Fishery Data Series No. 15-34

Assessment of Shore Angling Impacts to Kenai River Riparian Habitats, 2001

by

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and

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October 2015

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

Symbols and Abbreviations

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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

Effects of shore anglers on bank erosion and vegetation in Kenai River riparian habitats were assessed during the 2001 fishing season. The mean number of anglers counted in each of 40 survey sites varied from 0 to 7.3, and angler effort at these sites ranged from 0 to 2,784 angler-hours. Changes in bank position were measured annually from 1998 to 2001 and analyses for cumulative effects of angler effort (1998–2000), powerboat activity level, stream meander, and habitat type on bank loss (1998–2001) showed a significant effect for angler effort (P < 0.001); increased bank loss was associated with increased angler effort. Inseason angler effort had a significant effect on mean change in percent cover of vegetation (negative relationship) and water (positive relationship). There was no significant effect of cumulative angler effort (1998–2000) on changes in percent cover (1999–2001) in litter, but there were marginally significant effects on changes in percent cover of vegetation (negative relationship) and bare ground (positive relationship) and a significant effect of angler effort on the percent cover of water (positive relationship). Species composition analyses using Shannon diversity and evenness indices showed that there were significant effects of cumulative angler effort (1998–2000) on plant species diversity and evenness (1997–2001); both significantly decreased with increased angler effort. The cover of grasses, dandelions, and horsetails (*Calamagrostis* spp., *Taraxacum* spp., and *Equisetum* spp., respectively) was assessed for 1997 to 2001. Sites with high levels of angler effort (>800 angler-hours) had a mean loss in percent cover of grasses (2.3%) and a mean increase in percent cover of dandelions (3.6%) and horsetails (8.6%). At sites with low levels of angler effort (<150 angler-hours), there was a small increase in percent cover for all 3 species (<5%).

Key words: Kenai River, shore anglers, riparian habitat, habitat assessment, trampling, angler impacts, bank erosion, vegetation assessment, vegetation cover, plant diversity, plant evenness.

INTRODUCTION

BACKGROUND

The Kenai River (Figure 1) supports the largest freshwater sport fishery in Alaska with estimated angler-days of effort exceeding 358,000 in 2000 (Walker et al. 2003). Fishing effort occurs throughout the mainstem of the river but primarily occurs during a relatively short period (mid-May through August) downstream from Skilak Lake. Targeted species include Chinook salmon (*Oncorhynchus tshawytscha*), coho salmon (*O. kisutch*), sockeye salmon (*O. nerka*), pink salmon (*O. gorbuscha*), resident rainbow trout (*O. mykiss*), and Dolly Varden (*Salvelinus malma*).

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).

On the Kenai River, most anglers fish for sockeye salmon from riverbanks or while standing in the river 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.

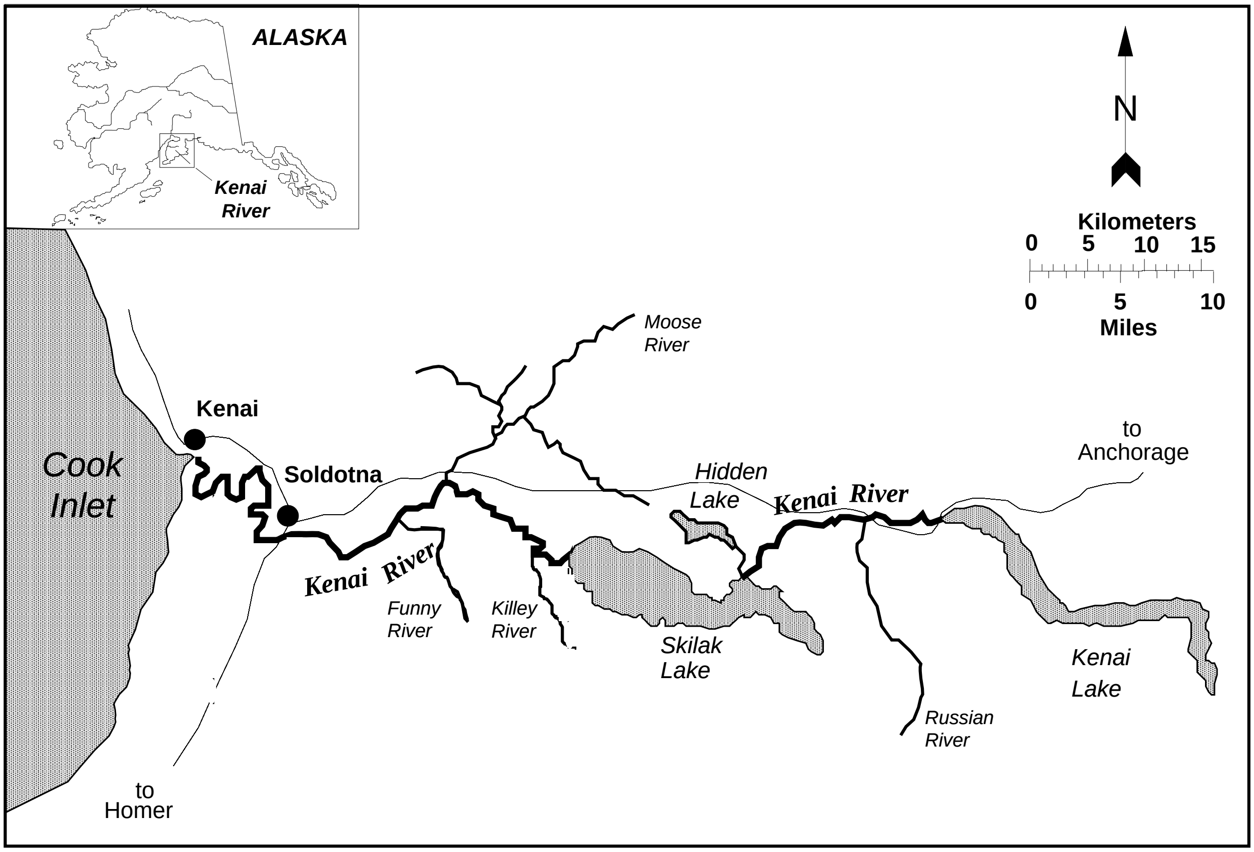
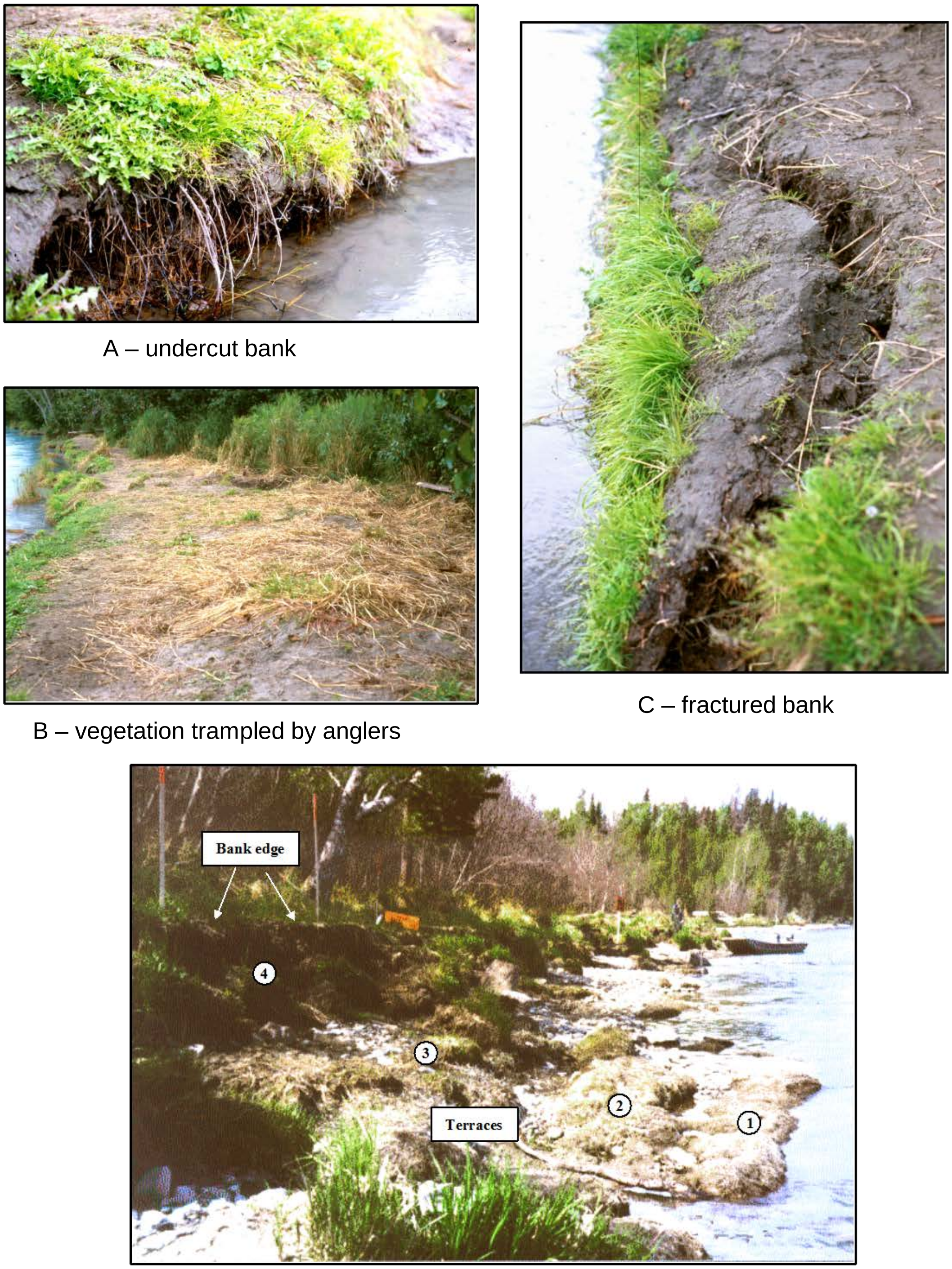


Figure 1.–Map of the Kenai River showing river reaches in which angler effort counts were conducted.

Shore anglers may negatively affect riparian and fish habitat by trampling and denuding vegetation, accelerating erosion of riverbanks. Natural erosion involves the undercutting of the bank by tractive energy of the river (Figure 2A), which leads to the bank rolling over, slumping, and eventually calving into the river (Waters 1995) (Figure 2C–D). This process may be accelerated by human activities such as increased boat wake energy to the riverbank (Scott 1982; Barrick 1984; Reckendorf 1989) and by increased activity (angling) on top of the riverbank, leading to a denuded riverbank (Figure 2B).

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.

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, BOF created the Riparian Habitat Fishery Management Plan (RHFMP) (5 ACC 56.065; Appendix A1). Within the RHFMP, BOF recognized the importance of maintaining the structural and functional integrity of riparian habitats and that freshwater fisheries can negatively impact them. To help mitigate this, 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.



A – undercut bank

B – vegetation trampled by anglers

C – fractured bank

D – terraced river bank (below ordinary high water)

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

During the 1999 BOF meetings, the Late Run Sockeye Salmon Management Plan was modified, resulting in another increased allocation of sockeye salmon to the Kenai River inriver sport fishery, but it also added specific language regarding riparian habitats (5 AAC 21.360; Appendix A2). This language specified that the increased allocation of sockeye salmon would be reconsidered if damage to riparian habitats occurred due to increased shore-based angling. It also made changes related to increased bank erosion resulting from boat wakes, providing for a drift-boat-only fishery to occur on Mondays in July and in 2000, implementing a regulation reducing the number of passengers in guided boats from 6 to 5 (guide plus 4 clients). Both of these changes 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 impacts to Kenai River riparian habitats and report the findings at the next regularly scheduled Cook Inlet regulatory meeting. In February 1999, ADF&G presented a report to the BOF detailing the difficulties in assessing shore angler impacts to juvenile fish habitat in riparian areas during 1996–1998 despite trying several methodologies (Larson and McCracken 1998; King and Hansen 1999). In 1998, ADF&G measured changes in bank position (King and Hansen 2001), and this 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 impacts 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 natural riverbank erosion and alter riparian habitat and whether anglers have long-term negative effects on riparian habitat.

OBJECTIVES

The primary goal of this project in 2001 was to assess the effects of shore anglers on changes in bank position and vegetative cover. Specific objectives were as follows:

1) Estimate total angler effort (in angler-hours) at selected sites throughout the mainstem Kenai River downstream of Skilak Lake.
2) Test the hypothesis that there is no linear relationship between angler effort and bank loss against the alternative that there is a positive relationship.
3) Estimate inseason (before and after the sport fishery for late-run sockeye salmon) and cumulative (June 1998 to June 2001) changes in percent cover by cover class at 12 sites located on the mainstem Kenai River downstream of Skilak Lake.
4) Test the hypothesis that there is no linear correlation between angler effort and cumulative change in percent cover of vegetation by cover class.

Other tasks were as follows:

1) Test the hypothesis that the mean bank loss is the same among habitat types (herbaceous vs. shrubland-herbaceous).
2) Estimate changes in vegetation diversity and evenness between years (1997–2001) at 12 sites located on the mainstem Kenai River downstream of Skilak Lake and test for a relationship with angler effort.

METHODS

The study area encompassed the Kenai River from its outlet at Skilak Lake to the Warren Ames Bridge.

BANK CHANGE AND ANGLER EFFORT

To test whether there was a relationship between shore angler effort and bank loss, 40 bank survey sites (21 herbaceous and 19 shrubland-herbaceous; Appendix B1) were selected for intensive measurements of bank position and estimates of angler effort. These are referred to as “angler-effort sites.” Most of these sites were originally selected in 1998 (King and Hansen 2001), but some sites were removed from study due to bank closures or stabilization projects, which changed the attributes of the sites, and some sites were added in 1999 to account for this (Appendix B1). The 2 macrohabitat types (herbaceous and shrubland-herbaceous) were selected from a total of 5 categories, including forest, shrubland, and disturbed[1] (King and Hansen 2001), because they may be more sensitive to angler traffic. For each macrohabitat type, sites were randomly selected such that varying levels of angler use (low, medium, high; previously determined from King and Hansen 2001) were represented. Boat activity level 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 of meander, outside of meander, or straight channel. Each site included 30 linear meters of riverbank and was flagged at the upstream and downstream boundaries to assist in identifying the sites. Bank measurements were taken in June before the fishery began (prefishery).

Bank Change

The previous protocol for obtaining bank measurements (King and Hansen 2001-2002) was modified in 2001 because the survey equipment was upgraded from a basic surveyor’s transit to an electronic total station with laser capabilities for distance measurement. The 2001 protocol was as follows: the total station was plumbed to a previously placed benchmark, sited to a previously placed backup mark, and then turned 180°, siting to the riverbank. A technician at the bank edge located a previously placed bank edge marker nail and placed a stadia rod with a prism on the bank edge in line with the marker nail and the benchmark (Figure 3). The technician operating the total station sited the prism and initiated an EDM (electronic distance measurement) for the horizontal distance, which was recorded. Following a previously established transect (King and Hansen 2001), 10 more measurements to the riverbank were obtained over a 30-meter distance (Figure 3). These were obtained using the total station to find the distance from the benchmark to a stake on the transect (d_1) and to the respective bank edge (d_2), and then allowing the instrument to calculate the third side of the triangle (D_3), which was the distance from the particular stake to the bank edge. For repeatability in measurements between sampling periods, crewmembers continued to place a 6-inch nail near the top edge of the riverbank using the designated protocol (King and Hansen 2002).

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[1] Forest: 10–100% tree cover. Shrubland: 25–100% shrub cover, less than 10% tree cover, shrubs greater than 5 ft in height. Shrubland/herbaceous: 25–100% shrub cover, less than 10% tree cover, shrubs less than 5 ft in height. Herbaceous: over 5% herbaceous cover, shrub cover less than 25%, tree cover less than 10%. Disturbed: 50% or greater of the area characterized by human perturbations.

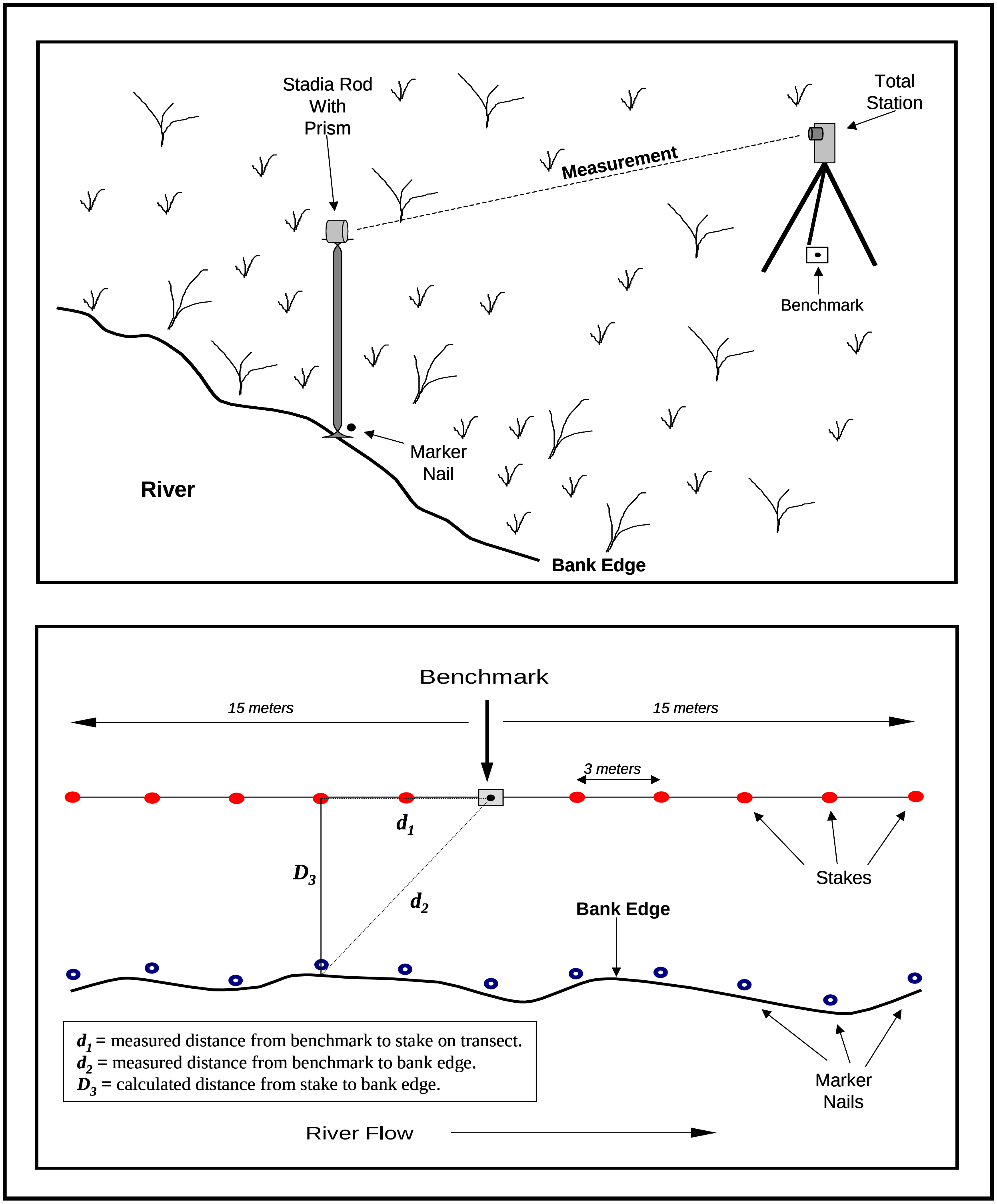

Figure 3.–Schematics for taking measurements from benchmark to bank (top) and along the transect to bank (bottom).

For each of the 40 sites, mean change in bank position was estimated as follows:

$$\overline{\Delta}_z = \frac{\sum_{i=1}^{n} \Delta_{zy}}{n_z} \tag{1}$$

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.

An analysis of observer-based measurement error was done for the 2001 bank measurements (Appendix C1). We have been conducting observer measurement error tests since 1999. For previous years, the observer-based measurement error was approximately 0.05 m, but with the equipment change in 2001 the measurement error was decreased to less than 0.02 m. Therefore, the bank was considered unchanged if the difference between years was within ±0.02 m.

Angler Effort

During the sport fishery for late-run sockeye salmon, angler effort for each sample day was estimated for each of the 40 sites specified above. A sample day consisted of a 16-hour period (0600–2200 hours). Counts were conducted systematically, commencing on 9 July and occurring every third day thereafter through 30 July. Five counts of shore anglers 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 using 2 motorized boats with 1 technician per boat. Each technician was responsible for conducting angler counts in an assigned river section: the outlet of Skilak Lake to Morgan’s Landing (RM 50–31) or Morgan’s Landing to Warren Ames Bridge (RM 31–5). Each boat was driven past the flagged survey sites in the assigned section and the number of shore anglers was recorded at each site at the moment of encounter. 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. Technicians entered data into a spreadsheet.

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

$$\hat{E} = \sum_{d=1}^{D} (\overline{c}_d \times \mathrm{ahd} \times \mathrm{sr}) \tag{2}$$

where

$$\overline{c}_d = \frac{\sum_{p=1}^{n_d} c_{dp}}{n_d} \tag{3}$$

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:

$$V(\hat{E}) = \left(1 - \frac{D}{3D}\right)\left(3D^2\right)\frac{\sum_{d=2}^{D}\left(\hat{E}_d - \hat{E}_{d-1}\right)^2}{2D(D-1)} + \frac{3D}{D}\sum_{d=1}^{D} v\left(\hat{E}_d\right) \tag{4}$$

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

$$v(\hat{E}_d) = v(\bar{c}_d)(\text{adh})^2 \tag{5}$$

and

$$v(\bar{c}_d) = \frac{\sum_{p=2}^{n_d}\left(c_{dp} - c_{d(p-1)}\right)^2}{2n_d\left(n_d - 1\right)}. \tag{6}$$

Effects of Angler Effort on Bank Change

An analysis of variance was used to test if 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:

$$\Delta_{ijkl} = \mu + \beta_i + \alpha_j + \phi_k + \lambda_l + \varepsilon_{ijkl} \tag{7}$$

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 level and the *l*th level of meander,

μ = overall mean,

β_i = the effect of the *i*th estimate of angler effort from the previous year,

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, and

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.

Simple linear regression was used to test for a significant linear relationship between cumulative angler effort (sum of effort estimates for 1998–2000) and cumulative mean change in bank position (2001 measurement minus mean for baseline measurement). The following model was used:

$$Y_i = \delta + \eta x_i + \varepsilon_i \tag{8}$$

where

Y_i = change in distance from a benchmark to the riverbank (postfishery distance minus prefishery distance),

δ = the intercept

η = the rate of change, and

x_i = the estimated angler effort at site *i*.

TRAMPLING AND ANGLER EFFORT

To assess the impact of bank trampling by anglers, a vegetation analysis was conducted on photos of 4 permanently marked vegetation plots located along a transect at each of 11 angler-effort survey sites (6 herbaceous and 5 shrub-herbaceous). For each macrohabitat type, sites were selected based on levels of angler use from historical (1995–1996) angler count data (King and Hansen 2001) and field inspection. Sites with little or no human use (low: 0–3 anglers) were defined as being pristine. All other sites were categorized into moderate or high angler use (4–11 anglers and more than 11 anglers, respectively). High-use areas within parks, waysides, and campgrounds, which receive substantial human activity for reasons other than angling, were not considered. The location of the survey sites (originally 12 in all), the 150-foot transect within each site, and the 4 permanently marked vegetation plots (48 inches × 30 inches) along each transect are described in King and Hansen (1999). One shrub-herbaceous site was excluded from the study in 2001 due to bank stabilization activities that had affected the vegetation plots. The study plots have been photographed annually in late June and mid-August (before and after the late-run sockeye salmon sport fishery) since 1997.

The protocol for locating and photographing the vegetation plots is described in King and Hansen (2001). Photos were cataloged by habitat survey site, plot, and date. The photos were scanned postseason and the computer images were analyzed using Adobe Photoshop[2] software following the protocol for photo imagery analysis outlined by Dietz and Steinlein (1996).

Change in Percent Cover by Cover Class

Percent cover for each vegetation plot within site *z* was estimated for each of 4 cover classes (vegetation, litter, bare ground, and water) and a mean percent cover (of the 4 plots) was determined for each site *z*. 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 pre- and postfishery time periods. The following model was used:

$$\Delta_{ijz} = \mu + \beta_i + \alpha_j + \beta\alpha_{ij} + \varepsilon_{ijz} \tag{9}$$

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

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 vegetation recovery from cumulative angler impacts (1998–2000), a repeated measures design was used to test if angler effort had a significant effect on the mean percent cover for each cover class (vegetation, litter, bare ground, water):

$$Y_{ijz} = \mu + \alpha_j + \gamma(\alpha)_{jz} + \beta_i + \varepsilon_{ijz} \tag{10}$$

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.

Changes in Plant Species Diversity and Evenness

Using the same protocol for estimating change in percent cover by cover class, we also estimated mean (from 4 plots) percent cover by plant species for each site for June 1997 and June 2001. For each site, we then calculated species diversity for each site using the Shannon diversity index (see Kent and Coker 1997):

$$H' = -\sum_{i=1}^{S} p_i \log p_i \tag{11}$$

where

S = total number of species at each site,

p_i = abundance of the *i*th species expressed as a proportion of total mean covers of all species at each site, and

log = log base 10.

To estimate the change in species diversity between years, we calculated the change in indices:

$$\Delta H' = H'_{June\ 2001} - H'_{June\ 1997} \tag{12}$$

where H' is the species diversity for each site in a particular year.

Twelve habitat survey sites were divided into 2 groups (low: less than 150 angler-hours versus high: greater than 800 angler hours) based upon the cumulative level of angler effort between 1998 and 2001 (Table 1). A parametric *t*-test was used to compare the change in diversity between the low and high effort sites.

Table 1.–Cumulative effort (1998–2001) at low and high effort sites used to test for differences in species diversity.

Low effort sites		High effort sites	
Site	Cumulative effort	Site	Cumulative effort
Patson	0	Airport	895
SNA	19	Swiftwater2	1,080
Sonar	84	KNA1	1,287
Moose	146	Swiftwater1	1,790 [a]
		Centennial	2,110
		Slikok2	2,191
		Slikok1	2,443
		KNA2	2,599

Source: Cumulative effort is calculated from 1998 data from King and Hansen (2001), 1999 data from King and Hansen (2002), and 2000 data from King and Hansen (2015).

[a] This site was removed from analysis due to bank stabilization in 2001.

Using the estimates of mean percent cover (from 4 plots) by plant species at each site, we calculated the plant species evenness index (see Kent and Coker 1997) for each site for June 1997 and June 2001:

$$J = \frac{\sum_{i=1}^{s} p_i \log p_i}{\log s} \tag{13}$$

where

S = total number of species at each site,

p_i = abundance of the *i*th species expressed as a proportion of total mean cover of all species at each site, and

log = log base 10.

Analysis of species evenness was identical to the analysis of species diversity.

Grass (*Calamagrostis spp*.), dandelions (*Taraxacum officiniale*), and horsetails (*Equisetum spp.*) are 3 widespread plant species at the survey sites and using the mean percent cover at each site, we assessed changes in mean percent cover for these species (June 1997–June 2001) by level of angler effort (low: less than 150 angler-hours versus high: greater than 800 angler-hours).

RESULTS

BANK CHANGE AND ANGLER EFFORT

Bank measurements were collected at 40 survey sites during June 2001. Site characteristics and bank change measurements (Δ_{ijkl}) for each site are listed in Appendix B1. The mean change in bank position from June 2000 to June 2001 ranged from a gain of 0.02 m to a loss of 0.54 m and averaged a loss of 0.11 m. Individual distance measurements from the transect line to the riverbank ranged from a gain of 0.21 m to a loss of 1.68 m. Twenty-two survey sites had individual distance measurements exceeding a loss of 0.20 m. While taking measurements at these sites, the crew visibly identified new calving at 15 of these sites. In 2001, 4 of the 40 survey sites had a mean change within ±0.02 m (Appendix B1). Therefore, these sites were considered unchanged.

We conducted 5 angler counts on each of 8 count days between 9 July and 30 July at each angler-effort site for a total of 40 angler counts per site (Appendix B2). The last 3 scheduled count days (2, 5, and 8 August) were not done because the sockeye salmon sport fishery was closed by Emergency Order on 1 August.

The mean daily counts of anglers by site ranged from 0 to 7.3, and estimates of angler effort at these sites during this period ranged from 0 to 2,784 angler-hours (Appendix B2). Angler-hours of effort exceeded 1,300 at 2 sites (R25.5 had 1,373 angler-hours and L17.0 had 2,784 angler-hours). Angler use of site R25.5 was uniquely different from other sites because the property is corporately owned with access primarily limited to employees during the sport fishery. A security officer was onsite to insure that all anglers fished while standing in the water. Because of these unusual circumstances, data from this site were considered biased and the site was excluded from analyses. Site L17.0 also experienced high levels of angler use but was not excluded from the 2001 analyses because there were no extenuating circumstances regulating angler behavior at this site.

There was a significant effect of angler effort on mean bank change (Table 2). Regression analysis showed increasing bank loss with increasing angler effort (Figure 4), but there were no significant effects for stream meander, habitat type, or powerboat activity on change in mean bank position (Table 2). Mean bank loss was greatest on the outside of a meander (−0.17 m) versus the inside of a meander (−0.04 m) or no meander (−0.05 m), as would be expected, but it was not significant. Mean bank loss was greater for shrub-herbaceous habitat (−0.13 m) versus herbaceous habitat (−0.04), but the relationship between habitat type and bank change was not significant. Bank loss was greater in areas of high powerboat activity (−0.27 m) versus areas of low powerboat activity (−0.06 m), although this was not significant. However, the small number of sites with high powerboat activity (5 high sites vs. 34 low sites) may have affected the power of the test.

Table 2.–Multivariate analysis of variance for effects of habitat type, stream meander, powerboat activity level, and cumulative shore angler effort (1998–2000) on mean change in bank position (1998–2001), Kenai River.

	Analysis of variance						
Source	df	Mean square	*F* value	*P>F*	Main effects	Sample size	Mean [a] (meters)
Habitat type	1	0.02	0.61	0.44			
					Herbaceous	21	-0.04
					Shrub/herbaceous	18	-0.13
Stream meander	2	0.03	0.89	0.42			
					None	18	-0.05
					Inside	10	-0.04
					Outside	11	-0.17
Boat activity level [b]	1	0.06	1.83	0.19			
					Low	34	-0.06
					High	5	-0.27
Angler effort (1998–2000)	1	0.98	29.37	<0.001		39	

[a] Mean change in mean bank position.

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

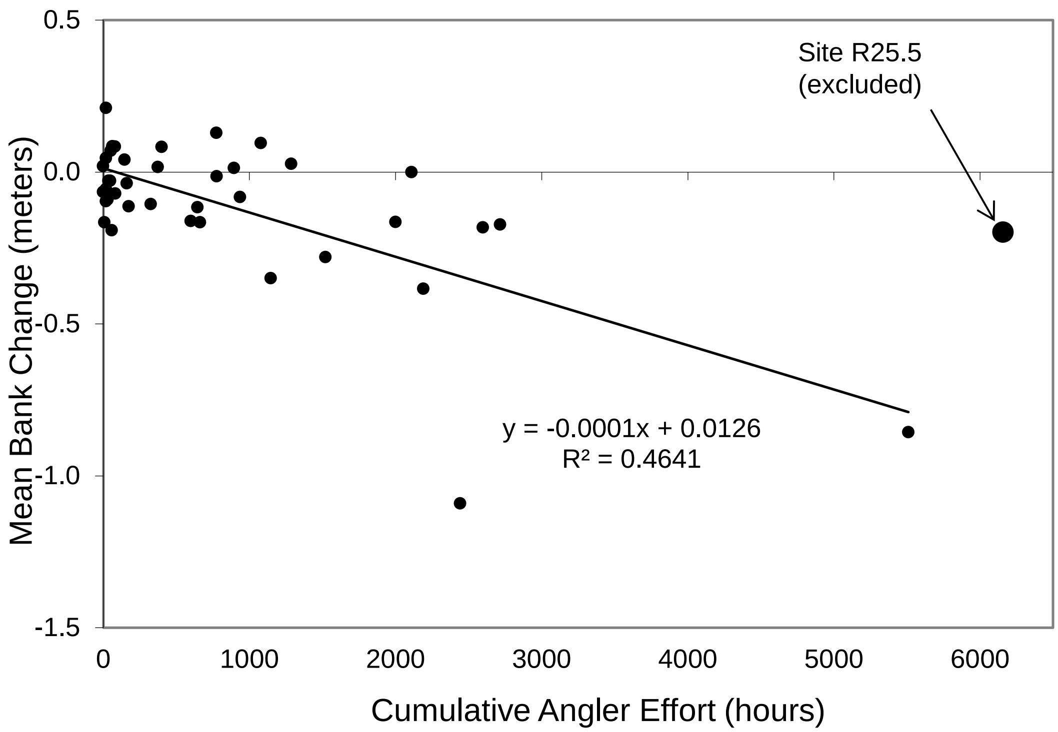

Figure 4.–Regression of cumulative angler effort (1998–2000) with mean change in bank position (August 1998–June 2001) at angler-effort survey sites, Kenai River.

TRAMPLING AND ANGLER EFFORT

Changes in Percent Cover by Cover Class

Trampling of vegetation near the riverbank was evaluated by examining vegetation plot photographs and assessing changes in percent cover for broad cover classes: vegetation, litter, bare ground, and water. Results for the 2001 inseason (pre- and postfishery) multivariate analysis of variance showed that estimated angler effort had a significant effect on the change in mean percent cover of vegetation (P = 0.05) and water (P < 0.01) (Table 3). Further analysis (regression, y = change in percent cover, x = cumulative angler effort) showed increasing angler effort resulted in a decrease in cover of vegetation and an increase in cover for water (Figure 5).

To assess cumulative changes resulting from angler foot traffic, we used a repeated measures analysis of variance with nested design to analyze the relationship between cumulative angler-effort estimates (1998–2000) and percent cover (vegetation, litter, bare ground, and water) from June 1999 to June 2001. Results showed no significant effect of cumulative angler effort on percent cover of litter (Table 4). There was a marginally significant effect (P = 0.06) of cumulative angler effort on percent cover of vegetation and bare ground and a significant effect on percent cover of water. Further analysis (regression, y = change in percent cover, x = cumulative angler effort) showed increasing cumulative angler effort was associated with decreasing percent cover of vegetation and increasing percent cover of bare ground and water (Figure 6).

Table 3.–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, 2001.

Change in percent cover	Source	P>F
Vegetation		
	Estimated angler effort	0.05
	Habitat type	0.08
	Interaction	0.51
Bare ground		
	Estimated angler effort	0.15
	Habitat type	0.70
	Interaction	0.13
Litter		
	Estimated angler effort	0.17
	Habitat type	0.55
	Interaction	0.51
Water		
	Estimated angler effort	<0.01
	Habitat type	0.05
	Interaction	<0.01

Table 4.–Analysis for effect of cumulative effort (1998–2000) on cumulative changes in percent cover by cover class (June 1999–June 2001).

Change in percent cover	Source	df	Mean square	F-value	Pr > F
Vegetation					
	Habitat type	1	1731.08	1.47	0.25
	Site (habitat type)	10	1181.13	1.50	0.18
	Cumulative effort	1	373.94	3.60	0.06
Litter					
	Habitat type	1	5.26	0.02	0.90
	Site (habitat type)	10	287.90	3.41	0.00
	Cumulative effort	1	0.36	0.01	0.92
Bare ground					
	Habitat type	1	988.30	2.18	0.17
	Site (habitat type)	10	454.12	1.77	0.10
	Cumulative effort	1	187.76	2.89	0.09
Water					
	Habitat type	1	205.05	0.59	0.46
	Site (habitat type)	10	345.82	2.27	0.04
	Cumulative effort	1	1048.25	6.94	0.01

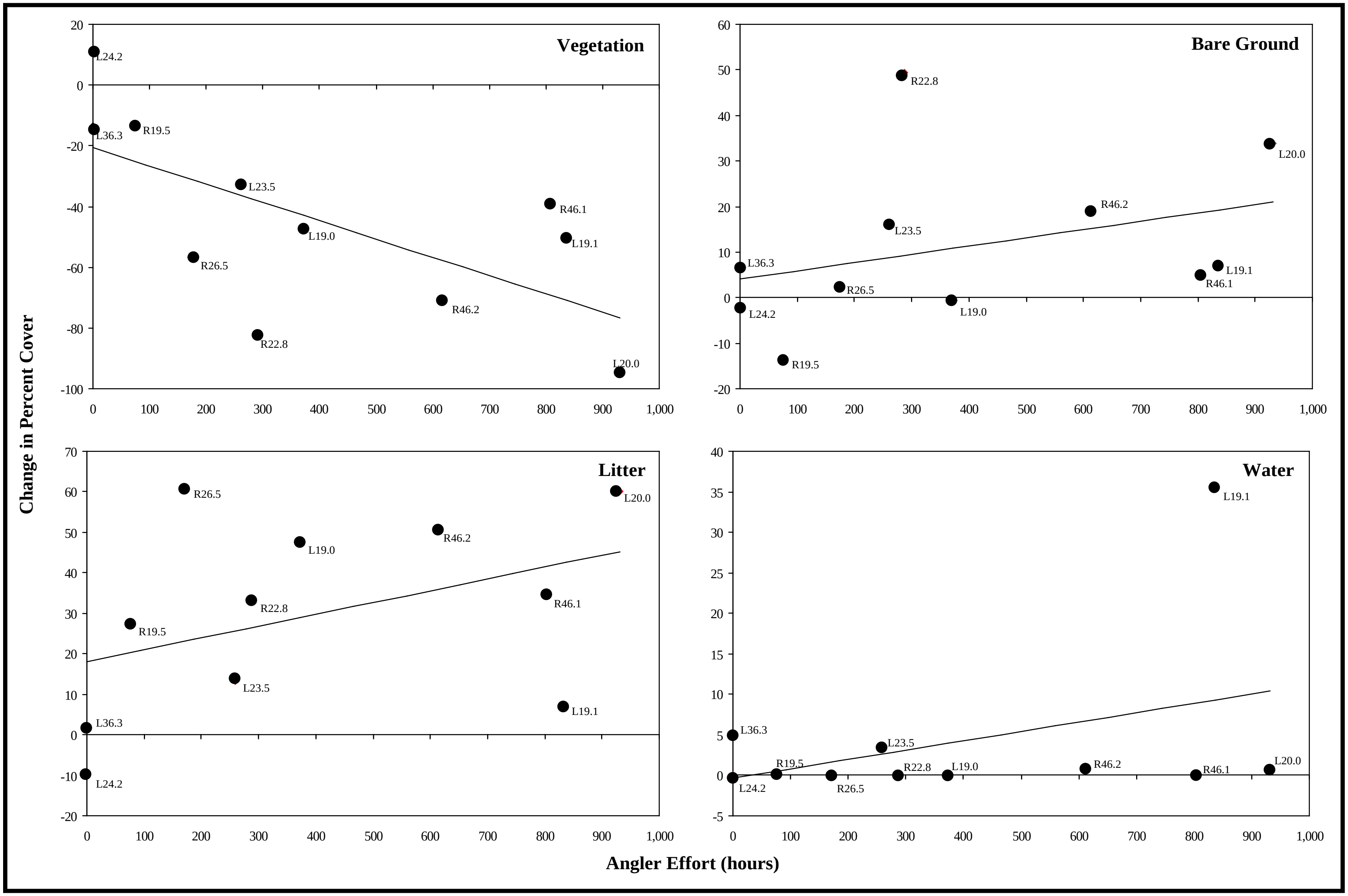

Figure 5.–Angler effort versus mean change in percent cover (postfishery minus prefishery) for vegetation, bare ground, litter, and water percent cover for permanent vegetation plots (n = 11), Kenai River, 2001.

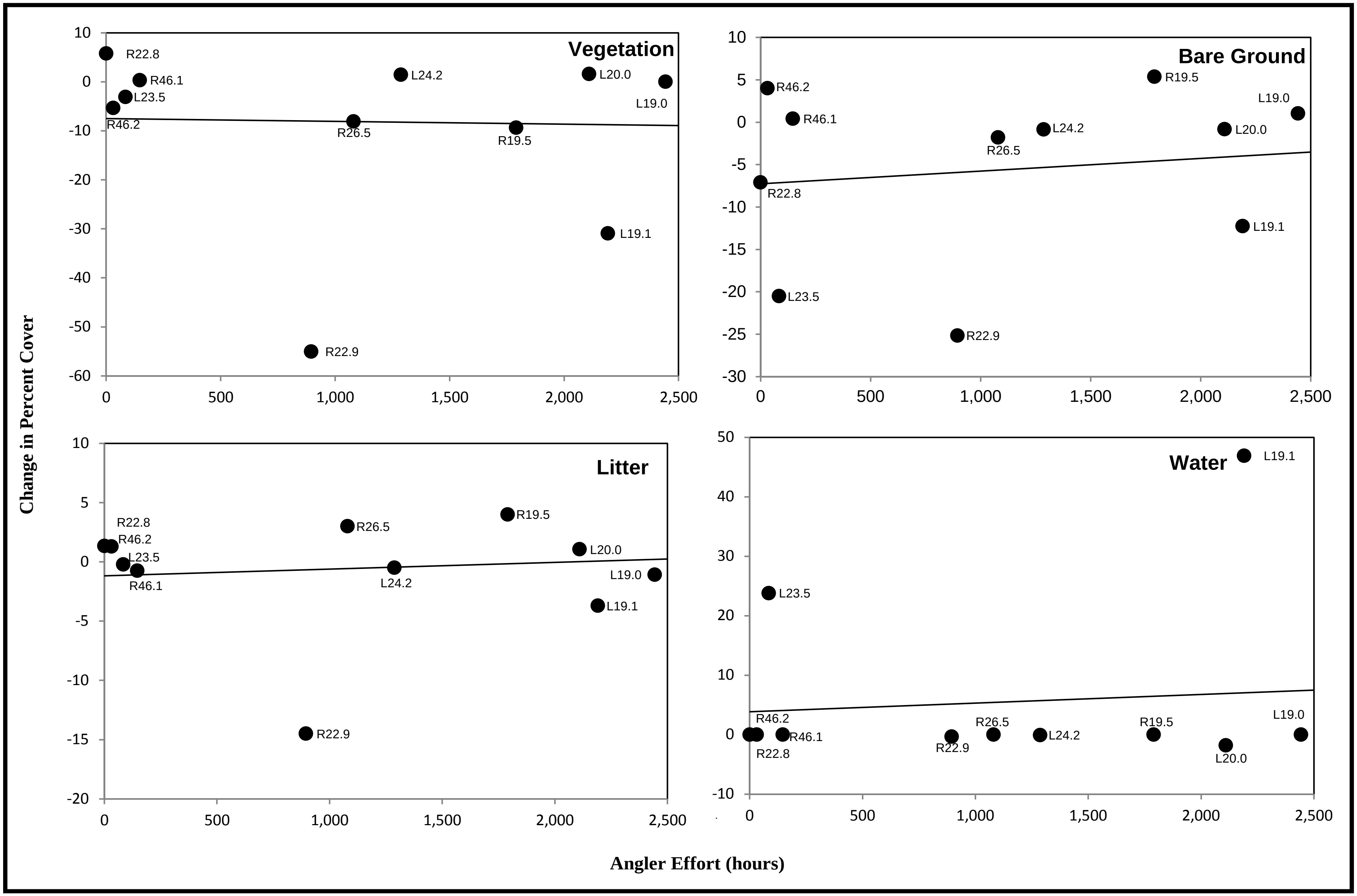

Figure 6.–Cumulative angler effort (1998–2000) versus mean change in percent cover (June 1999–June 2001) of vegetation, bare ground, litter, and water for permanent vegetation plots (n = 11), Kenai River.

Changes in Plant Species Diversity and Evenness

We used a 2-sample *t*-test to test for effects of cumulative angler effort (1998–2000) on changes in plant diversity and evenness between June 1997 and June 2001. (Note: because we did not estimate angler effort in 1997, the analysis compared 3 seasons of effort with 4 seasons of plant species assessment.) There was a significant decrease in species diversity ($t = -2.70$, $P = 0.012$) and evenness ($t = -2.00$, $P = 0.039$) with increased cumulative angler effort (Table 5, Figure 7). There was a mean decrease of −0.036 in the diversity index at high effort sites (greater than 800 angler-hours of effort) compared to a mean increase of 0.193 at low effort sites (less than 150 angler-hours of effort). Similarly with plant evenness, there was a mean decrease in the index (−0.004) at high effort sites compared to an increase (0.100) at low effort sites.

Table 5.–Summary statistics for change in plant species diversity and evenness from June 1997 to June 2001 by level of cumulative angler effort (1998–2000), Kenai River.

Change in index	Angler effort [a]	Number of sites	Mean	SE	Confidence interval	Index range
Diversity						
	High	8	-0.036	0.079	-0.223 – 0.150	-0.410 – 0.200
	Low	4	0.193	0.030	0.097 – 0.280	0.140 – 0.200
		Difference	-0.229	0.116	-0.488 – 0.030	
Evenness						
	High	8	-0.004	0.048	-0.118 – 0.111	-0.150 – 0.270
	Low	4	0.100	0.019	0.041 – 0.160	0.060 – 0.150
		Difference	-0.104	0.071	-0.263 – 0.055	

[a] High effort is greater than 800 angler-hours; low effort is less than 150 angler-hours.

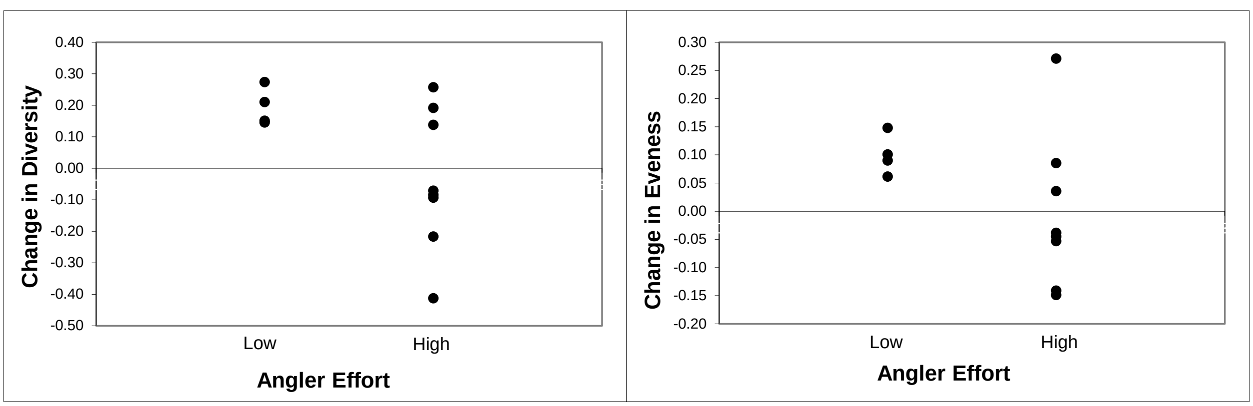

Figure 7.–Changes in plant species diversity and evenness (June 1997–June 2001) with respect to cumulative angler effort (1998–2000), Kenai River.

Note: High effort is greater than 800 angler-hours; low effort is less than 150 angler-hours.

Changes in mean percent covers for grass (*Calamagrostis spp*.), dandelions (*Taraxacum officiniale.*), and horsetails (*Equisetum spp.*) were assessed June 1997–June 2001 in habitat survey sites by level of angler effort (low: less than 150 angler-hours versus high: greater than 800 angler-hours). For low angler-effort sites, there was a small increase (<5%) in mean percent cover for all of these species (Figure 8). Sites with high levels of angler effort tended to have fewer grasses (mean loss of 8.6%) and more horsetails and dandelions. Mean percent cover for horsetails and dandelions increased by 2.3% and 3.6%, respectively.

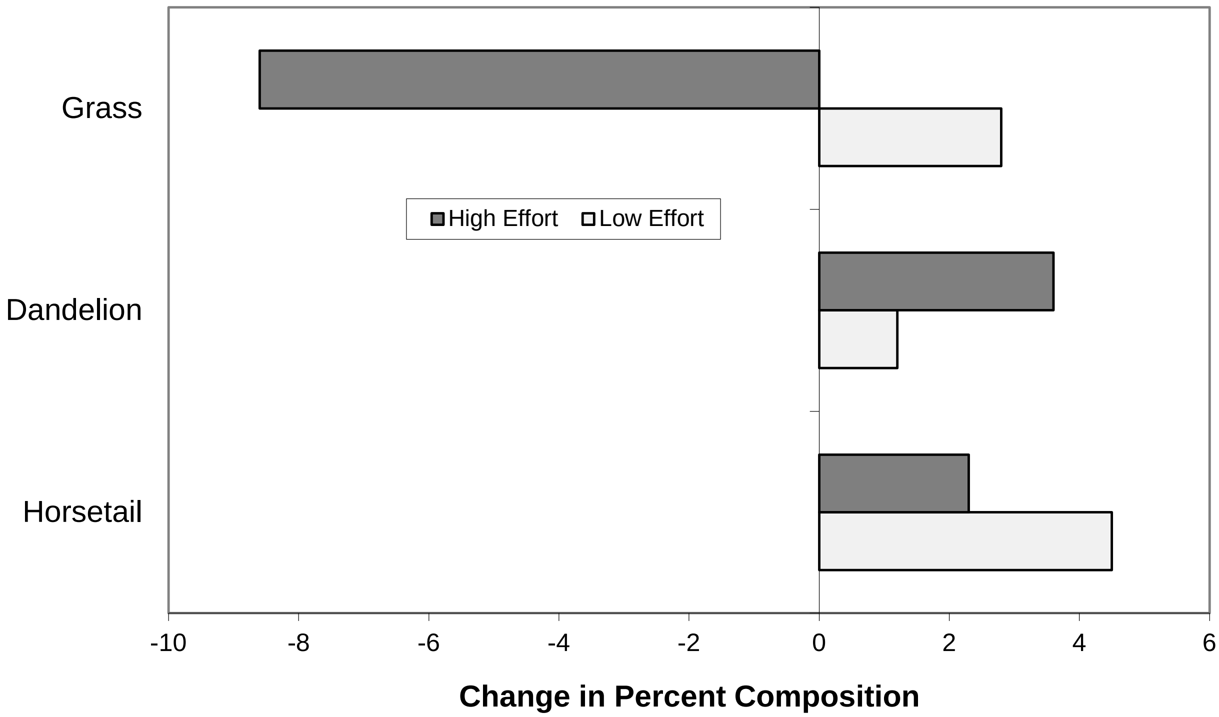

Figure 8.–Mean change in percent cover of selected plant species (June 1997–June 2001) at sites having low (<150 angler-hours) and high (>800 angler-hours) cumulative angler effort (1998–2000), Kenai River.

DISCUSSION

BANK CHANGE AND ANGLER EFFORT

Only 1 site had a positive mean bank change between June 2000 and 2001 (Appendix B1). Natural erosion can increase distance to bank edge in 2 ways: soil accretion and "rolling over." Accretion of sediments will generally occur as a result of deposition at or near the waterline rather than at the top of a defined bank. However, bank measurements were taken from the top of the bank, not near the waterline, so the likelihood of having soil accretion is small. Bank growth can also occur when the bank "rolls over" but remains attached and has not yet calved. New calving was observed at 15 of 22 survey sites that had individual distance measurements exceeding a loss of 0.20 m. Thus, it seems likely that any positive bank change indicates a site in the process of calving.

All other survey sites had a negative mean bank change. There were no significant effects of stream meander or habitat type on bank change. These indicate that natural erosion, related to tractive energy of the river and habitat type along the riverbank, was not significantly related to bank loss at these survey sites. Powerboat activity also had no significant effect on bank change; however, caution must be applied to this result due to sample size. The original selection of survey sites was determined by habitat type (20 of each) and angler use (low, medium, and high categories approximately equal in number for each habitat type). The stream meander and powerboat activity categories were assigned to each survey site once the site was selected. Coincidentally, stream meander categories were of similar sample size, but this was not the case for powerboat activity categories. However, the effect of powerboat activity may be quite small compared to angler activity. Angler impacts were significant (Table 1) and based upon the regression analysis of bank change versus angler-hours (Figure 4), the y-intercept (y = 0.0126 m) indicates very little bank change due to factors other than shore angler impacts (i.e., natural causes: stream meander, habitat type and human impacts: powerboat activity); barring these other factors, bank change is expected to be 0 cm at 0 angler-hours.

Initially, it was believed that shore angler impacts were small and that acquisition of cumulative bank measurements of bank loss would be required to show a relationship with angler effort. As the bank measurement methodology was refined, we were able to show a significant relationship for increased bank loss with increased angler effort, both annual (1999–2000 [King and Hansen 2015], 2000–2001) and cumulative (1998–2001, Table 1). The importance of these results is that the rate of bank loss versus shore angler effort is much higher than we anticipated (Figure 4).

Since the inception of this project in 1997, we have taken many photographs of the riverbanks in an effort to document change. The photos in Figure 9 were taken at site L19.1. This site receives high levels of angler use, occurs on an outside stream meander, and lies in a transition area of low to high powerboat traffic. Bank loss at this site may be a worst-case scenario, but it demonstrates how perturbations (natural and human-induced) can accelerate the rate of bank loss. The upper photo in Figure 9 shows this riverbank in June 1997. At that time, the herbaceous vegetation extended 5–15 feet from the shrub line to the bank edge. The tape measure in the next 2 photos shows the location of the transect line for vegetation sampling. This transect was located in June 1997 such that it had a 5-foot setback from the bank edge at each end. Due to the irregularity of the riverbank, the bank edge was usually greater than 5 feet from the transect. By June 2001 (lower left photo), much of the bank, including the vegetation plots, had calved into the river. For cumulative bank change at this site, we measured a loss exceeding 12 feet (4.63 m) at 1 location (Appendix B1), and a mean bank loss of about 3 feet (1.09 m) (Appendix B1). The baseline measurements for bank change were taken in 1998 so the overall loss since June 1997, when the vegetation transect was first located, would be even greater. The lower right photo (Figure 9), taken in August 2001 (postfishery), shows a large amount of bank lost behind (shoreward to) the tape measure delineating the vegetation transect. This loss, clearly exceeding 3 feet, will be measured as part of this project in June 2002.

June 1997

June 2001

August 2001

Figure 9.–Bank change at Site L19.1 (1997–2001), Kenai River.

TRAMPLING AND ANGLER EFFORT

Changes in Percent Cover by Cover Class

Trampling of vegetation in the nearshore area was evaluated by examining vegetation plot photographs and assessing changes in percent cover for broad cover classes: vegetation, litter, bare ground, and water. Water was a cover class that was added during the assessment process.

Results for the 2001 inseason (pre- and postfishery) multivariate analysis of variance showed that estimated angler effort had a significant effect on the change in mean percent cover of vegetation (P = 0.05) and water (P < 0.01) (Table 2). Increasing angler effort resulted in a decrease in cover of vegetation and an increase in cover for bare ground and water (Figure 5). This analysis is consistent with inseason results for percent cover change of vegetation since 1997, but this is the first year that inseason change for percent cover of water has been significant. This result is most likely due to seasonal bank calving encroaching on a vegetation plot, eventually resulting in all or part of a plot being lost into the river, which we observed (Figure 9). In one case, a plot became more easily inundated with water because the gradient from bank to waterline had been reduced due to angler foot traffic.

Changes In Plant Species Diversity and Evenness

Photos of plot 3 at site L24.2 (Figure 10) show changes in cover for June 1997–June 2001. This site receives no angler effort and the vegetation, in terms of both cover and species composition, remained stable between years.

Photos of plot 3 at site L19.1 (Figure 11) depict changes in plant cover and composition related to shore angler impacts from June 1997 to August 2001. Inseason data (June 1997 versus August 1997) show there was a visible, as well as measured, loss of percent cover for standing vegetation and a gain in percent cover of litter and bare ground. Between years (June), percent cover of vegetation varied: 87.7% in 1997, 61.6% in 1998, 80.5% in 1999, 92.0% in 2000, and 77.8% in 2001. Between June 1997 and June 1998, there was a loss in vegetation by 26.1 percentage points but by June 2000, vegetative cover exceeded that of June 1997. Vegetative cover decreased again in June 2001, but this was because the plot partially calved into the river. Overall, plant cover appears to recover following shore angler use but plant composition changes. Grass (*Calamagrostis spp*.) was dominant in the June 1997 photo. In the June 1998 photo, grass was present, but to a much lesser extent, and dandelions (*Taraxacum officiniale.*) had become established. By June 1999, dandelions were the dominant plant species in this plot. This species of dandelion is very cosmopolitan and occurs in waste areas and along roadsides (Hulten 1968). In June 2000, the plot was still dominated by dandelions, but horsetails (*Equisetum spp.*), another cosmopolitan species often found in marginal and disturbed soils (Hulten 1968), had become established. The last photo shows the plot in June 2001; the dominant plant species were dandelions and horsetails, and about 25% of the plot had calved into the river. Although we observed recovery in terms of total vegetation cover, changes in plant composition occurred resulting in loss of the original community and a change to a community of plants that are adapted to highly disturbed areas.

At sites with high angler use, the more dominant plants such as grasses were often destroyed, including the root structure, which allowed early colonizing species to become established. The more dominant, naturally occurring species may be less tolerant to heavy foot traffic and were replaced by plant species more tolerant of heavy foot traffic and disturbed soil conditions. Whether these newly established plant species provide good soil stabilization and contribute to bank integrity is unknown. Members of the genus *Calamagrostis* propagate through creeping rhizomes, often forming tussocks (Hulten 1968) that provide good ground cover and stabilize the soil, much like a vegetative mat. In contrast, plants in the genera *Taraxacum* and *Equisetum* have solitary stems, thus providing less soil stability than *Calamagrostis. Taraxacum* also has a taproot system that enables them to withstand the trauma of trampling because their root systems are deeper and less likely to be damaged, explaining its dominance in a disturbed community.

These results indicate that even though we may be observing adequate recovery of vegetation cover following angler activity, species composition is negatively affected (decrease in species diversity and evenness). How these shifts affect fish habitat is not clearly understood, but there is certainly concern for reduction in bank integrity, which results in increased bank erosion. Although we only used 3 seasons of cumulative angler effort data for comparison with 4 seasons of vegetation change, we were still able to detect a significant change. It is the rate of change (Figure 4) that is cause for concern regarding shore angler impacts to riparian habitat.

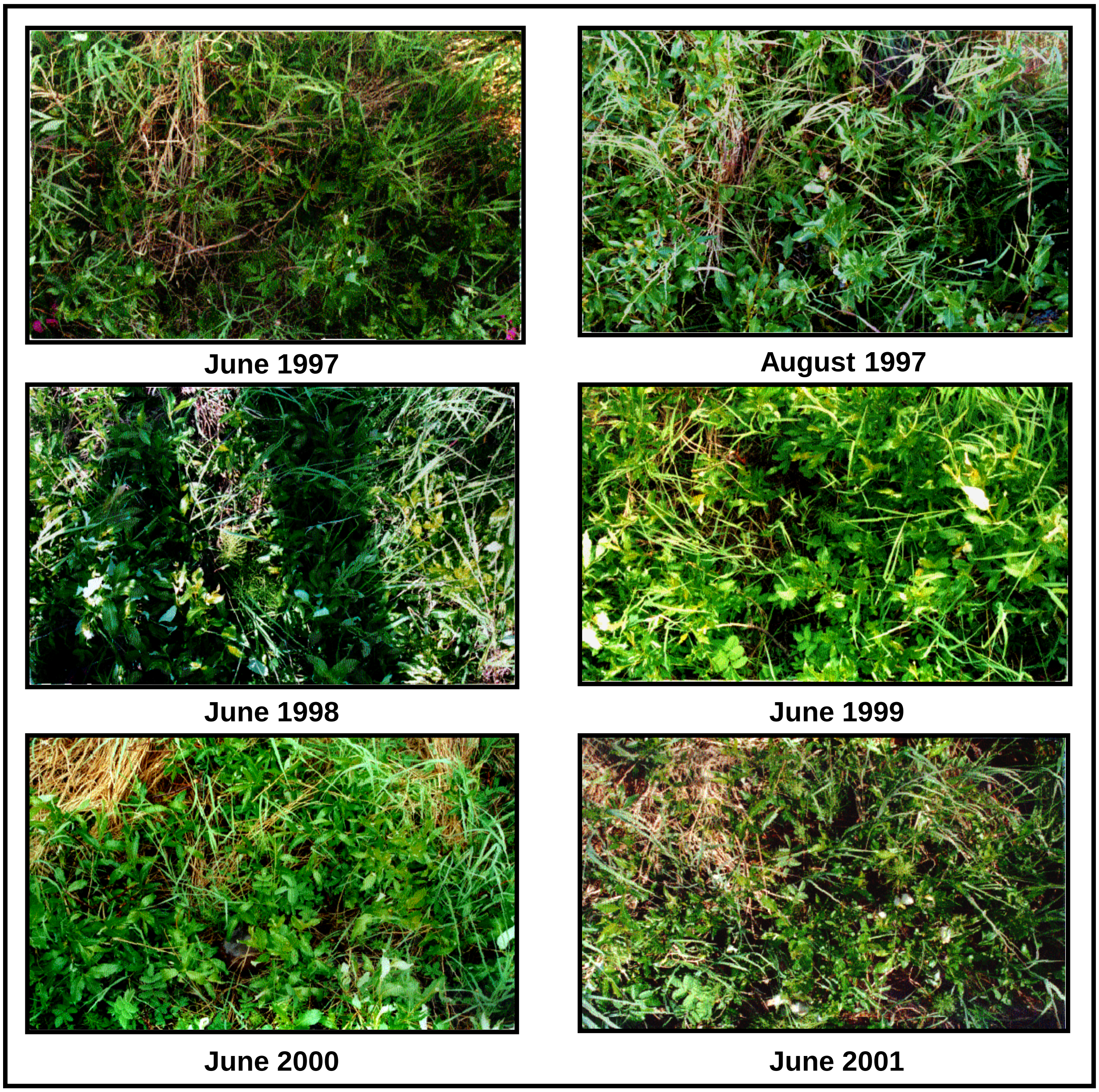

Figure 10.–Photos of vegetation plot 3 at site L24.2, Kenai River, 1997–2001.

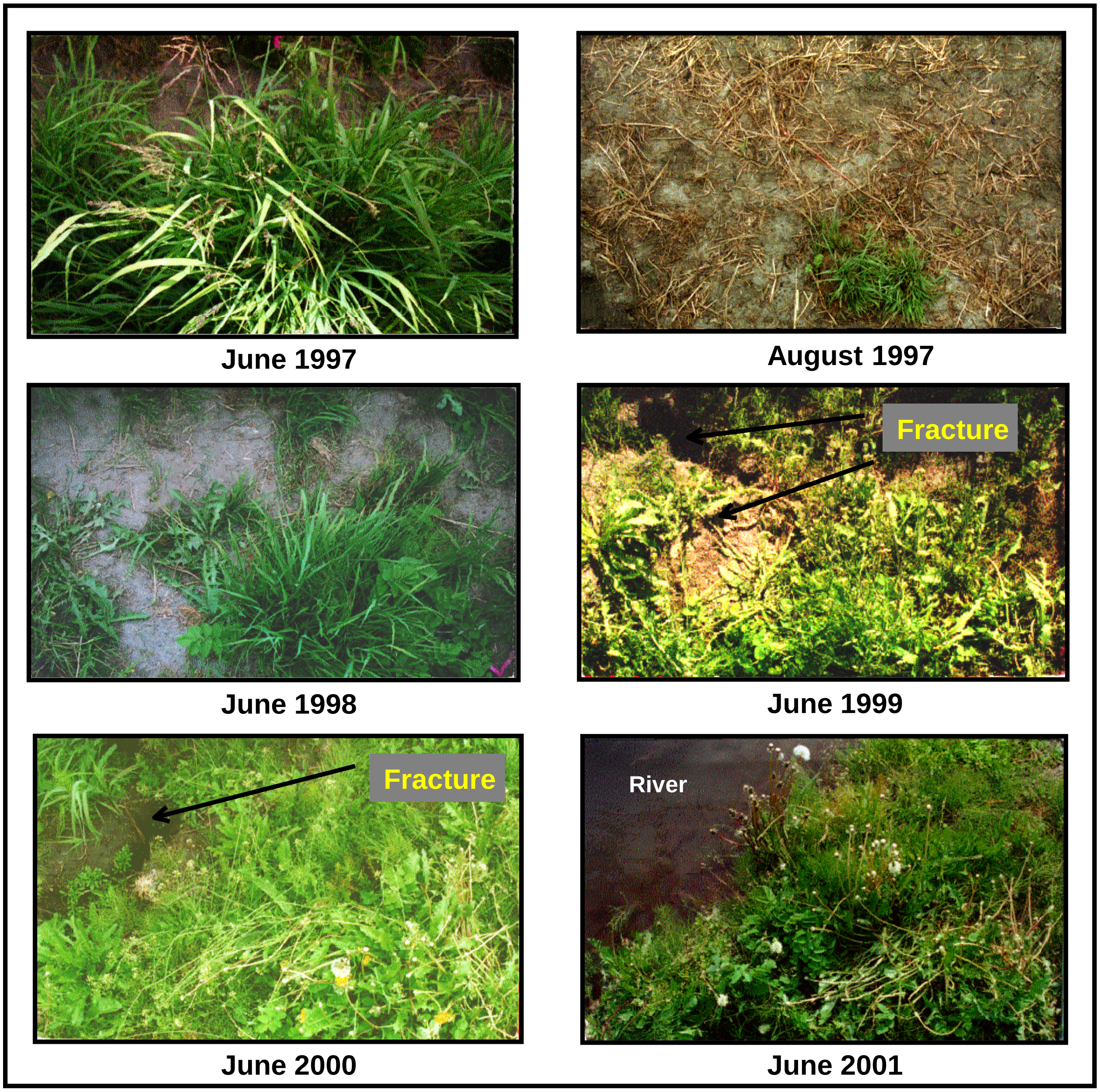

Figure 11.–Photos of vegetation plot 3 at site L19.1, Kenai River, 1997–2001.

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 better assess shore angler impacts. We feel that the bank erosion measurement program (1998–2000) and vegetation assessment using photo imagery analysis (1997–2001) are providing valuable information, representative of shore angler impacts to the riparian zone of the Kenai River. We continue to modify methods to improve the repeatability of the process and the accuracy of the data.

Due to methodological improvements, the bank erosion measurement program has provided consistent and meaningful results for the last 2 years. The methodology was most sensitive to detecting shore angler impacts while taking into consideration natural erosion (measured by assigning survey sites a position in the stream meander and habitat type) and human perturbations (measured by assigning survey sites a level of powerboat activity).

Prior to this report, for 1998 to 2000, we used 2 methods for conducting bank measurements: 1) the methods described in this report, and 2) a more extensive bank measurement program (King and Hansen 1999, 2001) that was done systematically at half-mile intervals on both banks from Skilak Lake to the Warren Ames Bridge. The second method differs from the first (described in this report) because only a single bank measurement was taken (in contrast with 11 measurements) at each survey site and the sites were located throughout the river, in areas of high and low powerboat activity. As such, the second method was more sensitive to detecting changes in bank position associated with powerboat activity (because of widespread distribution of sites) than shore angler activity (only 1 bank measurement).

In the future, we might consider combining the 2 bank measurement methods again. Sites could be evaluated by taking multiple bank measurements, but the number of sites that are located in areas of high powerboat activity should be increased. Currently, the survey sites having multiple bank measurements are predominantly located in areas of low powerboat activity (35 sites in low, 5 sites in high). In selecting the additional sites, equal sample sizes for stream meander categories and the varying levels of angler effort would also have to be considered. Although this study was not intended to evaluate effects from powerboat activity, the influence of this activity is fundamentally involved in bank erosion on the Kenai River (Scott 1982; Barrick 1984; Reckendorf 1989; Dorava and Moore 1997). As such, we should try to better understand the relationship between powerboat activities and change in bank position, particularly in areas that also receive high levels of shore angler use. It would also be appropriate to collect at least one more year of bank measurement data to further verify the relationship of increased bank loss associated with increased shore angler effort.

The assessment of vegetation using photo imagery analysis continues to provide good information on the impacts of trampling by shore anglers. Several of our high-impact sites are candidates for bank closure or stabilization beginning in 2002. These actions would prevent angler use of the site or physically affect the vegetation plots (boardwalks over the top of the plots). Hence, vegetation assessment would be completed in June 2002. This would provide one more season for assessment of cover as well as species composition. Although it was not done prior to the 2001 study, assessment of species composition change for years prior to 2001 is possible with archived photos and could be done to determine if there were significant changes in diversity and evenness that may have occurred over shorter time periods. Future vegetation assessment could also be used to monitor recovery at high-impact sites that were closed to angler traffic. This method may provide insight into vegetation recovery.

Prior to this report, shore angler distribution surveys were also conducted (King and Hansen 1999, 2001-2002, 2015). These surveys provided information relative to trends in shore angler use of public and private lands. The surveys also indicated where shore anglers fished (mainland bank, island, gravel bar) and their fishing platform (on bank, in water, on boardwalk, etc.). This was very useful information when evaluating shore angler impacts. We did not conduct these surveys in 2001, but this survey should be conducted again in 2002. In 2001, we observed shore anglers fishing in many new locations and therefore have concern regarding the growth in the sport fishery and related impacts to riparian habitat.

Quantification of habitat change usually requires a long-term commitment, particularly when annual measurements of change are perceived to be small, such as those caused by recreational use. After 3 seasons, significant relationships have been detected. We found that high levels of shore anglers tended to increase bank erosion and decrease the diversity and evenness of plant species. The ability to measure these change in a relatively short time period (bank erosion: annually for 2 seasons and cumulatively; plant species composition: over 4 seasons, but possibly sooner than assessed) suggests a strong relationship with shore angler activity and reason for concern. In addition, the analyses of cumulative bank change in 1999–2000 for all habitat survey sites showed a significant relationship between increasing bank loss for sites associated with high levels of powerboat activity; i.e., more boat wake impacts to the riverbank (King and Hansen 2015). Bank erosion is a natural result of stream dynamics, but when the amount of measured erosion significantly exceeds natural erosion levels, it becomes necessary to modify the activities contributing to the acceleration of bank erosion.

Anglers were found to significantly accelerate the bank erosion process and alter riparian habitat. Whether these effects have a cumulative, long term, negative impact on fish habitat is more challenging to answer. Biologists have documented the necessary components of fish habitat (Platts et al. 1983). Alteration of these habitats certainly raises concern (Tarbox and Bendock 1996), especially if that change occurs at a high rate. Quantifying these changes may be expensive and time-consuming but given the understanding that stream riparian areas provide the "structural and nonstructural habitat components (i.e. streambank vegetation, channel structure, and water quality) [that are] required to sustain productive fishery resources" (American Fisheries Society [AFS] policy statement #14, available at http://fisheries.org/docs/policy_statements/policy_14f.pdf [accessed 8/28/2014]), we suggest that fisheries managers should reevaluate how sport fisheries are prosecuted on the Kenai River. We should strive to provide acceptable levels of participation in these fisheries while minimizing their impacts to the riparian habitat.

ACKNOWLEDGMENTS

We would like to express our gratitude to those individuals who assisted with data collection and analysis. Tom Rhyner was the crew leader for the field season. He and Jason Pawluk contributed greatly to the overall success of the project by collecting bank erosion data, entering data into spreadsheets, assisting with vegetation plot photography, and cataloging site photos. Pam Russell conducted the photo imagery analysis on the vegetation plots.

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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.–Annual and cumulative bank change measurements (meters) at angler-effort sites, Kenai River, 1998–2001.

				Annual change statistics								Cumulative change statistics							
				Δ = Jun 1999 − Aug 1998				Δ = Jun 2001 − Jun 2000				Δ = Jun 2000 − Aug 1998 [d]				Δ = Jun 2001 − Aug 1998 [d]			
Site	H [a]	B [b]	M [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	0.00	-0.34	-0.13	0.01	0.86	-0.30	0.21	0.13	0.71	-0.30	0.08	0.11
L14.0	H	H	N	0.42	-0.35	0.09	0.05	0.19	-0.19	-0.09	0.01	0.43	-0.43	0.06	0.06	0.29	-0.27	-0.03	0.03
L17.0	H	H	N	New site in 1999				-0.31	-0.96	-0.54	0.05	0.02	-0.80	-0.32	0.09	-0.29	-1.46	-0.86	0.14
L17.5	SH	H	N	0.38	-1.54	-0.23	0.41	-0.05	-0.35	-0.14	0.01	0.47	-1.54	-0.21	0.38	0.42	-1.64	-0.35	0.38
R18.5	H	L	N	0.1	-3.18	-0.71	0.89	-0.02	-0.24	-0.12	0.00	0.28	-0.62	0.01	0.05	0.20	-0.82	-0.11	0.06
L19.0	SH	L	O	0.85	-0.16	0.08	0.07	0.21	-0.65	-0.15	0.06	0.19	-1.82	-0.23	0.36	0.24	-2.28	-0.38	0.55
L19.1	SH	L	O	0.07	-2.80	-0.27	0.71	0.18	-0.85	-0.41	0.12	0.26	-3.79	-0.68	1.21	0.32	-4.63	-1.09	1.61
R19.5	H	L	N	1999 is baseline year				0.03	-0.25	-0.08	0.01	0.00	-0.03	0.00	0.00	0.02	-0.13	-0.07	0.00
L20.0	H	L	N	0.44	-0.13	0.12	0.02	0.11	-1.15	-0.12	0.12	0.44	-0.13	0.12	0.02	0.38	-0.98	0.00	0.13
L21.0	H	L	N	0.23	-0.16	0.08	0.02	0.06	-0.31	-0.09	0.01	0.44	-0.06	0.17	0.02	0.30	-0.14	0.08	0.02
L21.4	SH	L	N	0.13	-0.98	-0.10	0.13	-0.05	-0.25	-0.16	0.00	0.31	-0.87	-0.01	0.14	0.06	-1.01	-0.17	0.14
L21.5	H	L	N	0.23	-0.10	0.08	0.01	-0.01	-1.68	-0.21	0.24	0.25	-0.27	0.09	0.02	0.13	-1.53	-0.12	0.23
R21.9	H	L	N	0.84	-0.69	0.07	0.14	-0.03	-0.59	-0.19	0.04	0.79	-0.70	0.02	0.13	0.66	-1.29	-0.17	0.26
L22.3	H	L	I	0.51	-0.09	0.05	0.03	0.07	-0.10	-0.03	0.00	0.53	-0.08	0.04	0.03	0.55	-0.10	0.02	0.03
R22.8	SH	L	N	0.97	-0.13	0.18	0.13	0.13	-0.17	-0.04	0.01	1.05	-0.37	0.14	0.18	0.97	-0.45	0.09	0.19
R22.9	SH	L	N	0.11	-0.11	0.01	0.00	Deleted; bank stabilization				0.19	-0.37	0.03	0.02	Deleted; bank stabilization			
L23.5	SH	L	O	0.32	-0.29	0.03	0.02	0.02	-0.12	-0.05	0.00	0.34	-0.29	0.06	0.02	0.36	-0.31	0.01	0.03
L23.6	H	L	N	0.11	-0.11	0.01	0.00	0.04	-0.10	-0.03	0.00	0.21	-0.17	0.00	0.01	0.13	-0.18	-0.04	0.01
L24.0	SH	L	I	0.14	-0.28	0.02	0.01	0.09	-0.08	-0.02	0.00	0.15	-0.27	0.04	0.02	0.21	-0.29	0.02	0.02
L24.2	H	L	I	New site in 1999				-0.02	-0.11	-0.07	0.00	0.00	0.00	0.00	0.00	-0.02	-0.11	-0.07	0.00
L24.3	H	L	N	0.08	-0.69	-0.12	0.05	Deleted; bank stabilization				0.12	-0.66	-0.09	0.05	Deleted; bank stabilization			
L25.0	SH	L	N	0.09	-0.08	0.02	0.00	0.05	-0.13	-0.06	0.00	0.14	-0.10	0.03	0.01	0.06	-0.20	-0.03	0.01
L25.5	SH	L	N	0.94	-0.03	0.12	0.08	0.08	-0.07	-0.01	0.00	1.02	-0.02	0.14	0.09	0.97	-0.05	0.13	0.08
R25.5	SH	L	N	1.31	-0.79	0.03	0.25	-0.01	-0.52	-0.17	0.02	1.42	-0.76	-0.04	0.30	1.35	-0.77	-0.22	0.32

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				Annual change statistics								Cumulative change statistics							
				Δ = Jun 1999 − Aug 1998				Δ = Jun 2001 − Jun 2000				Δ = Jun 2000 − Aug 1998 [d]				Δ = Jun 2001 − Aug 1998 [d]			
Site	H [a]	B [b]	M [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	-0.05	-0.45	-0.12	0.01	0.19	-0.15	-0.05	0.01	0.06	-0.42	-0.16	0.02
L25.7	H	L	O	0.42	-0.03	0.17	0.02	0.01	-1.13	-0.15	0.11	0.40	-0.02	0.14	0.01	0.27	-0.73	-0.01	0.07
L25.9	SH	L	N	1.43	-0.82	0.23	0.35	0.07	-0.05	0.02	0.00	1.36	-0.85	0.19	0.35	1.43	-0.82	0.21	0.35
R26.0	H	L	N	0.67	-0.79	-0.03	0.12	-0.03	-0.63	-0.13	0.03	0.66	-0.16	0.07	0.04	0.63	-0.53	-0.06	0.08
R26.5	SH	L	I	0.19	-0.07	0.03	0.01	0.02	-0.09	-0.04	0.00	0.21	-0.59	-0.05	0.04	0.12	-0.67	-0.09	0.05
R26.6	H	L	I	New site in 1999				0.04	-0.17	-0.11	0.00	0.11	-0.03	0.02	0.00	0.01	-0.14	-0.10	0.00
L26.9	SH	L	O	0.22	-0.41	-0.03	0.02	-0.01	-0.93	-0.14	0.07	0.17	-0.44	-0.03	0.02	0.14	-0.94	-0.17	0.09
R28.3	SH	L	O	0.10	-0.30	-0.02	0.01	-0.06	-0.33	-0.21	0.00	0.23	-0.08	0.10	0.01	0.01	-0.41	-0.11	0.01
R32.7	H	L	O	0.32	-0.14	0.06	0.02	0.02	-0.10	-0.04	0.00	0.34	-0.09	0.09	0.02	0.24	-0.18	0.05	0.02
L32.8	SH	L	O	0.33	0.01	0.15	0.01	0.05	-0.08	-0.03	0.00	0.30	0.02	0.12	0.01	0.22	0.00	0.08	0.00
L33.9	SH	L	N	0.27	-1.01	-0.25	0.21	0.09	-0.37	-0.06	0.02	0.30	-1.01	-0.22	0.22	0.27	-1.04	-0.28	0.24
R35.5	H	L	N	0.38	-0.32	-0.04	0.04	0.04	-0.02	0.00	0.00	0.15	-0.35	-0.08	0.03	0.13	-0.35	-0.08	0.03
L36.3	H	L	I	0.26	-0.03	0.09	0.01	0.00	-0.21	-0.06	0.00	0.23	0.00	0.10	0.01	0.23	-0.07	0.04	0.01
R36.5	H	L	O	0.45	-0.10	0.11	0.02	0.00	-0.10	-0.03	0.00	0.33	-0.08	0.10	0.01	0.29	-0.18	0.07	0.02
R38.5	SH	L	O	1.19	-0.22	0.14	0.21	0.02	-0.12	-0.07	0.00	0.07	-0.34	-0.09	0.02	-0.02	-0.36	-0.16	0.01
R40.3	H	H	I	0.15	-0.60	-0.05	0.05	0.01	-0.22	-0.09	0.00	0.11	-0.62	-0.10	0.07	0.07	-0.73	-0.19	0.07
R46.1	H	L	I	1.10	-0.02	0.21	0.13	0.00	-1.34	-0.24	0.15	0.39	-0.51	0.06	0.08	0.36	-1.03	-0.18	0.23
R46.2	H	L	I	0.37	-0.04	0.08	0.02	-0.02	-0.09	-0.06	0.00	0.43	-0.28	0.08	0.05	0.41	-0.32	0.03	0.05
Min				0.07	-3.18	-0.71		-0.31	-1.68	-0.54		0.00	-3.79	-0.68		-0.29	-4.63	-1.09	
Max				1.43	0.01	0.23		0.21	-0.02	0.02		1.42	0.02	0.21		1.43	0.00	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] 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.

[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 – Jun 1999). See King and Hansen (2002) for an explanation of the exclusion of the June 1998 bank measurements.

Appendix B2.–Summary of mean number of anglers counted and estimated effort (angler-hours) at angler-effort survey sites during the sport fishery for late-run sockeye salmon, Kenai River, 2001.

	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	25.0	25.5	25.7	25.9	26.9	32.8	33.9	36.3
9 Jul	0	0.8	1.0	0.4	0	0.8	0	0	0.8	0	0	0	0	0	0	0	0	0	0	0	0.2	0
12 Jul	0	2.4	0	0	0.6	0.2	0	0	0.2	0	0.2	0	0	0	0	0	0	0	0	0	0.8	0
15 Jul	0	10.4	2.0	0.8	2.2	1.0	0.6	0.4	0.4	0	1.4	0	0	0	0	2.8	0.2	0	0	0	1.8	0
18 Jul	0	11.8	2.2	2.0	3.8	3.2	1.6	1.2	1.4	0	0.8	0	0	0	0.2	1.2	0.6	0	0	0	4.2	0
21 Jul	0	10.8	3.2	0.4	1.8	1.6	1.6	2.0	0.8	0.2	1.6	0	0	0	0.4	0.8	1.4	0	0	0	3.0	0
24 Jul	0	10	4.8	0.8	3.4	6.4	1.8	0.4	0.8	0.4	0.8	0	0	0	0.4	0.6	0.4	0	0	0	2.8	0
27 Jul	0	7.6	3.0	2.0	4.6	4.4	2.2	1.0	3.2	0.2	0.2	0	0	0	0.8	0	0.4	0	0	0	4.6	0
30 Jul	0	4.2	0.8	1.4	1.0	1.8	0.2	0.8	2.2	0	0.4	0	0	0	0.8	0	0	0	0	0	2.4	0
Mean [a]	0.0	7.3	2.1	1.0	2.2	2.4	1.0	0.7	1.2	0.1	0.7	0.0	0.0	0.0	0.3	1	0.4	0.0	0	0	2.5	0
SE	0.0	0.9	0.4	0.2	0.3	0.4	0.2	0.2	0.3	0.0	0.2	0.0	0.0	0.0	0.0	0.2	0.1	0.0	0.0	0.0	0.3	0.0
Effort	0.0	2,784	816	374	835	931	384	278	470	38	259	0.0	0.0	0.0	125	259	144	0	0	0	950	0
SE	0.0	62.7	36.9	18.4	28.3	29.6	23.1	22.5	25.9	7.2	23.2	0.0	0.0	0.0	13.3	19.3	10.2	0.0	0.0	0.0	24.0	0.0

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	Survey Sites R--.-																	
Date	13.5	18.5	19.5	21.9	22.8	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
9 Jul	0	0	0	0	0	0.6	0	0	0	0	0	0	0	0	0	0	1.4	0.2
12 Jul	0	0	0	1.2	0	0.6	0	0	0	0	0	0	0	0	0	0	0	0
15 Jul	0	0	0	3.0	0	1.6	0.8	0	0	0	0.4	0	0	0	0	0	0.6	0.4
18 Jul	0	0.8	0.6	5.6	0.4	7.0	3.2	0	0	0.4	1.2	0	0	0	0.4	0	2.2	1.2
21 Jul	0	1.2	0.8	6.8	0.2	7.0	2.4	0	0.6	1.8	0	0	2.8	0	1.2	0	3.6	2.6
24 Jul	0.2	2.0	0	5.2	0.2	4.6	3.4	0	2.6	0.8	2.0	0	0.2	0	0.2	0	4.0	2.8
27 Jul	0	1.6	0.2	4.2	2.4	4.8	4.6	0.2	0.4	0.2	1.0	0	2.8	0.4	0.2	0	2.2	2.4
30 Jul	0	0.6	0	1.2	2.8	2.4	1.6	0	0	0	1.4	0	2.4	0	0	0	2.8	3.2
Mean [a]	0	0.8	0.2	3.4	0.8	3.6	2	0	0.5	0.4	0.8	0	1	0.1	0.3	0	2.1	1.6
SE	0.0	0.2	0.1	0.5	0.2	0.5	0.3	0.0	0.2	0.2	0.3	0.0	0.3	0.0	0.0	0.0	0.3	0.3
Effort	10	298	77	1,306	288	1,373	768	10	173	154	288	0	394	19	96	0	806	614
SE	2.9	22.8	15.0	42.5	16.7	33.1	25.0	2.9	19.3	13.8	29.9	0.0	24.0	4.2	9.3	0.0	29.7	22.7

[a] Average of the mean daily count of anglers. Five counts were conducted each sample day for a total of 40 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 which evolved with the field season, and used relatively good equipment. Since 1998, field personnel with experience have returned to the project, which improved consistency in data collection. The upgrade of equipment in 2001 from surveyor's transit to a total station greatly increased efficiency and repeatability, as well as accuracy.

During the 2001 Kenai River habitat study, 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 28 habitat survey sites. Using established protocol, 2 readers obtained 4 measurements at each site. The first 2 measurements were taken by each member of the 2-person crew during the normal bank sampling schedule; the last 2 measurements were taken by the 2-person crew at a later time. Rather than taking all 4 measurements at the same time, we felt measurement error would be more representative if the crewmembers returned to each site after a week or more time 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:

$$BR = \frac{\sum_{j=1}^{n_j} \left(\frac{\sum_{m=1}^{n_{m(j)}} \left(\left| R_{ijk} - \overline{R}_j \right| \right)}{n_{m(j)}} \right)}{n_j} \qquad \text{(B1)}$$

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 (= 4),[3]

n_j = number of sites j (=28).

Within-reader variability in bank measurements was also determined:

$$WR_i = \frac{\sum_{j=1}^{n_j}\left(\frac{\sum_{k=1}^{n_k}\left(\left|R_{ijk} - \overline{R}_{ij}\right|\right)}{n_k}\right)}{n_j} \tag{B2}$$

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 (=28).

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

$$BRE = \frac{\sum_{j=1}^{n_j}\left(\frac{\sum_{i=1}^{n_{m(j)}}\left(\frac{\left|R_{ijk} - \overline{R}_j\right|}{\overline{R}_j}\times 100\right)}{n_{m(j)}}\right)}{n_j}. \tag{B3}$$

Trampling

Measurements of cover class (and therefore, the effect of trampling) 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

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[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 4 measurements and should have been calculated as the average of each reader's average measurement (i.e., 2 measurements, each 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 (2) rather than the number of measurements (4).

selected from 88 pre- and postfishery habitat site photographs and then evaluated for percent cover in random order, after which they were randomized again and evaluated a second and then a third time. Absolute measurement error within a reader for each cover class was measured for 1 reader with 3 photo trials as follows:

$$WRE_i = \frac{\sum_j \left(\frac{\sum_k \left(\frac{\left| R_{ijk} - \overline{R}_{ij} \right|}{\overline{R}_{ij}} \times 100 \right)}{n_k} \right)}{n_j} \tag{B4}$$

where

WRE_i = within-reader variability 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 for 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 locating the bank edge was estimated as follows:

Technician	Bank measurement variability (cm)	Percent error
1	1.3	0.01
2	1.4	0.01
Average	1.3	0.01

The average within-reader variability in bank measurements over all readers was 1.3 cm, an improvement of 3 cm over previous years. The average within-reader percent error was 0.01, also an improvement over previous years (King and Hansen 2001-2002, 2015).

The between-reader variability was estimated to be 1.7 cm with a 1.82 percent error. Both estimates improved over previous years (King and Hansen 2001-2002, 2015).

In all cases there was little reader variability; average bank measurement variability was less than 2 cm and the average percent error was 0.01. The low reader error and consistency of the measurements is largely due to 3 things: 1) having returning personnel who are trained and familiar with methodologies, 2) beginning in 1999, implementing a better procedure to identify the bank edge location used for taking the bank measurement (i.e., placement of the marker nails), and 3) beginning in 2001, improving the quality of the measurement equipment.

Trampling

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

	Average measurement error (percentage points)				
Cover class	1997	1998	1999	2000	2001
Vegetation	6.9	6	4.5	4.4	12.8
Litter	27.3	23.1	18.7	26.4	18.9
Bare ground	44.7	29	22.1	20.5	29
Water	0	0.6	1.3	1.8	1.6

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. The same reader estimated cover for 1998–2001 photos; therefore, not only is the overall error minimized, but the bias associated with the estimate for cover of bare ground is minimized as well. 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 was necessary to separate the 2 cover classes. Therefore, both litter and bare ground are more likely to have greater measurement errors, although overall, this has been quite low.