cover change (1999–2000). The same was true for cumulative effort (1997–1999) and cumulative change (1997–2000), indicating that vegetation cover may recover between seasons. Measurement error tests were conducted for both bank position measurements (± 0.5 m) and vegetation cover (< 4%).

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

INTRODUCTION

BACKGROUND

The Kenai River (Figure 1) supports the largest freshwater sport fishery in Alaska with estimated effort exceeding 264,000 angler-days in 1999 (Howe et al. 2001). Although sport fishing occurs throughout the mainstem, most fishing occurs downstream from Skilak Lake during a relatively short period (June–August). 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*).

Presently, the majority of sport fishing effort on the Kenai River is directed at early- and late-run Chinook salmon and late-run sockeye salmon. Increased interest occurred in the sport fishery during the mid-1970s when anglers discovered methods for catching Chinook salmon while drifting from powerboats. There was a substantial increase in participation again in the mid-1980s as shore anglers discovered that sockeye salmon could be caught from the turbid waters of the Kenai River by applying fishing techniques used in the clear waters of the Russian River. These 2 discoveries contributed to the increasing popularity of the Kenai River as a sport fishing destination. Effort increased from 122,138 angler-days in 1977 (Mills 1979) to 289,165 in 1987 (Mills 1988). Participation in Kenai River fisheries peaked in 1995 with 377,710 angler-days of effort (Howe et al. 1996).

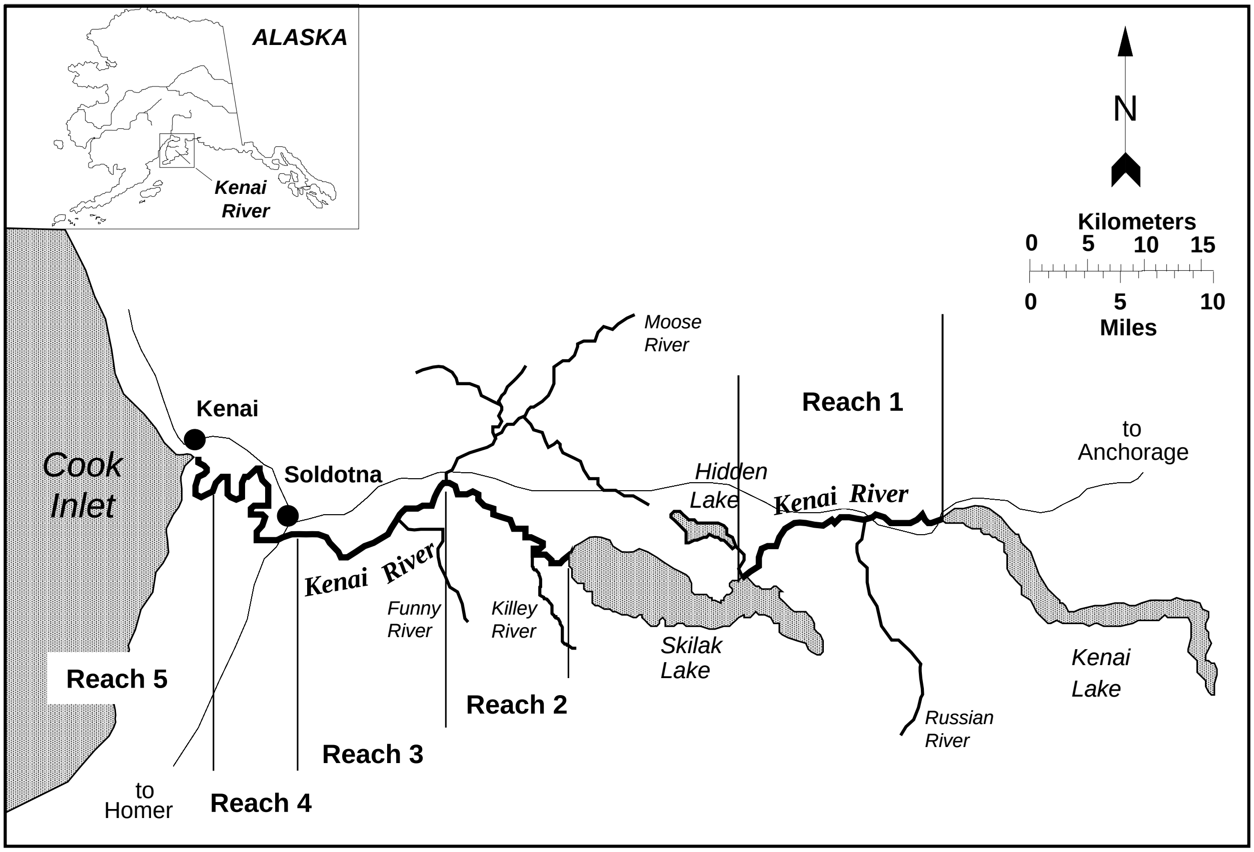

Figure 1.–Map of the Kenai River showing river reaches in which angler counts were conducted.

On the Kenai River, most anglers fish for sockeye salmon from riverbanks or while standing in the river along gravel bars at or near the shoreline. Some sockeye salmon anglers use boats to access desired fishing locations, but they seldom fish from boats. Because sockeye salmon angling is principally a shore-based fishery, damage to riparian habitat is a major concern to fishery and resource managers, Kenai River property owners, and stewards of Kenai River resources.

Shore anglers may negatively affect riparian and fish habitat by accelerating the natural erosion of riverbanks. Natural erosion involves the undercutting of the bank by river flow energy (Figure 2A), which leads to the bank rolling over, slumping, fracturing, and eventually calving into the river (Waters 1995) (Figure 2C). Successional subsurface terraces form over time as banks calve (Figure 2D). Human activities, such as angling from the bank, may lead to denuded riverbanks (Figure 2B), which can jeopardize bank integrity and speed erosion.

Historically, sockeye salmon have been harvested in the Cook Inlet commercial fishery. During the 1990s, actions by the Alaska Board of Fisheries (BOF) have resulted in increased allocation of late-run sockeye salmon to the inriver sport fishery, and the Alaska Department of Fish and Game (ADF&G) has increased the biological escapement goal for late-run sockeye salmon. Both actions have provided greater availability of sockeye salmon for the sport fishery.

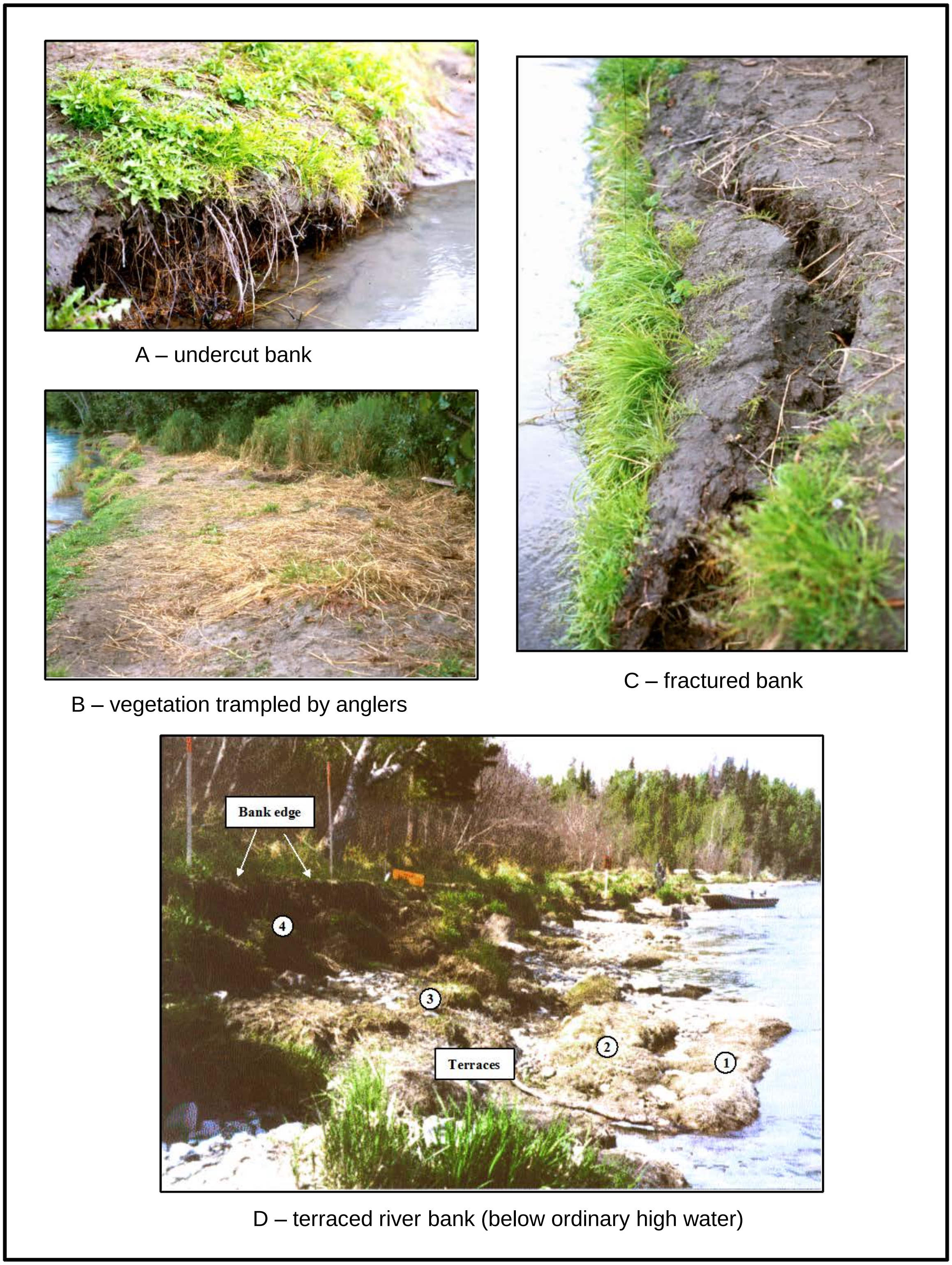

Figure 2.–Stages of bank erosion (Panels A, C, and D) and vegetation trampled by anglers (Panel B).

In 1996, the BOF increased the allocation and liberalized bag and possession limits for the inriver sport fishery and the personal use dip net fishery at the mouth of the Kenai River. However, realizing the importance of maintaining riparian habitats, the 1996 BOF expressed concern that their actions not result in damage to critical riparian habitats along the Kenai River. To help mitigate potential effects on riparian habitats from shore-based angling, the BOF granted the commissioner of ADF&G regulatory authority to close state, federal, or municipal riparian habitats to angling if that activity was likely to result in damage to riparian habitat that could negatively affect the fishery resources of upper Cook Inlet (5 AAC 56.065; Appendix A1).

During the 1999 BOF meetings, the Late-Run Sockeye Salmon Management Plan was modified again, resulting in another increased allocation of sockeye salmon to the inriver sport fishery of the Kenai River. However, the BOF also stated that if damage to riparian habitats occurred due to increased shore-based angling, the increased allocation of sockeye salmon would be reconsidered (5 AAC 21.360; Appendix A2). The BOF's concern about riparian habitat resulted in 2 additional regulatory changes in 1999, both relating to increased bank erosion from powerboats. First, the BOF provided for a drift-boat-only fishery to occur on Mondays in July, a day previously closed to fishing from boats. This would provide a means of evaluating the popularity of a nonmotorized fishery on the Kenai River. Second, effective in 2000, the BOF implemented a regulation reducing the number of passengers in guided boats from 6 to 5 (guide plus 4 clients), which addressed concerns about larger powerboat activities created by more heavily loaded boats. Results of a study about boat wake and Kenai River riparian habitats were documented by Dorava and Moore (1997).

In 1996, the BOF asked that ADF&G monitor angler use and effects on Kenai River riparian habitats and report the findings at the next regularly scheduled Cook Inlet regulatory meeting in February 1999. The ADF&G report to the BOF in 1999 detailed the difficulties of assessing shore angler impacts to juvenile fish habitat in riparian areas. We indicated that we had tried several methodologies (Larson and McCracken 1998; King and Hansen 1999) and that those used in 1998 (King and Hansen 2001) seemed to provide the most reliable information for assessing shore angler impacts. ADF&G was directed by the BOF to continue assessment of shore angler impacts and to report the findings at the next regularly scheduled Upper Cook Inlet BOF meetings (2002).

The purpose of this study is to provide information to the BOF about effects of shore anglers on the riparian habitat of the Kenai River. Specifically, this study addresses the question of whether anglers fishing from shore significantly accelerate the natural riverbank erosion process on the Kenai River. In addition, this study also addresses the question of whether anglers would shift from public to private property (e.g., commercial campgrounds and corporately owned recreation areas) if public sites were closed for habitat protection, possibly offsetting progress in habitat protection. To address these questions, we examined the distribution of anglers on public and private property, the use of fishing structures such as boardwalks, and the annual and cumulative changes in riverbank position measurements and vegetative cover with respect to varying angler effort.

OBJECTIVES

In 2000, the primary goals of this project were to document distribution of shore anglers throughout the mainstem Kenai River during the sport fishery for late-run sockeye salmon, and to assess the effects of shore anglers on changes in bank position and vegetative cover. Specific objectives were as follows:

1. Estimate the distribution of shore anglers within the mainstem Kenai River riparian areas downstream of Skilak Lake during the sport fishery for late-run sockeye salmon for the period 8 July to 10 August 2000, and test the hypothesis that the distribution with respect to land ownership (public vs. private) and river reach has not changed through time (1996–2000).
2. Estimate mean bank loss by macrohabitat throughout the mainstem Kenai River downstream of Skilak Lake.
3. Estimate total angler effort (angler-hours) at selected sites throughout the mainstem Kenai River downstream of Skilak Lake.
4. Test the hypothesis that there is no linear correlation between angler effort and bank loss.
5. Estimate changes in percent cover, both inseason (before and after the 2000 sport fishery for late-run sockeye salmon) and cumulative (June 1997 to June 2000), by cover class at 12 habitat survey sites located on the mainstem Kenai River downstream of Skilak Lake.
6. Test the hypothesis that there is no linear correlation between angler effort and changes in percent cover by cover class, both inseason and cumulative (June 1997 to June 2000), at the 12 selected habitat survey sites.

We also conducted soil composition analyses at the 12 habitat survey sites used in Objectives 5 and 6. This was a continuation of previous studies that assessed soil compaction related to angler traffic.

METHODS

Historically, the Kenai River has been divided into 5 reaches (Figure 1):

Reach 1– outlet at Kenai Lake to Jim's Landing (river miles [RM] 69–82; not included in this study)

Reach 2– outlet at Skilak Lake to Moose River (RM 36–50)

Reach 3– Moose River to the Soldotna Bridge (RM 21–36)

Reach 4– Soldotna Bridge to the Warren Ames Bridge (RM 5–21)

Reach 5– Downstream of the Warren Ames Bridge (RM 0–5; not included in this study)

Reach 5 was omitted from the study because very little angling from shore occurs there. Reach 1 has not been surveyed since 1997 because shore anglers in this reach primarily target sockeye salmon returning to the Russian River. These anglers tend to congregate around the Russian River confluence. Due to limited access points, this shore-based fishery is likely to undergo minimal downstream expansion, making it unnecessary to annually monitor angler distribution. Reaches 2–4 were used in this study.

DISTRIBUTION OF SHORE ANGLERS

To monitor shifting trends in angler behavior, such as changes in use of public versus private lands, changes in fishing locations, and changes in use of fishing platforms and walkways, we counted and categorized anglers fishing from shore during the sport fishery for late-run sockeye salmon (8 July–10 August 2000). A shore angler was defined as any person actively fishing from the shore; this excluded anglers fishing from moving boats or boats anchored in the channel.

Counts of anglers were conducted systematically every third day from 10 July through 3 August. Results from sockeye salmon creel surveys (King 1997; Schwager-King 1995) showed that the level of angler participation varies with river reach and time of day. Therefore, for weeks having 3 count days, at least 2 of the counts were conducted at a time of anticipated high angler participation (1200–2000 hours). For weeks having 2 count days, at least 1 count was conducted at a time of anticipated high angler participation. Counts were conducted on 7 weekday days and 2 weekend days. The start time for a count was the same in each river section and each count was completed within 2.5 hours.

Six project personnel conducted counts from 3 motorized skiffs, each with a boat operator and an angler observer who recorded data. The boat operator motored near the observed shore angler(s) and obtained a waypoint and location using a Garmin 45[1] differentially corrected geographic positioning system (DGPS), corrected to within an accuracy of 5 m. The angler observer recorded the following data:

1) DGPS waypoint number for 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) primary location of angler: bank, island, or gravel bar
5) secondary location of angler: on bank, in water, on boardwalk or other (dock, jetty, etc.).

When conducting a count, shore anglers were counted along the right bank (defined facing downstream) as the boat was driven downstream from the boat launch to the lower boundary of the assigned count section. Anglers were then counted along the left bank (defined facing downstream) as the boat was motored upstream to the upper boundary of the count section, then counted along the right bank as the boat was motored downstream again until the boat returned to the boat launch, completing a circle in a counterclockwise direction. At the completion of each count, waypoints were uploaded from each DGPS unit to a laptop computer.

Following the fishing season, Esri ArcGIS software was used to map the data. The 11 angler counts were summed and overlaid onto a geographic information system (GIS) basemap of the Kenai River. Angler use by land status (public or private) and location (primary: bank, island, gravel bar; secondary: on bank, in water, on boardwalk, other structure) were summarized on the basemap.

Angler count data for 2000 were compared to count data from 1996 to 1999. Chi-square tests were used to test for differences in the distribution of shore anglers by year and type of land ownership for each river reach (2–4; Figure 1). An analysis of variance (ANOVA) was used to look for a linear trend in percent angler use of public lands in any of the 3 reaches. The following model was used:

$$P_{mn} = \mu + \eta_m + \gamma_n + \eta\gamma_{mn} + \varepsilon_{mn} \tag{1}$$

---

[1] Product names used in this publication are included for scientific completeness but do not constitute product endorsement.

where

P_{mn} = the percent of anglers using public lands in the *m*th reach and the *n*th year,

μ = overall mean,

η_m = the effect of the *m*th reach,

γ_n = the effect of the *n*th year,

$\eta\gamma_{mn}$ = the interaction between the *m*th reach and the *n*th year, and

ε_{mn} = random error associated with the *m*th reach in the *n*th year.

BANK MEASUREMENT SITES

Annually from 1998 through 2000, bank positions for both banks of the Kenai River were measured at half-mile intervals in Reaches 2–4, starting at river mile 50. Within the intertidal area, downstream of river mile 12, bank measurements were taken at 1-mile intervals. A total of 172 sites were measured for bank position; these include 4 shrub, 8 disturbed, 29 shrub-herbaceous, 34 herbaceous, and 97 treed sites (Appendix B1).

Each site was classified using level of powerboat activity (low or high), hereafter referred to as boat activity, during the primary boating season (May–September) and predetermined from the results of a study conducted by Dorava and Moore (1997: Table 12).

Bank measurement sites were relocated each year using topographical maps, previously acquired GPS waypoints, and site photographs. At each site, 2-person crews verified or updated the following:

1) DGPS waypoint
2) site position relative to stream meander: inside meander, outside meander, none
3) macrohabitat type, based upon categories similar to those used by Viereck et al. (1982) and assessed in an area bounded by at least 30 m of riverbank and extending approximately 23 m onshore:
    a) Forest: 10–100% of the area has tree canopy cover, of which greater than 75% is deciduous or coniferous.
    b) Shrubland: 25–100% of the area has shrub canopy, but less than 10% of the area has tree canopy. Shrubs are greater than 5 ft in height and are present at the riverbank, possibly overhanging the stream.
    c) Shrubland-herbaceous: 25–100% of the area has shrub canopy, but less than 10% of the area has tree canopy. Shrubs are mostly less than 5 ft in height. Generally, no tall shrubs are present within 20 ft of the riverbank.
    d) Herbaceous: over 5% of the area has herbaceous canopy, but shrub canopy cover is less than 25% and tree canopy cover is less than 10%.
    e) Disturbed: 50% or greater of the area is characterized by human perturbations, such as lawns, structures, land clearing activities, etc.

With the assistance of photos, crews relocated the benchmark at each site. If necessary, benchmarks were found by locating the 2 backup marks and triangulating, using previously recorded data. Also, a previously placed rebar stake, set approximately 10 ft landward from the benchmark, could be used to assist in relocating the benchmark. Once the benchmark was located, crews set up a tripod with a surveyor's transit and plumbed to the surveyor's tack on the benchmark. Using the transit, the crew sited to a plumb bob located at the rebar stake and then rotated the transit 180° toward the riverbank. Along this bearing line, the crew located a 6-inch nail previously placed in the ground to mark the bank location for taking the distance measurement. Following established protocol (King and Hansen 2001), crewmembers obtained a distance measurement from the benchmark to the top edge of the riverbank (Figure 3). The crew recorded this measurement and the related compass bearing. Generally the marker nail was present. At some sites, the nail was missing and there was evidence of bank calving based upon photo documentation from the previous year. If the marker nail was missing, a new nail was placed in the riverbank following previously established protocol (King and Hansen 2002).

Steps taken to improve the repeatability of bank measurements included the following:

1) Several photographs were taken of the riverbank while the stadia rod remained in the same position used for taking the measurement.
2) A 6-inch nail was placed in the ground along the bearing line and 6 inches from the bank edge where the distance measurement was taken.
3) The distance measurement was taken by siting the transit to the rebar backup stake and then rotating the transit 180° to determine the bearing line to the riverbank.

The crew also recorded other descriptive and identifying information about the site to include in a revised sketch. Photographs were taken of the bank edge location with a mile marker sign, the backup marks, and benchmark. These photos will assist in identifying the site when returning for future measurements.

Using the measurements for the distance from the benchmark to the riverbank, we calculated the change in bank position as follows:

$$\Delta = \text{most recent measurement minus baseline measurement.} \tag{2}$$

An analysis of variance was used to test whether habitat type, position relative to meander, or level of boat activity had any significant effect on change in bank position. The following model was used:

$$\Delta_{ijk} = \mu + \beta_i + \alpha_j + \phi_k + \varepsilon_{ijk} \tag{3}$$

where

Δ_{ijk} = the change in distance from benchmark to the riverbank (most recent measurement minus baseline measurement) associated with the *i*th habitat type, the the *j*th position relative to meander, and the *k*th level of boat activity.

μ = overall mean,

β_i = the effect of the *i*th habitat type,

α_j = the effect of the *j*th position relative to meander,

ϕ_k = the effect of the *k*th level of boat activity,

ε_{ijk} = random error associated with the *i*th habitat type, the *j*th position relative to meander, and the *k*th level of boat activity.

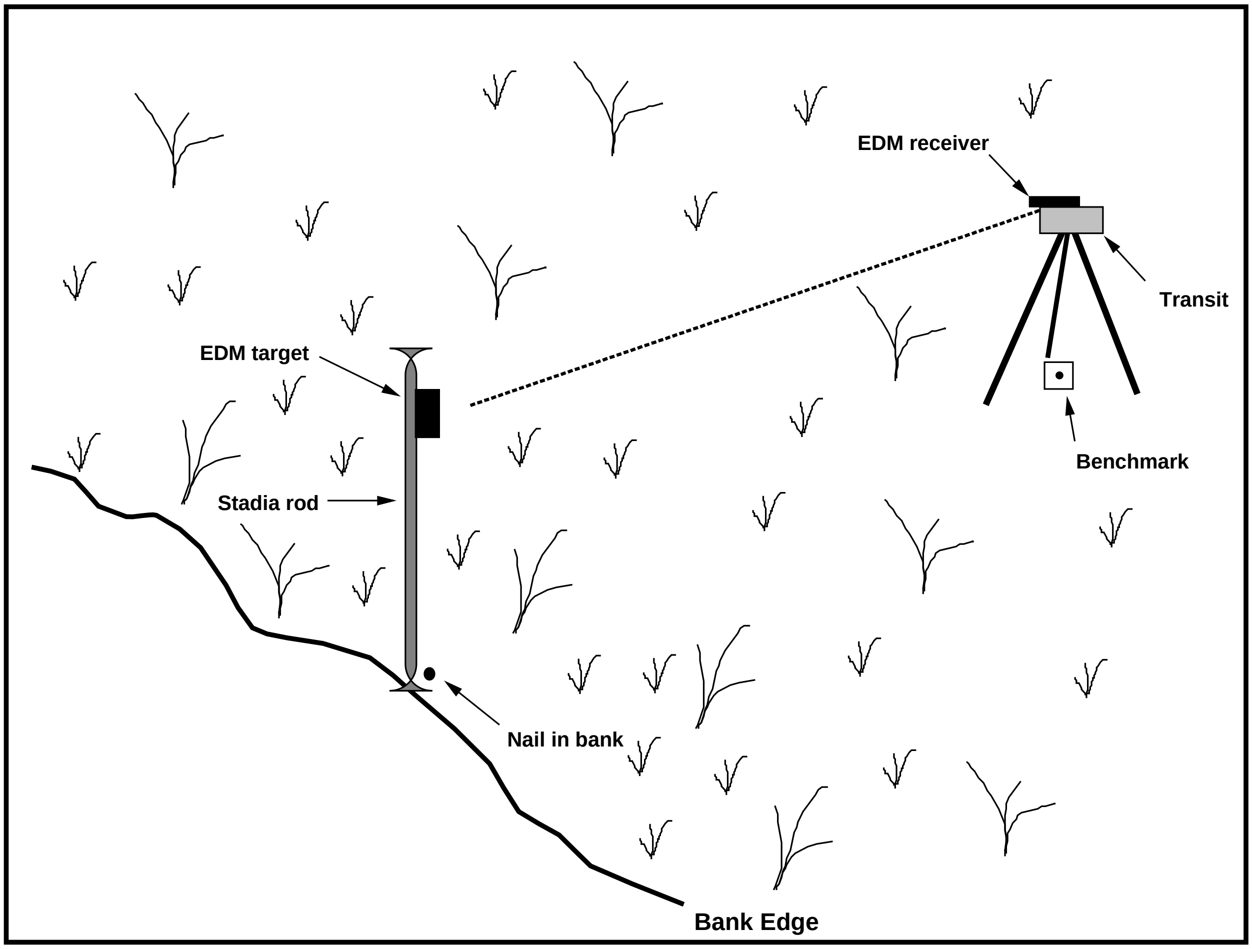

Figure 3.–Schematic of instrument layout for taking bank position measurements, 2000.

Angler-effort Sites

To test for a relationship between shore angler effort and bank change, 42 of the bank measurement sites (22 herbaceous and 20 shrubland-herbaceous; Appendix B2) were selected for more intensive measurements of bank loss and estimates of angler effort. These are hereafter referred to as "angler-effort sites." The two macrohabitat types (herbaceous and shrubland-herbaceous) were selected because they may be more sensitive to angler traffic than forest and shrubland. For each macrohabitat type, sites were selected such that each level of angler use category (see "Distribution of Shore Anglers" section) was nearly equally represented. Each angler-effort site included 30 linear meters of riverbank. Measurements were taken in June, before the fishery began (prefishery).

Bank Change

During June, the crew used established protocol (King and Hansen 2001) to take 11 measurements to the riverbank, 1 every 3 m, over a 30 m distance (Figure 4), at each angler-effort site. To improve repeatability of the measurement process, crewmembers placed a 6-inch nail near the top edge of the riverbank using designated protocol (King and Hansen 2002). Each angler-effort site was flagged at the upstream and downstream boundaries to assist in identifying the sites when conducting angler-effort counts.

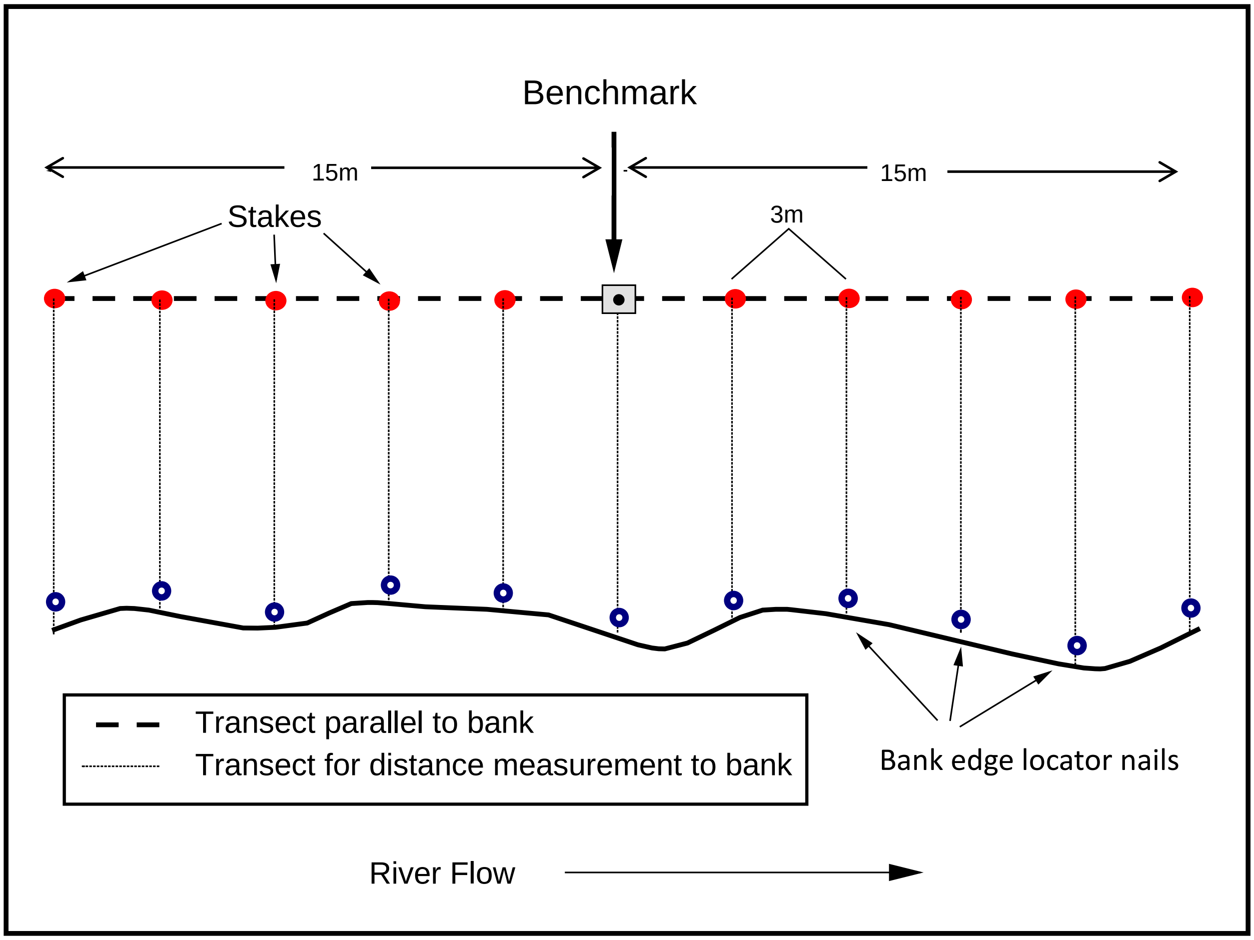

Figure 4.–Schematic of transects for distance to bank measurements at angler-effort sites, 2000.

For each angler-effort site, the mean bank position change was estimated as follows:

$$\overline{\Delta}_z = \frac{\sum_{i=1}^{n} \Delta_{zy}}{n_z} \qquad (4)$$

where

$\overline{\Delta}_z$ = mean change in bank position at site *z*,

Δ_{zy} = change in bank measurement at measurement location *y* at site *z* and measured as the change in distance from benchmark (and other stakes) to the riverbank (most recent measurement minus the baseline measurement), and

n_z = number of bank measurements at site *z*.

In 1999 and 2000, observer measurement error both within and between readers was approximately 0.05 m (Appendix C1), and therefore the bank was considered unchanged if the difference between years was within ±0.05 m.

Angler Effort

During the sport fishery for late-run sockeye salmon, angler effort for each sample day was estimated for each of the sites specified above. A sample day consisted of a 16-hour period (0600–2200 hours). Days were sampled as described above in the section "Distribution of Shore Anglers." From 10 July to 3 August, we conducted 5 counts of shore anglers at each angler-effort site on 9 days for a total of 45 angler counts per site. Counts were conducted systematically within each sample day. The time of the first count of each day was chosen at random as a whole or half hour between 0600 and 0930 hours, with the remaining 4 counts occurring at 2.5-hour intervals. Each angler observed during a count represented 1 angler-hour.

We conducted shore angler counts from 3 motorized boats with 2 project personnel per boat (a boat operator and an observer). The boat operator motored past the flagged survey sites in their assigned area, and the observer counted and recorded the number of anglers at each site at that moment.

Total angler effort measured in angler-hours was estimated for each site as follows:

$$\hat{E} = \sum_{d=1}^{D} (\bar{c}_d \times \text{ahd} \times \text{sr}) \tag{5}$$

where

$$\bar{c}_d = \frac{\sum_{p=1}^{n_d} c_{dp}}{n_d} \tag{6}$$

and where

$\bar{c}_d$ = average number of anglers per count on day d,

c_{dp} = number of anglers observed during count p on day d,

n_d = number of angler counts on day d,

ahd = angler-hours per day (= 16),

sr = days between systematic samples (= 3), and

D = total number of days sampled.

Variance of total angler effort for each site was estimated as follows:

$$V(\hat{E}) = \left(1 - \frac{D}{3D}\right)\left(3D^2\right)\frac{\sum_{d=2}^{D}\left(\hat{E}_d - \hat{E}_{d-1}\right)^2}{2D(D-1)} + \frac{3D}{D}\sum_{d=1}^{D} v\left(\hat{E}_d\right) \tag{7}$$

where $\hat{E}_d$ is estimated angler effort for day *d* and

$$v(\hat{E}_d) = v(\bar{c}_d)(\text{adh})^2 \quad (8)$$

and

$$v(\bar{c}_d) = \frac{\sum_{p=2}^{n_d}\left(c_{dp} - c_{d(p-1)}\right)^2}{2n_d\left(n_d - 1\right)}. \quad (9)$$

Effects of Angler Effort on Bank Change

An analysis of variance was used to test whether angler effort had a significant effect on mean change in bank position between years at the angler-effort sites (controlled for habitat type, boat activity level, and stream meander). The following model was used:

$$\Delta_{ijkl} = \mu + \beta_i + \alpha_j + \phi_k + \lambda_l + \varepsilon_{ijkl} \quad (10)$$

where

Δ_{ijkl} = the mean change in distance from benchmark (and other stakes) to the riverbank (most recent measurement minus baseline measurement) associated with the *i*th level of angler effort in the *j*th habitat type with the *k*th level of boat activity and the *l*th level of meander,

μ = overall mean,

β_i = the effect of the *i*th estimate of anger effort,

α_j = the effect of the *j*th habitat type,

ϕ_k = the effect of the *k*th level of boat activity,

λ_l = the effect of the *l*th level of meander,

ε_{ijkl} = random error associated with the *i*th level of angler effort in the *j*th habitat type with the *k*th level of boat activity and the *l*th level of meander.

For annual changes, we used estimates of angler effort for 1999 (King and Hansen 2002) and mean bank positional change from June 1999 to June 2000 because anglers fishing during the 1999 season would have the most direct effect on bank position through June 2000. For cumulative bank change, we used mean bank positional change from August 1998 to June 2000, and the sum of angler effort for 1998 and 1999. See King and Hansen (2002) for an explanation of the exclusion of the June 1998 bank measurements.

Boat activity during the primary boating season from May to September was determined using the results of a previous study (Dorava and Moore 1997: Table 12): low or high. Meander level was designated as site position relative to stream meander: inside meander, outside meander, or none (see Bank Measurement Sites methods above).

Angler use of site R25.5 was different from other sites because the property is corporately owned and employees are the primary users. A security officer was onsite to insure that all anglers stood in the water while fishing. Because of these unusual circumstances, data from this site were considered biased and the site was excluded from analyses.

VEGETATION ANALYSIS SITES

Vegetation Analysis

To evaluate the effects of bank trampling by anglers, we conducted annual vegetation assessments beginning in 1997 using the same 6 herbaceous and 6 shrubland-herbaceous sites. These sites were also included in the "Angler-effort" sites assessments. These permanent habitat survey sites, their locations, the 150-foot transect within each site, the 4 permanently marked vegetation plots (48 in × 30 in) along each transect, and the site selection criteria are all described in King and Hansen (1999).

Using DGPS, site photos, a metal detector, and a tape measure, 2 project personnel relocated each habitat survey site, its respective transect, and 4 vegetation plots. Permanent rebar stakes, inserted flush with the ground at the 2 corners of each plot lying along the 150-foot vegetation transect (example: stakes at 30 ft and 34 ft), were relocated. Two corners of a 48 in × 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 inches toward the river. Photographs of the plot were taken using a Minolta 35 mm camera. While standing on a stepladder, a technician centered the camera over the plot approximately 5 ft above ground level and took a picture. Occasionally, it was necessary to use an umbrella over the plot to minimize shadowing effects. Sometimes an automatic flash was used to further enhance lighting uniformity. Photos were taken of all vegetation plots at the end of June (prefishery) and again in mid-August (postfishery). Photos were cataloged by habitat survey site, plot, and date.

Postseason, the photos were scanned and the computer images analyzed using Adobe Photoshop software following the protocol for photo imagery analysis outlined by Dietz and Steinlein (1996). Area by cover class (vegetation, litter, bare ground, and water) and percent cover by cover class were estimated. A mean percent cover for each site was determined from the 4 plots.

A multivariate analysis of variance was used to test if angler effort had a significant effect on change in the mean percent cover for each cover class between prefishery and postfishery time periods. The following model was used:

$$\Delta_{ijz} = \mu + \beta_i + \alpha_j + \beta\alpha_{ij} + \varepsilon_{ijz} \qquad (11)$$

where

Δ_{ijz} = the change in mean percent cover (postfishery percent minus prefishery percent), associated with the *i*th level of angler effort in the *j*th habitat type at site *z*,

μ = overall mean,

β_i = the effect of the *i*th estimate of anger effort,

α_j = the effect of the *j*th habitat type,

$B\alpha_{ij}$ = the interaction between the *i*th estimate of angler effort and *j*th habitat type, and

ε_{ijz} = random error associated with the *i*th level of angler effort in the *j*th habitat type at site *z*.

To assess annual vegetation recovery, the previous multivariate model (Equation 11) was used to test whether angler effort in 1999 had a significant effect on change in mean percent cover from

June 1999 to June 2000, where Δ_{ijz} is the change in mean percent cover (June 2000 percent cover minus June 1999 percent cover).

A repeated measures design was used to analyze the cumulative effects of angler effort on the mean percent cover for each cover class (vegetation, litter, bare ground, water):

$$Y_{ijz} = \mu + \alpha_j + \gamma(\alpha)_{jz} + \beta_i + \varepsilon_{ijz} \tag{12}$$

where

Y_{ijz} = mean percent cover for cover class associated with the *i*th level of angler effort in the *j*th habitat type at site *z*,

μ = overall mean,

α_j = the effect of the *j*th habitat type,

$\gamma(\alpha)_{jz}$ = the effect of the *z*th site in the *j*th habitat type,

β_i = the effect of the *i*th estimate of cumulative angler effort, and

ε_{ijz} = random error associated with the *i*th level of cumulative angler effort, the effect of the *z*th site in the *j*th habitat type.

Soil Analysis

Since 1997, we have collected soil resistance measurements at the 12 habitat survey sites described in the "Vegetation Analysis" section. We intended to use these measurements as an indicator of soil compaction related to the level of angler use at the sites. We were unable to correlate these data between sites because we did not know if soil composition between sites was similar. In 2000, we collected soil samples along the 150-foot vegetation transect at each of these sites. Using a soil core sampler, we randomly collected 2 core samples from each of 4 vegetation plots along the transect. For each habitat survey site, the 6 sample cores were mixed in a plastic bag. Postseason, the soil samples were submitted to the University of Alaska Plant and Soil Test Lab for soil composition analyses.

RESULTS

DISTRIBUTION OF SHORE ANGLERS

We conducted 11 counts of shore anglers throughout the study area. Counts were conducted systematically, commencing on 10 July and occurring once every third day thereafter through 3 August, with a second count conducted on both 22 and 28 July.

Daily total angler counts during the 2000 study ranged from 186 anglers on 3 August to 2,129 anglers on 16 July (Table 1). The highest total counts occurred from 16 to 25 July and exceeded 1,100 anglers daily. The highest angler count in a single reach was 993 anglers in Reach 3 on 16 July. Angler counts decreased gradually from 16 July to 3 August.

Table 1.–Counts of shore anglers by river reach during the sport fishery for late-run sockeye salmon, Kenai River, 1995–2000.

Date	Count time	Reach 1 [a]	Reach 2	Reach 3	Reach 4	Total
1995		255 [b]	451	1,101	1,161	2,968
1996 [c]		1,189 [b]	1,532	2,942	1,846	7,509
1997		2,220	1,473	2,555	2,108	8,356
1998 [d]			2,365	5,200	3,964	11,529
1999			2,170	4,846	4,011	11,027
2000 [e]						
10 Jul	11:30		37	103	96	236
13 Jul	14:30		42	271	217	530
16 Jul	15:30		361	993	775	2,129
19 Jul	18:30		294	750	408	1,452
22 Jul	9:00		303	538	344	1,185
	14:00		398	497	410	1,305
25 Jul	10:00		190	574	379	1,143
28 Jul	10:30		270	344	193	807
	15:30		164	338	258	760
31 Jul	15:00		113	147	121	381
3 Aug	17:00		43	80	63	186
Totals			2,215	4,635	3,264	10,114

Sources: 1995: Unpublished data from D. Vincent-Lang, Alaska Department of Fish and Game, Division of Sport Fish, Anchorage, AK, personal communication; 1996: Revised data from Larson and McCracken (1998); 1997: King and Hansen (1999); 1998: King and Hansen (2001); 1999: King and Hansen (2002).

[a] No counts were conducted in Reach 1 in the years 1998–2000.

[b] These counts were omitted in previous analyses because the counts included shore anglers downstream of Jim's Landing to Skilak Lake.

[c] Some anglers were excluded from the previously reported totals because not all had been assigned to public or private property.

[d] There were 2 angler distribution counts per count day in 1998.

[e] Shore angler counts were terminated after 3 August. An emergency order effective 5 August closed the Kenai River to sport fishing for late-run sockeye salmon.

During 2000, 51.8% of anglers fished from public lands and 48.2% from private lands (Table 2). The percentage of anglers using public land in 2000 was relatively unchanged from 1999 in Reach 2, but less in Reach 3, and slightly more in Reach 4. In each reach, the percentage of anglers using public and private lands by year was significantly different based on chi-square tests (Table 2). However, no linear trend in percent angler use of public lands for 1996–2000 was detected in any of the 3 reaches (analysis of variance, $F = 1.02$, df = 1, $P = 0.34$).

Table 2.–Counts, mean, and percent of shore anglers by reach, year, and property ownership during the sport fishery for late-run sockeye salmon, Kenai River, 1995–2000.

	Number of anglers [a]			Mean			Percent				
Year	Public	Private	Total	Public	Private	Total	Public	Private	χ^{2} [b]	df	P
Reach 1 [c]											
1995 [d]	233	0		77.7	0.0		100.0	0.0			
1996	1,175	14		146.9	1.8		98.8	1.2	12.67	1	<0.01
1997	2,215	5		184.6	0.4		99.8	0.2			
Reach 2											
1995	240	211		80.0	70.3		53.2	46.8			
1996	810	722	1,532	101.3	90.3	191.5	52.9	47.1	133.31	4	<0.01
1997	778	695	1,473	64.8	57.9	122.8	52.8	47.2			
1998	1,199	1,166	2,365	54.5	53.0	107.5	50.7	49.3			
1999	1,379	791	2,170	98.5	56.5	144.7	63.5	36.5			
2000	1,402	813	2,215	127.5	73.9	201.4	63.3	36.7			
Reach 3											
1995	452	649		150.7	216.3		41.1	58.9			
1996	874	2,068	2,942	109.3	258.5	367.8	29.7	70.3	287.23	4	<0.01
1997	1,013	1,542	2,555	84.4	128.5	212.9	39.6	60.4			
1998	2,368	2,832	5,200	107.6	128.7	236.4	45.5	54.5			
1999	2,330	2,516	4,846	166.4	179.7	323.1	48.1	51.9			
2000	1,988	2,647	4,635	180.7	240.6	421.4	42.9	57.1			
Reach 4											
1995	703	458		234.3	152.7		60.6	39.4			
1996	1,062	784	1,846	132.8	98.0	230.8	57.5	42.5	72.31	4	<0.01
1997	1,051	1,057	2,108	87.6	88.1	175.7	49.9	50.1			
1998	2,414	1,550	3,964	109.7	70.5	180.2	60.9	39.1			
1999	2,217	1,794	4,011	158.4	128.1	267.4	55.3	44.7			
2000	1,847	1,417	3,264	167.9	128.8	296.7	56.6	43.4			
All Reaches Combined [e]											
1995	1,628	1,318		542.7	439.3		55.3	44.7			
1996	2,746	3,574	6,320	343.3	446.8	790.0	43.4	56.6	230.06	4	<0.01
1997	2,842	3,294	6,136	236.8	274.5	511.3	46.3	53.7			
1998	5,981	5,548	11,529	271.9	252.2	524.0	51.9	48.1			
1999	5,926	5,101	11,027	423.3	364.4	735.1	53.7	46.3			
2000	5,237	4,877	10,114	476.1	443.4	919.5	51.8	48.2			

Sources: 1995: Unpublished data from D. Vincent-Lang, Alaska Department of Fish and Game, Division of Sport Fish, Anchorage, AK, personal communication; 1996: Revised data from Larson and McCracken (1998); 1997: King and Hansen (1999); 1998: King and Hansen (2001); 1999: King and Hansen (2002).

[a] Number of counts conducted each year was as follows: 1995 = 3, 1996 = 8, 1997 = 12, 1998 = 22, 1999 = 14, 2000 = 11. Generally only 1 angler count was conducted on a count day, except in 1998 when 2 angler counts were conducted each count day.

[b] Chi-square test for differences in the percentages of anglers using public and private lands between years for each reach. These tests excluded 1995 angler counts because they were not considered representative of the fishery.

[c] No angler counts were conducted in Reach 1 in the years 1998–2000.

[d] To make comparable, 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 Skilak Lake, an area not evaluated in other years.

[e] Totals are excluded for 1995 because they are not considered representative. There were only 3 total counts, and only 2 were conducted on peak days. Totals for 1996–2000 exclude Reach 1. The chi-square test includes reaches 2–4 and years 1996–2000.

The primary location of over 90% of shore anglers was mainland banks in 2000 (Table 3). Of those anglers that used mainland banks, 51.5% stood in the water and 29.2% stood on the bank. The remainder (19.3%) fished from boardwalks or other structures (Table 4). There were significant differences in the distribution of angler counts over primary location categories between years (total anglers over all reaches for the years 1997–2000: $\chi^2 = 41.2$, df = 6, $P < 0.01$), and for mainland banks anglers, there were differences in the distribution of angler counts over secondary location categories (boardwalk or other structure, water, or bank) between years ($\chi^2 = 57.0$, df = 6, $P < 0.01$), but the differences between observed and expected distributions were generally small (< 5% for most χ^2 bins).

Table 3.–Primary location of anglers in each river reach during the sport fishery for late-run sockeye salmon, Kenai River, 1997–2000.

		River Reach				
Year	Primary angler location	2	3	4	Total	%
1997						
	Mainland banks	1,319	2,412	1,915	5,646	92.0
	Gravel bar	88	62	128	278	4.5
	Island	66	81	65	212	3.5
	Total	1,473	2,555	2,108	6,136	
1998						
	Mainland banks	2,200	4,896	3,645	10,741	93.2
	Gravel bar	162	61	136	359	3.1
	Island	3	243	183	429	3.7
	Total	2,365	5,200	3,964	11,529	
1999						
	Mainland banks	2,032	4,528	3,589	10,149	92.0
	Gravel bar	108	102	220	430	3.9
	Island	30	216	202	448	4.1
	Total	2,170	4,846	4,011	11,027	
2000						
	Mainland banks	2,155	4,374	2,906	9,435	93.3
	Gravel bar	24	61	218	303	3.0
	Island	36	200	140	376	3.7
	Total	2,215	4,635	3,264	10,114	

Sources: 1997: King and Hansen (1999); 1998: King and Hansen (2001); 1999: King and Hansen (2002).

Table 4.–Secondary location of anglers using mainland banks in each river reach during the sport fishery for late-run sockeye salmon, Kenai River, 1997–2000.

Year	Secondary location for mainland banks anglers	River Reach 2	3	4	Total	%
1997						
	On bank	386	758	502	1,646	29.2
	In water	822	1,119	1,098	3,039	53.8
	Boardwalk	62	452	275	789	14.0
	Other structures	49	83	40	172	3.0
	Total	1,319	2,412	1,915	5,646	
1998						
	On bank	456	1,469	834	2,759	25.7
	In water	1,517	2,155	2,233	5,905	55.0
	Boardwalk	78	1,092	366	1,536	14.3
	Other structures	149	180	212	541	5.0
	Total	2,200	4,896	3,645	10,741	
1999						
	On bank	601	1,513	734	2,848	28.1
	In water	1,148	1,979	2,376	5,503	54.2
	Boardwalk	175	924	239	1,338	13.2
	Other structures	108	112	240	460	4.5
	Total	2,032	4,528	3,589	10,149	
2000						
	On bank	609	1,400	747	2,756	29.2
	In water	1,207	1,967	1,688	4,862	51.5
	Boardwalk	181	950	434	1,565	16.6
	Other structures	158	57	37	252	2.7
	Total	2,155	4,374	2,906	9,435	

Sources: 1997: King and Hansen (1999); 1998: King and Hansen (2001); 1999: King and Hansen (2002).

BANK MEASUREMENT SITES

Annual (June 1999 to June 2000) change in distance from benchmark to bank edge ranged from −1.94 m to +0.77 m (Appendix B1). Measured change was equal to or within ±0.05 m for 104 survey sites. Twenty-eight survey sites had a measurement increase (bank growth) greater than 0.05 m; of these, 2 had a measurement increase exceeding 0.30 m. Forty survey sites had a measurement decrease (bank loss) of more than 0.05 m; of these, 9 had a measurement decrease exceeding 0.30 m.

Analysis of variance showed there was no significant effect of habitat type, position relative to meander, or boat activity level on the amount of annual (June 1999 to June 2000) bank position change at these bank measurement sites (Table 5).

Table 5.–Analysis of variance for effects of habitat type, position relative to meander, and boat activity level on annual bank positional change (June 1999 to June 2000) at 172 bank survey sites, Kenai River.

	Analysis of variance				Duncan's test			
Source	df	Mean square	*F* value	*P* > *F*	Main effects	Sample size	Mean	Duncan grouping
Habitat type	4	0.03	0.43	0.79				
					Shrub	4	0.03	A
					Disturbed	8	0.00	A
					Tree	97	−0.03	A
					Herbaceous	34	−0.06	A
					Shrub/herbaceous	29	−0.08	A
Meander	2	0.15	2.2	0.11				
					Inside	27	0.00	A
					None	95	−0.02	A
					Outside	50	−0.01	A
Boat activity	1	0.07	0.99	0.32				
					Low	115	−0.03	A
					High	57	−0.06	A

Cumulative bank change for June 1998–June 2000 ranged from −3.81 m to +2.37 m (Appendix B1). Bank change was equal to or within ±0.05 m at 47 sites. Bank increase was documented at 60 sites; 11 of those sites exceeded 0.30 m. Bank loss was measured at 65 sites, with 28 sites exceeding 0.30 m. Analysis of variance showed there was no significant effect of habitat type and position relative to stream meander on the amount of cumulative bank position change at the bank measurement sites (Table 6). However, there was a significant effect of boat activity level on cumulative bank position change (F = 4.19, df = 1, *P* = 0.04). The mean bank loss was 0.04 m in in low boat activity areas and 0.26 m in high boat activity areas.

Table 6.–Analysis of variance for effects of habitat type, position relative to meander, and boat activity on cumulative bank positional change (June 1998 to June 2000) at 170 bank survey sites, Kenai River.

	Analysis of variance				Duncan's test			
Source	df	Mean square	*F* value	*P* > *F*	Main effects	Sample size	Mean	Duncan grouping
Habitat type	4	0.07	0.17	0.96				
					Shrub	4	0.03	A
					Disturbed	8	−0.08	A
					Tree	97	−0.15	A
					Herbaceous	32	−0.01	A
					Shrub/herbaceous	29	−0.13	A
Meander	2	0.47	1.11	0.33				
					Inside	25	0.00	A
					None	95	−0.08	A
					Outside	50	−0.23	A
Boat activity	1	1.77	4.19	0.04				
					Low	113	−0.04	A
					High	57	−0.26	B

Note: Two sites were new in 1999 and excluded from this analysis.

ANGLER-EFFORT SITES

Mean bank positional change ranged from −0.41 m to +0.12 m at angler-effort sites from June 1999 to June 2000 (Appendix B2). Individual measurements ranged from −1.76 m to +0.75 m (Appendix B2). In 2000, mean counts of anglers per site ranged from 0 to 6.8 (Appendix B3). Angler effort at each site ranged from 0 to 2,938 angler hours and exceeded 1,100 angler hours at 3 sites.

Stream meander and angler effort, but not habitat type or boat activity level, had significant effects on change in bank position (Table 7). Bank loss increased with angler effort (Figure 5).

Analysis of variance results showed there was no significant effect of habitat type, boat activity level, or site position relative to stream meander on cumulative (August 1998–June 2000) bank change at angler-effort sites (Table 8). However, there was a significant effect of cumulative angler effort on cumulative bank change (Table 8); bank loss increased with angler effort (Figure 6).

Table 7.–Analysis of variance for effects of angler effort (1999), habitat type, site position relative to stream meander, and boat activity level on mean bank positional change (June 1999–June 2000) at angler-effort sites, Kenai River.

	Analysis of variance				Duncan's test			
Source	df	Mean square	*F* value	*P* > *F*	Main effects	Sample size	Mean	Duncan grouping
Habitat type	1	0.00	0.29	0.59				
					Herbaceous	22	-0.02	A
					Shrub/Herb	19	-0.04	A
Meander	2	0.03	4.05	0.03				
					None	18	-0.01	A
					Inside	11	-0.01	A
					Outside	12	-0.07	B
Boat activity	1	0.00	0.11	0.74				
					Low	36	-0.02	A
					High	5	-0.07	A
Effort 1999	1	0.15	27.64	0.00				

Note: The shrubland/herbaceous site 25.5 was removed from the analysis because of bias (see methods).

[a] Site position relative to stream meander: inside of meander, no meander, outside of meander.

[b] Boat activity level determined from Dorava and Moore (1997: Table 12).

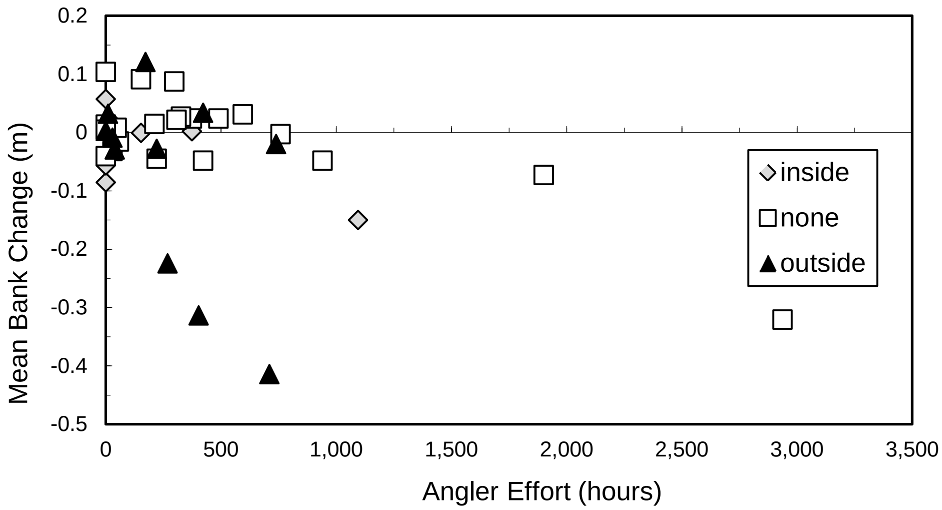

Figure 5.–Mean change in bank position (June 1999–June 2000) in relation to annual angler effort (1999) for each meander category, Kenai River.

Note: Negative values indicate bank loss.

Table 8.–Analysis of variance for cumulative effects of angler effort (1998 and 1999), habitat type, site position relative to stream meander, and boat activity level on cumulative mean bank positional change (August 1998–June 2000) at angler-effort sites, Kenai River.

	Analysis of variance				Duncan's test			
Source	df	Mean square	*F* value	*P* > *F*	Main effects	Sample size	Mean	Duncan grouping
Habitat type	1	0.02	0.27	0.61				
					Herbaceous	22	-0.02	A
					Shrub/Herb	19	-0.03	A
Meander	2	0.03	0.5	0.61				
					None	17	0.02	A
					Inside	11	0.01	A
					Outside	12	-0.04	A
Boat activity	1	0.01	0.41	0.53				
					Low	36	0.01	A
					High	5	-0.07	A
Effort 98–99	1	0.29	5.16	0.03				

Note: The shrubland/herbaceous site 25.5 was removed from the analysis because of bias (see methods).

[a] Site position relative to stream meander: inside of meander, no meander, outside of meander.

[b] Boat activity level determined from Dorava and Moore (1997: Table 12).

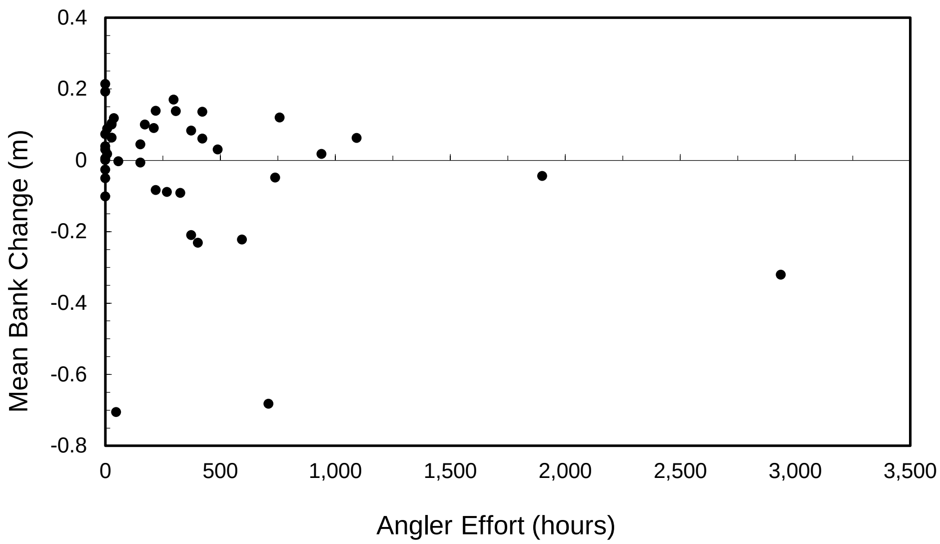

Figure 6.–Mean change in bank position (August 1998–June 2000) with respect to cumulative angler effort (1998 and 1999), Kenai River.

Note: Negative values indicate bank loss.

VEGETATION ANALYSIS SITES

In 2000, angler effort had a significant effect on the inseason change in mean percent cover of vegetation, litter, and bare ground, but no significant effect on percent cover of water (Table 9). There was a significant interaction between habitat type and angler effort on change in mean percent cover of vegetation (Table 9). When divided by habitat type, vegetative cover decreased as angler effort increased for both herbaceous and shrubland-herbaceous sites but the rate of change was greater at shrubland-herbaceous sites (Table 10, Figure 7). For both habitat types combined, both litter and bare ground cover increased as angler effort increased and the rate of change was nearly the same (Table 10, Figure 7). Within-reader observer measurement error was 4.4–6.9% for the vegetation cover class and 0–27% for all cover classes (Appendix C1).

Neither angler effort (1999) nor habitat type had a significant effect on annual change in mean percent cover (June 1999–June 2000; Table 11, Figure 8). Cumulative angler effort (1997–1999) had no significant effect on change in percent cover of vegetation (June 1997–June 2000; Table 12, Figure 9).

Five textural classes were identified from soil composition analyses: sand (3 sites), loamy sand (4 sites), sandy loam (3 sites), sandy clay loam (1 site), and loam (1 site) (Table 13). Sand was the most prevalent component (51.2–93.2%), silt composition ranged from 5.2% to 40.8%, and clay was the least common component (1.6–27.6%). These textural classes were not associated with a specific habitat type.

Table 9.–Multivariate analysis of variance for effects of angler effort with inseason change (prefishery vs. postfishery) in percent cover by cover class from photo imagery analysis of permanent vegetation plots at habitat survey sites, Kenai River, 2000.

Change in percent cover	Source	P>F
Vegetation		
	Estimated angler effort	<0.01
	Habitat type	0.18
	Interaction	0.01
Bare ground		
	Estimated angler effort	0.01
	Habitat type	0.37
	Interaction	0.38
Litter		
	Estimated angler effort	<0.01
	Habitat type	0.40
	Interaction	0.15
Water		
	Estimated angler effort	0.32
	Habitat type	0.86
	Interaction	0.34

Table 10.–Tests for effects of parameter estimates of angler effort on change in vegetation cover by habitat type and for change in litter or bare ground cover for all habitats from the multivariate analysis of variance given in Table 7 for permanent vegetation plots at habitat survey sites, Kenai River, 2000.

Habitat type	Change in percent cover	Parameter	Estimate	SE	P>T
Herbaceous					
	Vegetation	Intercept	6.50	5.62	0.26
		Slope	-0.06	0.01	<0.01
Shrub/Herbaceous					
	Vegetation	Intercept	22.31	11.66	0.06
		Slope	-0.13	0.03	<0.01
Combined					
	Litter	Intercept	-2.84	4.76	0.55
		Slope	0.05	0.01	<0.01
	Bare ground	Intercept	-5.62	3.74	0.14
		Slope	0.02	0.01	<0.01

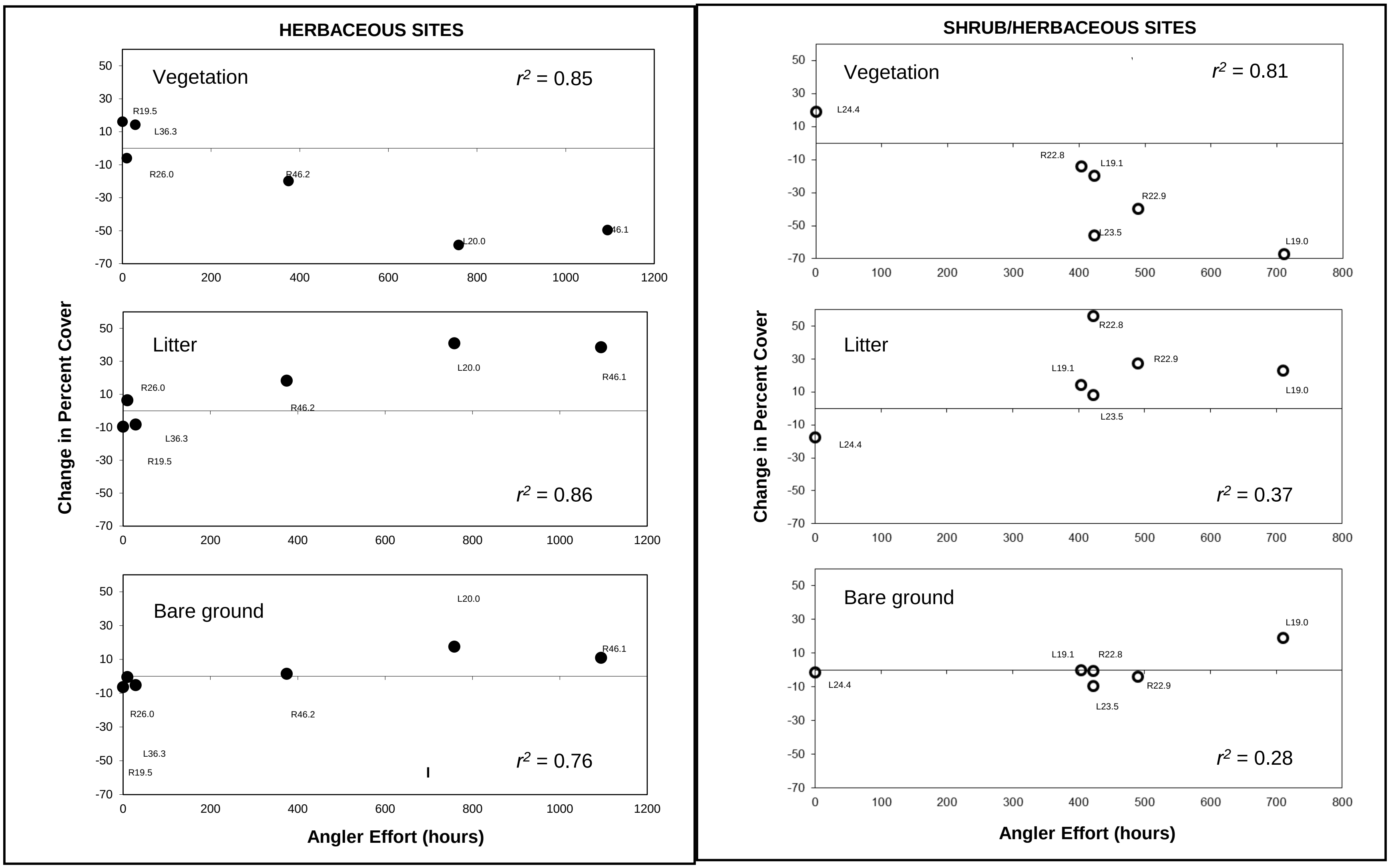

Figure 7.–Angler effort (2000) versus mean change (prefishery to postfishery) in percent cover of vegetation (top), litter (middle), and bare ground (bottom) for permanent vegetation plots at herbaceous (left) and shrubland/herbaceous (right) habitat sites (*n* = 6 each), Kenai River.

Table 11.–Multivariate analysis of variance for effects of angler effort (1999) with annual change (June 1999–June 2000) in percent cover by cover class for permanent plots at habitat survey sites, Kenai River.

Change in percent cover	Source	P>F
Vegetation		
	Estimated angler effort	0.66
	Habitat type	0.81
	Interaction	0.98
Bare ground		
	Estimated angler effort	0.26
	Habitat type	0.91
	Interaction	0.70
Litter		
	Estimated angler effort	0.14
	Habitat type	0.74
	Interaction	0.95
Water		
	Estimated angler effort	0.80
	Habitat type	0.89
	Interaction	0.41

Table 12.–Analysis of variance (repeated measures with a nested treatment arrangement) for effects of angler effort (1999) with annual change (June 1999–June 2000) in percent cover by cover class for permanent vegetation plots at habitat survey sites, Kenai River.

Source	df	Mean square	F value	Pr > F
Habitat type	1	2,851.54	3.37	0.10
Site (habitat type)	10	845.17	1.22	0.31
Cumulative effort	1	270.93	3.46	0.07

Table 13.–Soil composition for 12 habitat survey sites, Kenai River, 2000.

		Soil composition			
Site	Habitat type[a]	% Sand	% Silt	% Clay	Textural class
R19.5	H	93.2	5.2	1.6	sand
L23.5	SH	91.2	7.2	1.6	sand
L20.0	H	89.2	6.8	4.0	sand
R46.1	H	84.8	5.2	10.0	loamy sand
L36.3	H	84.8	11.2	4.0	loamy sand
L24.2	SH	81.2	12.8	6.0	loamy sand
R26.6	H	78.8	17.2	4.0	loamy sand
R22.8	SH	75.2	19.2	5.6	sandy loam
R22.9	SH	71.2	21.2	7.6	sandy loam
L19.1	SH	71.2	20.8	8.0	sandy loam
R46.2	H	59.2	13.2	27.6	sandy clay loam
L19.0	SH	51.2	40.8	8.0	loam

[a] Macrohabitat types: H = herbaceous, SH = shrubland/herbaceous; see methods for definitions.

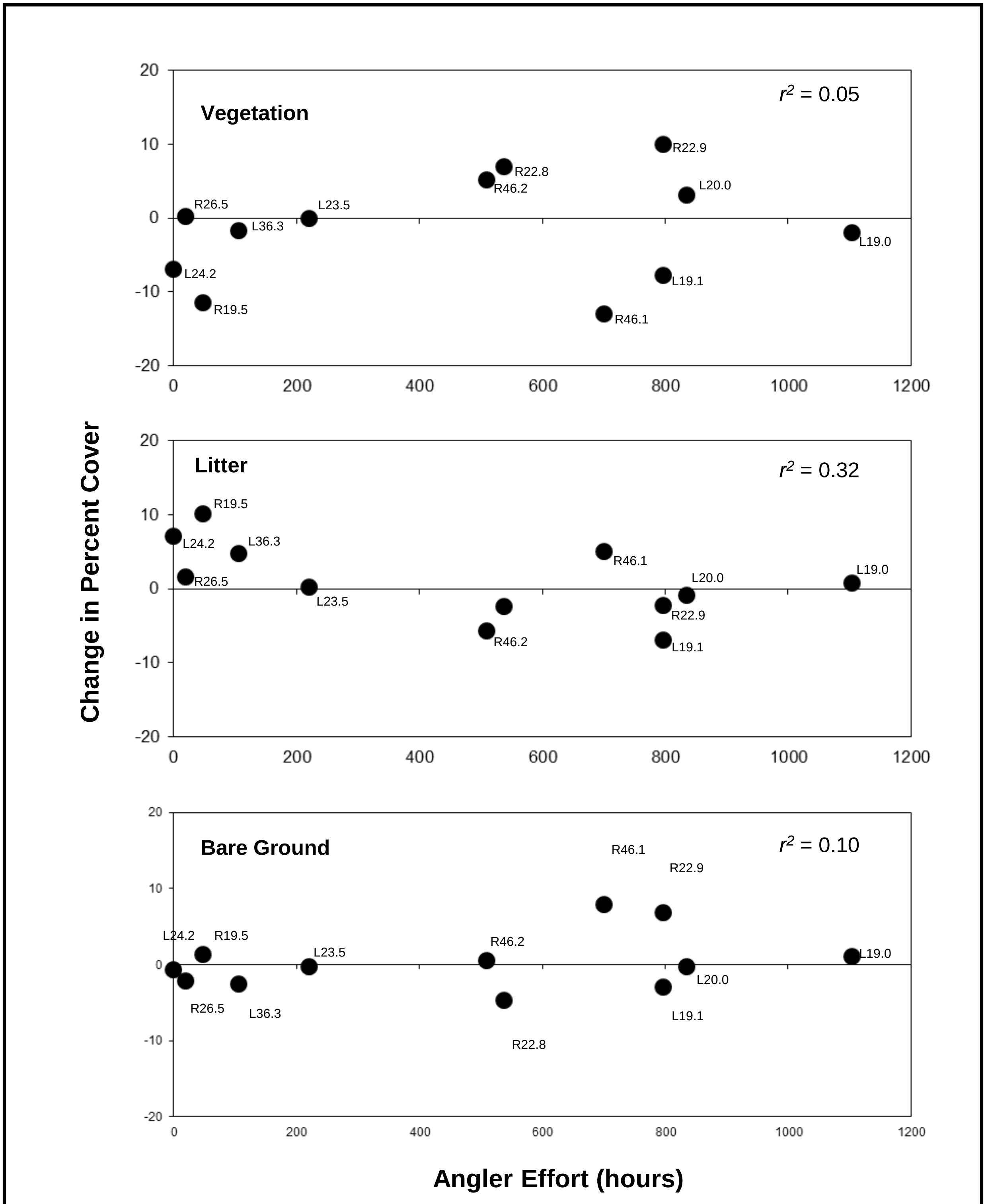

Figure 8.–Angler effort (1999) versus annual change (June 1999–June 2000) in percent cover of vegetation, litter, and bare ground for permanent vegetation plots (*n* = 12 each), Kenai River.

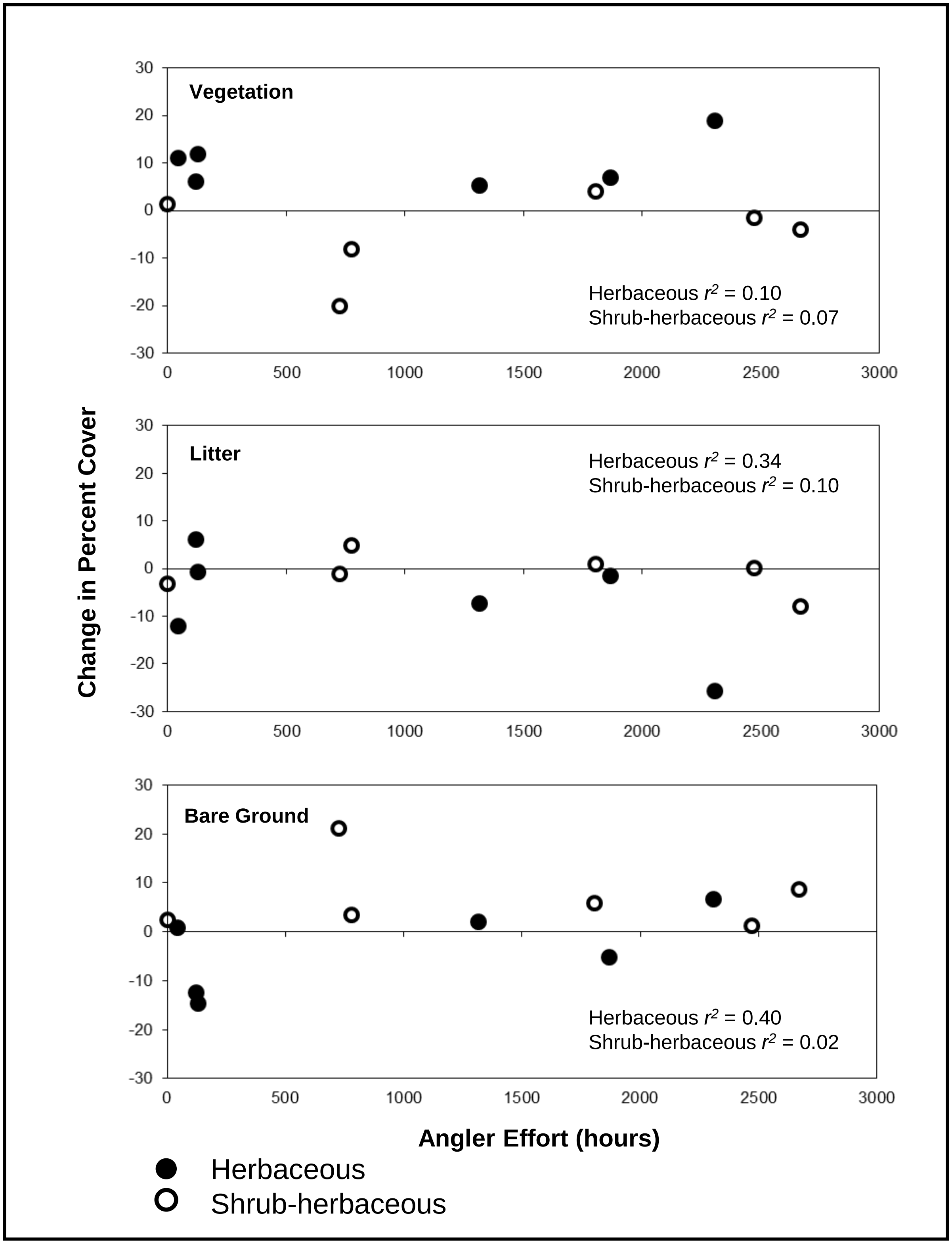

Figure 9.–Cumulative angler effort (1997–1999) versus mean change (June 1997–June 2000) in percent cover of vegetation, litter, and bare ground for herbaceous (n = 6) and shrub-herbaceous (n = 6) permanent vegetation plots, Kenai River.

DISCUSSION

DISTRIBUTION OF SHORE ANGLERS

Due to a smaller than expected return of late-run sockeye salmon to the Kenai River in 2000 (Gamblin et al. 2004), participation in the fishery diminished earlier than usual. An emergency order closed the river to fishing for sockeye salmon effective 5 August, and as a result, we did not conduct our last 2 scheduled angler distribution counts. Despite these circumstances, the mean angler count for each reach in 2000 was higher than any other year since we began angler counts in 1996 and was 25% higher than the 1999 mean count (Table 2).

When this study first began in 1995, there was concern that bank closures implemented to rehabilitate or protect riparian habitat might shift fishing pressure from public lands to private lands. However, there was little correlation between bank closures and changes in public and private land use in previous studies (King and Hansen 2001-2002), and after 1997, the total length of closed mainland banks has remained at about 15.5 miles (Table 12).

Although less than 1% of waterfront downstream of Skilak Lake has boardwalks or other similar structures (Mike Wiedmer, ADF&G, Anchorage, personal communication), 19.3% of mainland banks anglers fished from them (Table 4). This indicates that when boardwalks are present anglers use them, which should help minimize shore angler impacts to riparian habitats.

Table 14.–Miles of riverbank closed to shore angling by river reach, Kenai River, 1996–2000.

Reach	1996	1997	1998	1999	2000
1	0.4	0.4	0.4	0.4	0.4
2	0.1	0.1	0.1	0.1	0.1
3	2.9	2.9	10.9	11.2	11.2
4[a]	2.5	2.5	4.2	4.2	4.0
Total	5.9	5.9	15.6	15.9	15.7

[a] Excludes shorelines of islands between river miles 17.0 and 17.3.

BANK MEASUREMENT SITES

Analysis of the bank measurement sites showed a significant effect of boat activity level on cumulative bank position change with a mean bank loss of 0.04 m in low activity areas and a mean loss of 0.26 m in high boat activity areas, indicating that sites with greater boat activity, and hence greater wakes and tractive energy (Dorava and Moore 1997), are associated with greater bank loss.

Bank measurement increases greater than 0.05 m were probably due to the bank “rolling over” but remaining attached, rather than due to sediment accretion. Sediment accretion generally occurs as a result of deposition at or near the waterline, but our measurements were taken from the top of the bank. Sites with the greatest increase were located in intertidal areas where natural bank changes such as rolling over and sloughing occur more frequently.

One source of error in collecting bank measurements is relocation of the bank edge. Our current methodology of using nails to mark the bank edge, which was implemented in 1999, proved to be very repeatable in 2000. We had small measurement error associated with this process (Appendix C1) and will continue to use this method.

ANGLER-EFFORT SITES

Our study found that angler effort had a significant effect on both annual and cumulative bank change. However, correlating angler use with bank changes may be difficult because of angler behavior, physical characteristics of riverbanks, and natural processes. For example, counts of anglers may be high at a location with little bank erosion because access to the river is limited and anglers stay in the water rather than moving from place to place, thus minimizing human effects on bank erosion. Physical characteristics of riverbanks, such as rocks, overhanging vegetation, or steepness, may limit angler movement and thus reduce angler impacts.

On the other hand, at locations with unlimited access to the water, anglers may move more frequently, which could accelerate bank erosion. Natural riverbank processes such as rolling over, slumping, and calving can confound correlations between anglers and erosion. In addition, other factors such as powerboat activity further complicate these relationships. Long-term studies are necessary to determine if angler use accelerates bank erosion.

Although there was a significant effect of boat activity on bank loss detected in the analysis of the bank measurement sites, no significant effects were detected in the analysis of the angler-effort sites. This could be due to the smaller sample size (n = 42 vs. n = 172).

VEGETATION ANALYSIS SITES

Our data, as well as previous studies (King and Hansen 1999-2001), strongly support the concern that there are negative inseason impacts to vegetation as a result of angler foot traffic. As angler effort increased there was a decrease in percent cover of vegetation and an increase in percent cover of litter and bare ground, but our data have not shown that this vegetation loss is permanent. However, our study does not address changes in plant species composition, which may also affect fish habitat and bank integrity if there is a transition from bank-stabilizing species such as grasses to less stabilizing "weedy" species such as dandelions and horsetails.

Since 1997, we have used soil penetrability to assess soil compaction (King and Hansen 1999-2001), but analyses were limited to within-site comparisons because we did not know the soil composition of each site. In the current study, we took soil samples, hoping that soil composition between sites would be similar so that between-site comparisons could be made. However, soil texture was diverse, with 5 classes among 12 habitat survey sites, so we cannot compare soil penetrability between sites.

RECOMMENDATIONS

Assessment of shore angler impacts to Kenai River riparian habitats has been ongoing since 1996. During this time, project personnel have implemented and tested various methods to best assess shore angler impacts. This was the third year of the project in its current design with angler distribution surveys, vegetation assessment using photo imagery analysis, and bank position measurements that include sites with multiple measurements. We recommend continuation of the study and the following improvements:

1. Photo assessment of vegetation does not address changes in plant species diversity resulting from trampling and how that may affect the riparian zone and fish habitat. We recommend that species composition changes be assessed by comparing species composition from photos taken in June 1997 with photos from June 2002.

2. Soil types between sites were too varied to correlate penetrability measurements and angler effort between sites. This limits our ability to assess soil compaction related to angler foot traffic. We recommend discontinuing this phase of the project.
3. Our bank measurement program can be improved by reducing measurement error, which can be accomplished by use of better equipment and improved methodology. A total station surveyor's transit would greatly improve the accuracy and precision of these measurements.

In addition to the study design improvements listed above, we also recommend the following:

4. More public education on low-impact shore angling techniques and improved enforcement at areas closed to bank fishing.
5. Implementation of an aerial photogrammetry study that could provide valuable information regarding changes in the riparian corridor through time. The study should assess bank positional changes and changes in percent cover of vegetation in the riparian corridor. Combined with data from the current study, a photogrammetry study of the whole area could provide insight into cause and effect relationships leading to changes in riparian habitat. Ultimately, this information would be useful for development of a long-term habitat monitoring program for the Kenai River.

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REFERENCES CITED

Dietz, H., and T. Steinlein. 1996. Determination of plant species cover by means of image analysis. 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 No. 97-4105.

Gamblin, M., L. E. Marsh, P. Berkhahn, and S. Sonnichsen. 2004. Area management report for the recreational fisheries of the Northern Kenai Peninsula, 2000 and 2001. Alaska Department of Fish and Game, Fishery Management Report No. 04-04, Anchorage. http://www.adfg.alaska.gov/FedAidPDFs/fmr04-04.pdf

Howe, A. L., G. Fidler, A. E. Bingham, and M. J. Mills. 1996. Harvest, catch, and participation in Alaska sport fisheries during 1995. Alaska Department of Fish and Game, Fishery Data Series No. 96-32, Anchorage. http://www.adfg.alaska.gov/FedAidPDFs/fds96-32.pdf

Howe, A. L., R. J. Walker, C. Olnes, K. Sundet, and A. E. Bingham. 2001. Participation, catch, and harvest in Alaska sport fisheries during 1999. Alaska Department of Fish and Game, Fishery Data Series No. 01-08, Anchorage. http://www.adfg.alaska.gov/FedAidPDFs/fds01-08.pdf

King, M. A. 1997. Fishery surveys during the recreational and personal use dip net fisheries for late-run sockeye salmon to the Kenai River, 1995. Alaska Department of Fish and Game, Fishery Data Series No. 97-4, Anchorage. http://www.adfg.alaska.gov/FedAidPDFs/fds97-04.pdf

King, M. A., and P. 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. http://www.adfg.alaska.gov/FedAidPDFs/fds99-09.pdf

King, M. A., and P. Hansen. 2002. Assessment of shore angling impacts to Kenai River riparian habitats, 1999. Alaska Department of Fish and Game, Fishery Data Series 02-19, Anchorage. http://www.adfg.alaska.gov/FedAidPDFs/fds02-19.pdf

King, M. A., and P. A. Hansen. 2001. Assessment of shore angling impacts to Kenai River riparian habitats during 1998. Alaska Department of Fish and Game, Fishery Data Series No. 01-3, Anchorage. http://www.adfg.alaska.gov/FedAidPDFs/fds01-03.pdf

Larson, L. L., and B. 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. http://www.adfg.alaska.gov/FedAidPDFs/fds98-10.pdf

Mills, M. J. 1979. Alaska statewide sport fish harvest studies. Alaska Department of Fish and Game, Federal Aid in Fish Restoration, Annual Performance Report 1978-1979, Project F-9-11(20)SW-I-A, Juneau. http://www.adfg.alaska.gov/FedAidPDFs/FREDf-9-11(20)SW-I-A.pdf

Mills, M. J. 1988. Alaska statewide sport fisheries harvest report, 1987. Alaska Department of Fish and Game, Fishery Data Series No. 52, Juneau. http://www.adfg.alaska.gov/FedAidPDFs/fds-052.pdf

Platts, W. S., W. F. Megahan, and G. W. Minshall. 1983. Methods for evaluating stream, riparian, and biotic conditions. General Technical Report INT-138: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, Ogden, UT. http://www.treesearch.fs.fed.us/pubs/29138

Schwager-King, M. A. 1995. Fishery surveys during the recreational fishery for late-run sockeye salmon in the Kenai River, 1994. Alaska Department of Fish and Game, Fishery Data Series No. 95-28, Anchorage. http://www.adfg.alaska.gov/FedAidPDFs/fds95-28.pdf

Viereck, L. 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.

Waters, T. F. 1995. Sediment in streams; sources, biological effects, and control. Fisheries Society Monograph 7, Bethesda, Maryland.

APPENDIX A: KENAI RIVER MANAGEMENT PLANS

Appendix A1.–5 ACC 56.065 Riparian Habitat Fishery Management Plan adopted in May 1996 by the Alaska Board of Fisheries (repealed 1 October 2006).

(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 24 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 A2.–5 AAC 21.360 Kenai River Late-Run Sockeye Salmon Management Plan (first part) adopted in June 1999 by the Alaska Board of Fisheries (modifications have been made since).

(a) The department shall manage the Kenai River late-run sockeye salmon stocks primarily for commercial uses in order to provide commercial fishermen with an economic yield from the harvest of these salmon resources based on abundance. The department shall also manage the commercial fisheries to minimize the harvest of Northern District coho, late-run Kenai River chinook, and Kenai River coho salmon stocks in order to provide personal use, sport, and guided sport fishermen with a reasonable opportunity to harvest salmon resources, as specifically set out in 5AAC 21.357, 5AAC 21.358, and 5AAC 21.359.

(b) The Kenai River late-run sockeye salmon commercial, sport, and personal use fisheries shall be managed to

(1) meet an optimum escapement goal (OEG) range of 500,000–1,000,000 late-run sockeye salmon;

(2) achieve inriver goals as established by the board and measured at the Kenai River sonar counter located at river mile 19; and

(3) distribute the escapement of sockeye salmon evenly with the OEG range, in proportion to the size of the run.

(c) Based on preseason forecasts and inseason evaluations of the total Kenai River late-run sockeye salmon return during the fishing season, the run will be managed as follows:

(1) at run strengths of less than 2,000,000 sockeye salmon, the department shall manage for an inriver goal range of 600,000–850,000 sockeye salmon past the sonar counter at river mile 19 as follows:

(2) at run strengths of 2,000,000–4,000,000 sockeye salmon, the department shall manage for an inriver goal range of 750,000–950,000 sockeye salmon past the sonar counter at river mile 19 as follows:

(3) at run strengths greater than 4,000,000 sockeye salmon, the department shall manage for an inriver goal range of 850,000–1,100,000 sockeye salmon past the sonar counter at river mile 19 as follows:

(d) The sonar count levels established in (b)(2), (c)(1), and (c)(2) of this section may be lowered by the board if noncommercial fishing, after consideration of mitigation efforts, results in a net loss of riparian habitat on the Kenai River. The department will, to the extent practicable, conduct habitat assessments on a schedule that conforms to the Board of Fisheries (board) triennial meeting cycle. If the assessments demonstrate a net loss of riparian habitat caused by noncommercial fishermen, the department is requested to report those findings to the board and submit proposals to the board for appropriate modification of the Kenai River late-run sockeye salmon inriver goal.

APPENDIX B: SITE MEASUREMENTS

Appendix B1.–Bank change measurements (benchmark measurement to bank edge) at the bank measurement sites (*n* = 172), Kenai River, 1998–2000.

Site	Habitat type [a]	Boat level [b]	Meander [c]	Annual change (m) Δ = Jun 99 − Jun 98	Δ = Jun 00 − Jun 99	Cumulative change (m) Δ = Jun 00 − Jun 98
L6.0	H	L	N	0.14	0.10	0.24
R6.0	H	L	N	−3.83	0.02	−3.81
L7.0	H	L	O	2.13	0.24	2.37
R7.0	H	L	O	0.07	0.05	0.12
L7.7	H	L	N	2.00	0.28	2.28
R8.0	H	L	N	0.60	−1.26	−0.66
L9.0	H	H	N	0.38	−0.03	0.35
R9.0	SH	H	O	0.09	0.03	0.12
L10.0	H	H	I	0.07	0.01	0.08
L11.0	H	H	I	−0.30	−0.09	−0.39
R11.0	T	H	O	−0.19	−0.05	−0.24
L11.5	T	H	N	−1.36	0.77	−0.59
R11.5	T	H	O	−0.08	0.06	−0.02
L12.0	T	H	N	−0.61	−0.07	−0.68
R12.1	T	H	N	−0.19	−0.06	−0.25
L12.5	S	H	N	0.04	0.03	0.07
R12.5	T	H	N	−0.14	−0.38	−0.52
L13.0	T	H	N	0.02	0.03	0.05
R13.0	T	H	N	−2.09	−0.24	−2.33
L13.5	T	H	N	−0.05	0.04	−0.01
R13.5	SH	H	I	0.00	0.00	0.00
R13.9	T	H	N	−0.19	0.59	0.40
L14.0	H	H	N	0.85	−0.05	0.80
L14.5	T	H	N	0.00	−0.07	−0.07
R14.7	T	H	N	−0.17	−0.13	−0.30
L15.0	T	H	N	−0.22	0.01	−0.21
R15.0	T	H	N	0.72	−0.01	0.71
R15.5	T	H	O	−0.01	−0.03	−0.04
R16.0	T	H	I	−0.17	0.06	−0.11
L16.5	T	H	N	−0.15	−0.13	−0.28
R16.5	T	H	N	−0.15	−0.09	−0.24
L17.0	H	H	N	−0.49	−0.80	−1.29
R17.0	D	H	N	−1.33	−0.09	−1.42
L17.5	SH	H	N	0.22	0.05	0.27
R17.5	D	H	O	0.19	0.12	0.31
L18.0	T	L	I	0.36	−0.11	0.25
R18.0	S	H	N	0.02	0.00	0.02
L18.3	T	H	N	0.07	0.03	0.10

-continued-

Site	Habitat type [a]	Boat level [b]	Meander [c]	Annual change (m) Δ = Jun 99 − Jun 98	Annual change (m) Δ = Jun 00 − Jun 99	Cumulative change (m) Δ = Jun 00 − Jun 98
R18.5	H	L	N	0.00	−0.62	−0.62
L19.0	SH	L	O	0.14	−1.76	−1.62
R19.0	T	L	N	0.31	0.03	0.34
L19.1	SH	L	O	−0.88	−0.55	−1.43
R19.5	H	L	N	0.14	−0.01	0.13
L19.6	T	L	O	−1.47	0.03	−1.44
L20.0	H	L	N	0.21	0.01	0.22
R20.0	T	L	O	−0.06	0.00	−0.06
L20.5	T	L	N	0.01	0.02	0.03
R20.5	T	L	O	0.02	−0.03	−0.01
L21.0	H	L	N	0.68	0.01	0.69
R21.0	D	L	N	−0.12	0.07	−0.05
L21.4	SH	L	N	0.00	0.03	0.03
L21.5	H	L	N	0.16	−0.04	0.12
R21.5	T	L	N	0.09	−0.02	0.07
R21.9	H	L	N	−0.08	−0.06	−0.14
L22.0	S	L	N	0.01	0.10	0.11
L22.3	H	L	I	−0.10	−0.05	−0.15
R22.5	T	L	N	−0.31	0.04	−0.27
R22.8	SH	L	N	−0.84	−0.02	−0.86
R22.9	SH	L	N	−0.04	0.08	0.04
L23.0	T	L	N	0.15	0.01	0.16
L23.5	SH	L	O	0.05	0.03	0.08
R23.5	T	L	N	−0.03	0.06	0.03
L23.6	H	L	O	−0.20	0.05	−0.15
L24.0	SH	L	I	0.08	0.01	0.09
R24.0	T	L	O	0.08	0.08	0.16
L24.2	H	L	I	New in 1999	0.00	New in 1999
L24.3	H	L	I	−0.04	0.08	0.04
R24.5	T	L	N	0.08	0.02	0.10
L25.0	SH	L	N	0.10	0.05	0.15
R25.0	T	L	I	−0.01	0.05	0.04
L25.5	SH	L	N	0.03	0.05	0.08
R25.5	SH	L	N	−0.30	0.00	−0.30
R25.6	SH	L	O	−0.30	−0.02	−0.32
L25.7	H	L	O	0.25	−0.02	0.23
L25.9	SH	L	N	0.11	−0.04	0.07
R26.0	H	L	N	0.05	0.02	0.07

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Site	Habitat type [a]	Boat level [b]	Meander [c]	Annual change (m) Δ = Jun 99 − Jun 98	Annual change (m) Δ = Jun 00 − Jun 99	Cumulative change (m) Δ = Jun 00 − Jun 98
L26.5	H	L	N	-0.01	0.04	0.03
R26.5	SH	L	I	-0.03	0.00	-0.03
R26.6	H	L	I	New in 1999	0.00	New in 1999
L26.9	SH	L	O	0.01	-0.05	-0.04
R27.0	T	L	I	0.60	0.04	0.64
L27.5	T	L	N	0.08	0.04	0.12
R27.5	SH	L	N	-0.49	-0.03	-0.52
L28.0	SH	L	N	-0.10	0.03	-0.07
R28.3	SH	L	O	-0.03	0.07	0.04
L28.5	T	L	N	0.40	0.08	0.48
L29.0	T	L	N	-0.07	0.00	-0.07
R29.0	T	L	N	0.05	0.01	0.06
R29.4	T	L	I	-0.30	0.04	-0.26
L29.5	T	L	N	-0.16	0.11	-0.05
L30.0	T	L	N	-0.17	0.05	-0.12
R30.0	T	L	N	-0.01	-0.01	-0.02
L30.5	T	L	N	-0.04	0.02	-0.02
R30.5	T	L	O	0.11	0.03	0.14
L31.0	T	L	N	-0.01	0.05	0.04
R31.0	SH	L	N	0.01	-0.04	-0.03
L31.5	T	L	N	0.24	-0.01	0.23
R31.5	D	L	O	0.60	-0.14	0.46
L32.0	D	L	N	0.15	0.01	0.16
R32.1	SH	L	O	0.12	-0.08	0.04
L32.5	T	L	N	0.10	0.00	0.10
R32.7	H	L	O	-0.38	0.03	-0.35
L32.8	SH	L	O	-0.06	-0.02	-0.08
R33.0	T	L	I	0.05	-0.12	-0.07
L33.5	S	L	N	-0.07	-0.02	-0.09
R33.5	T	L	I	-0.01	0.02	0.01
L33.9	SH	L	N	0.16	0.03	0.19
R34.0	T	L	I	-0.02	-0.14	-0.16
L34.5	T	L	O	0.06	0.03	0.09
R34.5	T	L	N	-0.06	-0.02	-0.08
L35.0	T	L	N	-0.06	-0.06	-0.12
R35.0	SH	L	O	-0.04	-0.10	-0.14
L35.5	T	L	N	0.11	-0.10	0.01
R35.5	H	L	N	0.00	0.13	0.13
L36.0	T	L	O	0.13	-0.03	0.10

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Site	Habitat type [a]	Boat level [b]	Meander [c]	Annual change (m) Δ = Jun 99 − Jun 98	Annual change (m) Δ = Jun 00 − Jun 99	Cumulative change (m) Δ = Jun 00 − Jun 98
R36.1	T	L	O	−0.03	0.00	−0.03
L36.3	H	L	I	−0.08	−0.03	−0.11
L36.5	T	L	N	0.09	0.10	0.19
R36.5	H	L	O	−0.16	0.04	−0.12
L37.0	SH	L	N	0.13	0.00	0.13
R37.0	D	L	O	0.08	0.01	0.09
L37.5	T	L	O	0.14	−0.03	0.11
R37.5	T	L	O	−0.56	0.04	−0.52
L38.0	D	L	N	−0.13	0.00	−0.13
R38.0	T	L	I	−0.03	0.07	0.04
L38.5	T	L	N	0.26	0.00	0.26
R38.5	SH	L	O	−0.04	0.06	0.02
L39.0	T	L	O	−0.03	−0.35	−0.38
R39.0	T	H	N	0.16	0.02	0.18
L39.5	T	H	N	−0.01	−0.03	−0.04
R39.5	T	H	O	−0.18	0.07	−0.11
L40.0	T	H	O	−0.02	−0.03	−0.05
R40.3	H	H	I	−0.05	0.10	0.05
L40.5	T	H	O	−0.82	−1.94	−2.76
L41.0	T	H	O	0.02	−0.02	0.00
R41.0	T	H	N	−0.44	0.07	−0.37
L41.5	T	H	N	0.35	−0.07	0.28
R41.5	T	H	N	0.12	−0.13	−0.01
L42.0	T	H	O	−1.20	−0.64	−1.84
R42.0	D	H	O	−0.12	0.03	−0.09
L42.5	SH	H	N	0.07	−0.05	0.02
R42.5	T	H	N	0.03	−0.02	0.01
R42.9	T	H	N	−0.30	0.20	−0.10
L43.0	T	H	O	0.20	−0.13	0.07
L43.5	T	H	O	−0.62	−0.05	−0.67
R43.5	T	H	O	−0.02	0.08	0.06
L44.0	T	H	O	−3.10	−0.19	−3.29
R44.1	T	H	I	−0.14	0.11	−0.03
L44.5	H	H	I	−0.05	−0.07	−0.12
R44.5	T	H	O	−0.34	−0.08	−0.42
L45.0	T	H	N	0.00	−0.17	−0.17
R45.0	T	H	N	0.19	0.01	0.20

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				Annual change (m)		Cumulative change (m)
Site	Habitat type [a]	Boat level [b]	Meander [c]	Δ = Jun 99 − Jun 98	Δ = Jun 00 − Jun 99	Δ = Jun 00 − Jun 98
L45.5	SH	H	I	0.24	−0.06	0.18
L46.0	T	H	O	0.10	−0.02	0.08
R46.1	H	L	I	−0.01	0.06	0.05
R46.2	H	L	I	−0.08	−0.09	−0.17
R46.5	T	L	O	−0.20	−0.07	−0.27
L46.7	T	L	I	−0.03	0.01	−0.02
R46.9	T	L	O	−0.03	0.00	−0.03
L47.0	T	L	I	0.05	0.02	0.07
L47.5	T	L	O	0.09	0.04	0.13
R47.5	T	L	O	0.30	−0.02	0.28
L48.0	T	L	N	0.00	−0.03	−0.03
R48.0	T	L	N	−0.62	−0.02	−0.64
L48.5	T	L	N	−0.09	0.00	−0.09
R48.5	T	L	N	−0.05	−0.03	−0.08
L49.0	T	L	N	−0.02	−0.03	−0.05
R49.0	T	L	N	0.06	−0.06	0.00
L49.5	H	L	N	−0.21	−0.07	−0.28
R49.5	T	L	N	0.03	−0.01	0.02
L50.0	T	L	N	0.07	−0.02	0.05
R50.0	T	L	N	0.01	−0.17	−0.16
Min				−3.83	−1.94	−3.81
Max				2.13	0.77	2.37

Note: Changes are determined from the value of the bank measurement on the first date minus the value on the second date (e.g., Δ = [Jun 1999 value] – [Jun 1998 value]).

[a] Macrohabitat types: D = disturbed, H = herbaceous, S = shrubland, SH = shrubland/herbaceous, T = forest; see methods for definitions.

[b] Boat activity level: L = low, H = high; determined from Dorava and Moore (1997: Table 12).

[c] Site position relative to stream meander: I = inside of meander, N = no meander, O = outside of meander..

Appendix B2.–Annual and cumulative bank change measurements (meters) at angler-effort sites, Kenai River, 1998–2000.

				Annual change statistics								Cumulative change statistics [d]							
				Δ = Jun 1999 − Aug 1998				Δ = Jun 2000 − June 1999				Δ = Jun 1999 − Aug 1998				Δ = Jun 2000 − Aug 1998			
Site	Hab [a]	Boat [b]	Mdr [c]	Max	Min	Mean	Var	Max	Min	Mean	Var	Max	Min	Mean	Var	Max	Min	Mean	Var
R13.5	SH	H	I	0.82	-0.32	0.16	0.12	0.24	0.00	0.06	0.00	0.82	-0.32	0.16	0.12	0.86	-0.30	0.21	0.13
L14.0	H	H	N	0.42	-0.35	0.09	0.05	0.03	-0.08	-0.03	0.00	0.42	-0.35	0.09	0.05	0.43	-0.43	0.06	0.06
L17.0	H	H	N	New site in 1999.				0.02	-0.80	-0.32	0.09	New site in 1999.				0.02	-0.80	-0.32	0.09
L17.5	SH	H	N	0.38	-1.54	-0.23	0.41	0.18	-0.17	0.02	0.01	0.38	-1.54	-0.23	0.41	0.47	-1.54	-0.21	0.38
R18.5	H	L	N	0.10	-3.18	-0.71	0.89	0.28	-0.62	0.01	0.05	0.10	-3.18	-0.71	0.89	0.23	-3.14	-0.71	0.89
L19.0	SH	L	O	0.85	-0.16	0.08	0.07	0.11	-1.76	-0.31	0.35	0.85	-0.16	0.08	0.07	0.19	-1.82	-0.23	0.36
L19.1	SH	L	O	0.07	-2.80	-0.27	0.71	0.19	-1.14	-0.41	0.19	0.07	-2.80	-0.27	0.71	0.26	-3.79	-0.68	1.21
R19.5	H	L	N	1.82	0.06	0.89	0.35	0.04	-0.03	0.00	0.00	1.82	0.06	0.89	0.35	0.28	-0.03	0.00	0.00
L20.0	H	L	N	0.44	-0.13	0.12	0.02	0.06	-0.09	0.00	0.00	0.44	-0.13	0.12	0.02	0.44	-0.13	0.12	0.02
L21.0	H	L	N	0.23	-0.16	0.08	0.02	0.21	0.01	0.09	0.00	0.23	-0.16	0.08	0.02	0.44	-0.06	0.17	0.02
L21.4	SH	L	N	0.13	-0.98	-0.10	0.13	0.26	-0.01	0.09	0.01	0.13	-0.98	-0.10	0.13	0.31	-0.87	-0.01	0.14
L21.5	H	L	N	0.23	-0.10	0.08	0.01	0.14	-0.17	0.01	0.01	0.23	-0.10	0.08	0.01	0.25	-0.27	0.09	0.02
R21.9	H	L	N	0.84	-0.69	0.07	0.14	0.03	-0.13	-0.05	0.00	0.84	-0.69	0.07	0.14	0.79	-0.70	0.02	0.13
L22.3	H	L	I	0.51	-0.09	0.05	0.03	0.05	-0.07	0.00	0.00	0.51	-0.09	0.05	0.03	0.53	-0.08	0.04	0.03
R22.8	SH	L	N	0.97	-0.13	0.18	0.13	0.08	-0.36	-0.05	0.01	0.97	-0.13	0.18	0.13	1.05	-0.37	0.14	0.18
R22.9	SH	L	N	0.11	-0.11	0.01	0.00	0.14	-0.47	0.02	0.03	0.11	-0.11	0.01	0.00	0.19	-0.37	0.03	0.02
L23.5	SH	L	O	0.32	-0.29	0.03	0.02	0.07	-0.03	0.03	0.00	0.32	-0.29	0.03	0.02	0.34	-0.29	0.06	0.02
L23.6	H	L	N	0.11	-0.11	0.01	0.00	0.11	-0.08	-0.02	0.00	0.11	-0.11	0.01	0.00	0.21	-0.17	0.00	0.01
L24.0	SH	L	I	0.14	-0.28	0.02	0.01	0.08	-0.04	0.02	0.00	0.14	-0.28	0.02	0.01	0.15	-0.27	0.04	0.02
L24.2	H	L	I	New site in 1999.				0.00	0.00	0.00	0.00	New site in 1999.				0.00	0.00	0.00	0.00
L24.3	H	L	N	0.08	-0.69	-0.12	0.05	0.10	-0.05	0.03	0.00	0.08	-0.69	-0.12	0.05	0.12	-0.66	-0.09	0.05
L25.0	SH	L	N	0.09	-0.08	0.02	0.00	0.07	-0.05	0.01	0.00	0.09	-0.08	0.02	0.00	0.14	-0.10	0.03	0.01
L25.5	SH	L	N	0.94	-0.03	0.12	0.08	0.08	-0.03	0.02	0.00	0.94	-0.03	0.12	0.08	1.02	-0.02	0.14	0.09
R25.5	SH	L	N	1.31	-0.79	0.03	0.25	0.11	-0.38	-0.07	0.03	1.31	-0.79	0.03	0.25	1.42	-0.76	-0.04	0.30

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Appendix B2.–Page 2 of 2.

				Annual change statistics								Cumulative change statistics[d]							
				Δ = Jun 1999 − Aug 1998				Δ = Jun 2000 − June 1999				Δ = Jun 1999 − Aug 1998				Δ = Jun 2000 − Aug 1998			
Site	Hab[a]	Boat[b]	Mdr[c]	Max	Min	Mean	Var	Max	Min	Mean	Var	Max	Min	Mean	Var	Max	Min	Mean	Var
R25.6	SH	L	O	0.12	-0.15	-0.03	0.01	0.11	-0.12	-0.02	0.00	0.12	-0.15	-0.03	0.01	0.19	-0.15	-0.05	0.01
L25.7	H	L	O	0.42	-0.03	0.17	0.02	0.07	-0.08	-0.03	0.00	0.42	-0.03	0.17	0.02	0.40	-0.02	0.14	0.01
L25.9	SH	L	N	1.43	-0.82	0.23	0.35	0.05	-0.12	-0.04	0.00	1.43	-0.82	0.23	0.35	1.36	-0.85	0.19	0.35
R26.0	H	L	N	0.67	-0.79	-0.03	0.12	0.75	-0.01	0.10	0.05	0.67	-0.79	-0.03	0.12	0.66	-0.16	0.07	0.04
R26.5	SH	L	I	0.19	-0.07	0.03	0.01	0.02	-0.60	-0.09	0.03	0.19	-0.07	0.03	0.01	0.21	-0.59	-0.05	0.04
R26.6	H	L	I	New site in 1999				0.11	-0.03	0.02	0.00	New site in 1999.				0.11	-0.03	0.02	0.00
L26.9	SH	L	O	0.22	-0.41	-0.03	0.02	0.07	-0.06	0.00	0.00	0.22	-0.41	-0.03	0.02	0.17	-0.44	-0.03	0.02
R28.3	SH	L	O	0.10	-0.30	-0.02	0.01	0.22	0.07	0.12	0.00	0.10	-0.30	-0.02	0.01	0.23	-0.08	0.10	0.01
R32.7	H	L	O	0.32	-0.14	0.06	0.02	0.10	-0.01	0.03	0.00	0.32	-0.14	0.06	0.02	0.34	-0.09	0.09	0.02
L32.8	SH	L	O	0.33	0.01	0.15	0.01	0.01	-0.07	-0.03	0.00	0.33	0.01	0.15	0.01	0.30	0.02	0.12	0.01
L33.9	SH	L	N	0.27	-1.01	-0.25	0.21	0.13	-0.02	0.03	0.00	0.27	-1.01	-0.25	0.21	0.30	-1.01	-0.22	0.22
R35.5	H	L	N	0.38	-0.32	-0.04	0.04	0.13	-0.23	-0.05	0.01	0.38	-0.32	-0.04	0.04	0.15	-0.35	-0.08	0.03
L36.3	H	L	I	0.26	-0.03	0.09	0.01	0.17	-0.06	0.02	0.01	0.26	-0.03	0.09	0.01	0.23	0.00	0.10	0.01
R36.5	H	L	O	0.45	-0.10	0.11	0.02	0.04	-0.12	-0.01	0.00	0.45	-0.10	0.11	0.02	0.33	-0.08	0.10	0.01
R38.5	SH	L	O	1.19	-0.22	0.14	0.21	0.11	-1.53	-0.22	0.29	1.19	-0.22	0.14	0.21	0.07	-0.34	-0.09	0.02
R40.3	H	H	I	0.15	-0.60	-0.05	0.05	0.10	-0.31	-0.06	0.01	0.15	-0.60	-0.05	0.05	0.11	-0.62	-0.10	0.07
R46.1	H	L	I	1.10	-0.02	0.21	0.13	0.41	-0.96	-0.15	0.18	1.10	-0.02	0.21	0.13	0.39	-0.51	0.06	0.08
R46.2	H	L	I	0.37	-0.04	0.08	0.02	0.10	-0.27	0.00	0.01	0.37	-0.04	0.08	0.02	0.43	-0.28	0.08	0.05
Min				0.07	-3.18	-0.71		0.00	-1.76	-0.41		0.07	-3.18	-0.71		0.00	-3.79	-0.71	
Max				1.82	0.06	0.89		0.75	0.07	0.12		1.82	0.06	0.89		1.42	0.02	0.21	

Note: Changes are determined from the value of the bank measurement on the first date minus the value on the second date (e.g., Δ = [Jun 1999 value] – [Aug 1998 value]).

[a] Macrohabitat types: H = herbaceous, SH = shrubland/herbaceous; see methods for definitions.

[b] Wake level: L = low, H = high; determined from Dorava and Moore (1997: Table 12).

[c] Site position relative to stream meander: I = inside of meander, N = no meander, O = outside of meander.

[d] Cumulative change since August 1998 or earliest measured date after that (i.e., for L17.0, L24.2, and R26.6, Δ = Jun 2000 – June 1999) See King and Hansen (2002) for an explanation of the exclusion of the June 1998 bank measurements.

Appendix B3.–Summary of mean number of anglers counted and estimated effort (angler-hours) at angler-effort sites during the sport fishery for late-run sockeye salmon, Kenai River, 2000.

	Survey sites L--.-																						
Date	14.0	17.0	17.5	19.0	19.1	20.0	21.0	21.4	21.5	22.3	23.5	23.6	24.0	24.2	24.3	25.0	25.5	25.7	25.9	26.9	32.8	33.9	36.3
10 Jul	0	3.8	0.2	0	0	0	0	0	0	0	0	0	0	0	0.2	0	0	0.4	0	0	0	0	0
13 Jul	0	6.6	0	0	0.2	0.2	0	0	0	0	0.4	0	0	0	0	0	0.2	0	0	0	0	0	0
16 Jul	0	12.6	1.8	2.4	1.6	4.2	2.4	0.6	0.8	0.2	1.6	0	0	0	2.2	0	2.4	0.8	0	0	0	2.4	0.4
19 Jul	0.6	11	2.4	2	2.2	5	0.4	0.8	0.2	0.8	0	0.4	0	0	2.4	0	2.2	1	0	0	0	4	0
22 Jul	0	5.2	0.8	1.2	4.6	3	0.8	0.4	0.2	1	0	0.2	0	0	1	0	0	1.2	0	0	0.4	2	0
25 Jul	0	11.4	1	1.8	3.4	2	2.4	0.8	2.6	0.4	1.8	0.4	0	0	1	0	1.6	0.6	0	0	0.4	3.4	0.2
28 Jul	0	7	1.6	0.6	2.4	0.6	0.2	0.6	0.2	0.8	2.8	0.2	0	0	0	0	0	0.4	0	0	0	0.2	0
31 Jul	0	2.2	0	0	0.4	0.8	0	0	0.4	0	1.4	0	0	0	0	0	0	0.2	0	0	0	0.4	0
3 Aug	0	1.4	0	0.4	0	0	0	0	0	0	0.8	0	0	0	0	0	0	0	0	0	0	0	0
Mean [a]	0.1	6.8	0.9	0.9	1.6	1.8	0.7	0.4	0.5	0.4	1.0	0.1	0	0	0.8	0	0.7	0.5	0	0	0.1	1.38	0.07
SE	0.3	4.9	1.5	1.4	2.0	2.1	1.7	0.8	1.4	0.7	1.4	0.5	0.0	0.0	1.5	0.0	2.1	0.8	0.0	0.0	0.4	1.9	0.3
Effort	29	2,938	374	403	710	758	298	154	211	154	422	58	0	0	326	0	307	221	0	0	38	595	29
SE	42	358	141	129	147	116	185	93	132	74	114	59	0	0	119	0	178	85	0	0	53	137	29

-continued-

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	Survey sites R--.-																		
Date	13.5	18.5	19.5	21.9	22.8	22.9	25.5	25.6	26.0	26.5	26.6	28.3	32.7	35.5	36.5	38.5	40.3	46.1	46.2
10 Jul	0	0	0	0.2	0.2	0	0.6	0	0	0	0	0	0	0	0	0	0	0	0
13 Jul	0	0	0	1	0.4	0.8	2.4	0	0	0	0	0.4	0	0	0	0	0	0	0
16 Jul	0	0	0	8.4	3.2	0.6	8	2.6	0	0	0	0	0.2	1.6	0	1.2	0	1.8	1.8
19 Jul	0	0	0	4.6	1.8	2.2	6.6	3.8	0	0	0	0.2	0	0.2	0	1.6	0	3.2	0.6
22 Jul	0	0	0	1.8	1.6	1.8	5.8	2.4	0	0	0	0.2	0	1.2	0.6	1.8	0	3.2	2.2
25 Jul	0	0.8	0	3.2	0.8	1	7.2	2.6	0	0	0	1.8	0	0.4	0	0	0	5.8	0.6
28 Jul	0	0.2	0	0.2	0.6	1.4	4.4	2.4	0	0	0	1	0	1.2	0	1	0	4.2	2
31 Jul	0	0	0	0	0.2	1.6	2.4	1	0	0	0	0	0	0	0	0	0	2.8	0.6
3 Aug	0	0	0	0.2	0	0.8	2.2	0.6	0	0	0.2	0	0	0	0	0	0	1.8	0
Mean [a]	0	0.11	0	2.18	0.98	1.13	4.40	1.71	0	0	0.02	0.40	0.02	0.51	0.07	0.62	0	2.53	0.87
SE	0.0	0.4	0.0	3.1	1.6	1.3	3.7	1.8	0.0	0.0	0.1	1.3	0.1	1.2	0.3	1.1	0.0	2.6	1.4
Effort	0	48	0	941	422	490	1901	739	0	0	10	173	10	221	29	269	0	1094	374
SE	0	42	0	176	135	145	311	148	2	0	19	118	13	139	40	107	0	206	151

[a] Average of the mean daily count of anglers. Five counts were conducted each sample day for a total of 45 counts at each site.

APPENDIX C: ANALYSIS OF OBSERVER-BASED MEASUREMENT ERROR

Precise and accurate measurements of environmental conditions can be difficult due to biases associated with observer errors that can be compounded by normal fluctuations in physical and biological conditions. This problem includes repeatability of sampling within and between observers (Platts et al. 1983). The inability to repeat a procedure that defines a measurement can lower precision; for example, when measuring bank edge, an observer may not consistently locate the reference points that define the measurement, thus obtaining different measurements when the bank may not have changed at all.

Subjective observations most often provide low precision. Factors that 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). In the 1998 Kenai River habitat project, personnel had mixed educational backgrounds, were provided short training that evolved with the field season, and used relatively good equipment. In 1999 and 2000, the majority of field personnel returned to the project, which improved consistency in data collection.

During the 2000 Kenai River habitat project, we conducted measurement error analyses on the bank edge measurements and the trampled vegetation assessment.

Methods

Bank Measurements

Reader variability was estimated for distance-to-bank measurements taken from the benchmark at 26 habitat survey sites. Using established protocol, 4 readers each obtained a measurement from the benchmark at each site during the normal bank sampling schedule; 2 of the readers each took a second measurement at a later time for a total of 6 measurements at each site. Rather than taking all 6 measurements at the same time, we felt that measurement error would be more representative if crewmembers returned to each site after a week or more had elapsed. This was intended to reduce the ability of crewmembers to remember site characteristics previously used to identify the bank edge for measurement. Between-reader variability, the difference in reader *i*'s measurement at site *j* during sample *k* and the average of all other measurements at site *j*, was estimated as follows:

$$BR = \frac{\sum_{j=1}^{n_j} \left(\frac{\sum_{m=1}^{n_{m(j)}} \left(\left| R_{ijk} - \overline{R}_j \right| \right)}{n_{m(j)}} \right)}{n_j} \qquad \text{(C1)}$$

where

BR = between-reader variability,

R_{ijk} = measurement by reader i at site j on sample k,[1]

$\overline{R}_j$ = average of all measurements at site j,[2]

$n_{m(j)}$ = number of measurements m at site j (= 6),[3]

n_j = number of sites j (= 26).

Within-reader variability in bank measurements was also determined:

$$WR_i = \frac{\sum_{j=1}^{n_j}\left(\frac{\sum_{k=1}^{n_k}\left(\left|R_{ijk} - \overline{R}_{ij}\right|\right)}{n_k}\right)}{n_j} \tag{C2}$$

where

WR_i = within-reader variability for reader i,

R_{ijk} = bank measurement by reader i for site j on sample k,

$\overline{R}_{ij}$ = average measurement over all samples by reader i for site j,

n_k = number of samples k (= 2),

n_j = number of sites j (= 26).

Percent errors of both between- and within-reader variability were determined similarly. For example, between-reader percent error (BRE) was determined as follows:

$$BRE = \frac{\sum_{j=1}^{n_j}\left(\frac{\sum_{i=1}^{n_{m(j)}}\left(\frac{\left|R_{ijk} - \overline{R}_j\right|}{\overline{R}_j}\times 100\right)}{n_{m(j)}}\right)}{n_j} \tag{C3}$$

---

[1] Editor's note: P. Hansen (personal communication, 2015) states that using R_{ijk} is incorrect and that the calculation should have used $\overline{R}_{ij}$, the average of the samples k of each reader i at site j. However, due to this error, the estimate of between reader variability is biased high and therefore cannot underrepresent the variability.

[2] Editor's note: P. Hansen (personal communication, 2015) states that the average measurement at site j was incorrectly calculated as the average of all 6 measurements and should have been calculated as the average of each reader's average measurement (i.e., 4 measurements, 2 of which were the average of 2 measurements).

[3] Editor's note: P. Hansen (personal communication, 2015) states that the sum should be over the number of readers (4) rather than the number of measurements (6).

Vegetation

Measurements of cover class (and therefore, the effect of trampling on vegetation) were determined from photographs by 1 reader. To measure variability in the reader's estimates of percent cover, 16 photographs (8 from herbaceous sites and 8 from shrub-herbaceous sites) were randomly selected from 94 pre- and postfishery habitat site photographs (2 photo plots were unreadable) and then evaluated for percent cover in random order, and then randomized again and evaluated a second and a third time. Absolute measurement error within a reader for each cover class was measured for 1 reader with 3 photo trials as follows:

$$WRE_i = \frac{\sum_j \left(\frac{\sum_k \left(\frac{\left| R_{ijk} - \overline{R}_{ij} \right|}{\overline{R}_{ij}} \times 100 \right)}{n_k} \right)}{n_j} \tag{C4}$$

where

WRE_i = within-reader measurement error for reader *i*,

R_{ijk} = measurement of percent cover for cover class by reader *i* for site *j* on trial *k*,

$\overline{R}_{ij}$ = average measurement over all trials by reader *i* at site *j*,

n_k = number of trials *k* (= 3),

n_j = number of sites *j* (= 16).

Results and Discussion

Bank Measurements

Within-reader variability for each technician in locating the bank edge was estimated as follows:

Technician	Bank measurement variability (cm)	Percent error
1	8.2	1.2
2	7.1	1.1
3	2.2	0.4
4	1.8	0.4
Average	4.8	0.8

The average within-reader variability in bank measurements over all readers was 4.8 cm, similar to 1999 (4.9 cm; King and Hansen 2002). The average percent error was 0.8, also similar to 1999 (1.0%; King and Hansen 2002).

The between-reader variability was estimated to be 4.7 cm with a 0.8 percent error. Both estimates are similar to the 1999 estimates (4.7 cm and 1.1 percent error; King and Hansen 2002).

In all cases, the average bank measurement variability was less than 5 cm and the average percent error less than 1.2. The low reader error and consistency of the measurements is largely due to 2 things: 1) having returning personnel who were trained and familiar with the methodologies, and 2) implementing procedures for better identifying the bank edge location used for taking the measurement (i.e., placement of the nail markers).

Vegetation

Estimates of within-reader measurement error for each cover class are as follows:

	Average measurement error (percentage points)			
Cover class	1997	1998	1999	2000
Vegetation	6.9	6	4.5	4.4
Litter	27.3	23.1	18.7	26.4
Bare ground	44.7	29	22.1	20.5
Water	0	0.6	1.3	1.8

Within-reader error for the 3 main cover classes (vegetation, litter, and bare ground) has decreased steadily since 1997. The most marked improvement has been associated with bare ground (from 45% to 21%). During photo imagery analysis, pixels are assigned to each cover class in a specified order. The protocol recommends assessment of vegetation first and bare ground last. Once the number of pixels for vegetation, litter, and water have been assigned, bare ground is calculated by subtracting the sum of those from the total number of pixels for the photo. This method has been shown to bias the estimate of percent bare ground higher and likely makes it more variable than other estimates because it is dependent upon pixel assignment to the other cover classes. Within-reader error for water and vegetation coverage were lower due to the ease in discerning these cover types. Separating litter from bare ground can be highly subjective when using color enhancement, increasing variability in the estimate. In the photo imagery process described by Dietz and Steinlein (1996), litter and bare ground were lumped together. To assess effects of trampling, it is necessary to separate the 2 cover classes even though the misclassification between the 2 cover classes is relatively high.