Kenai River Rehabilitation and Protection Program: Assessment of Streambank Habitat Treatments

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ABSTRACT

Fish habitat was evaluated at a total of 32 undisturbed, disturbed, and rehabilitated streambank sites along the Kenai River in southcentral Alaska during May and August, 1999. Rehabilitated treatments were defined as Cabled spruce trees only, Bioengineered which consisted of brush layering only, and Bioengineered-plus which consisted of brush layering with cabled spruce or root wads. Habitat variables that were measured included: Fine-stem debris, Other woody debris, Undercut banks, Shoreline complexity, Overhanging vegetation, and water velocity. Although few statistically valid conclusions were derived, higher mean habitat values were observed at Cabled Spruce, Bioengineered-plus and Undisturbed treatments than at Bioengineered or Disturbed treatments. The results suggest that for the habitat variables we evaluated, the Bioengineered-plus and Cabled Spruce treatments resemble the Undisturbed treatment more closely the than other treatments, and that the Bioengineered treatment resembles the Disturbed treatment more closely than other treatments. We recommend that streambank rehabilitation projects incorporate multiple techniques that will increase irregularity and complexity.

A modified depletion method using baited minnow traps for estimating abundance of juvenile salmonids was evaluated at nine sampling locations. Abundance estimates of juvenile chinook salmon (*Oncorhynchus tshawytscha*) were obtained for seven sampling locations. Of these, two passed the Goodness of Fit Test ($\alpha = 0.05$). This method of estimating juvenile salmonid abundance has merit, but it requires more development and evaluation. Juvenile chinook salmon were generally abundant among all study sites. We speculate that under usual summer conditions in the Kenai River, juvenile salmon have a reduced reliance on streambank cover, and their distribution is more dependent on the availability of low water velocity rearing habitat. However, the undisturbed and rehabilitated streambank cover is important to maintain a stable, complex streambank.

INTRODUCTION

The Kenai River drainage is a glacially-influenced river system that encompasses nearly 5,700 km^2 on the Kenai Peninsula, Alaska. The drainage includes two large lakes and numerous tributaries. Average monthly discharges typically range from 28 to 480 m^3/sec, with summer discharges of approximately 425 to 2200 m^3/sec (Bigelow et al. 1989). Five species of Pacific salmon (*Oncorhynchus* sp.), rainbow trout (*O. mykiss*), Dolly Varden (*Salvelinus malma*), and other resident species migrate, spawn, and rear in the river and these fish support substantial sport, commercial, subsistence and personal use fisheries. Much of the drainage is road accessible, and supports significant residential, commercial, and recreational development. Increased land use has resulted in impacts to riparian habitat along the Kenai River and, during recent decades, there has been increasing concern about streambank degradation (Bendock 1989; Bendock and Bingham 1988; Burger, et al. 1983; Estes and Kuntz 1986; Liepitz 1994).

Burger, et al (1983) performed a comprehensive investigation of juvenile and adult salmon habitat needs in the Kenai River and reported that almost 80% of the juvenile chinook salmon (*O. tshawytscha*) longer than 50 mm were captured in nearshore rearing areas where the average water velocity was less than 33 cm/sec. A total of 75% of these juveniles was observed where water velocities were 18.3 cm/sec or less. Bendock (1989) and Bendock and Bingham (1988) concluded that any alterations to Kenai River streambanks should be made with considerations of suitable nearshore rearing and migration habitat for juvenile chinook salmon. Murphy et al. (1989) and a summary by Healey (1991) have also emphasized the dependence of juvenile chinook salmon on low-velocity, nearshore habitat with cover in mainstem reaches of rivers. High-quality rearing conditions are especially important for juvenile chinook salmon because they spend only one growing season in freshwater before they become smolts (Healey 1991). Larger, fatter chinook salmon fry mature at a higher rate than smaller fish (Silverstein et al. 1998) and larger juvenile coho salmon (*O. kisutch*) had higher overwinter and marine survival than smaller individuals (Quinn and Peterson 1996).

Liepitz (1994) inventoried nearshore juvenile salmon rearing habitat along the Kenai River mainstem to assess the effects of human-induced riverbank alterations and concluded that over 11.1% of available chinook salmon rearing habitat has been impacted by bank trampling, vegetation denuding, and structural development along the riverbanks. King and Hansen (1999) investigated the relationship between angler traffic and bank integrity variables along the Kenai River and suggested a post-fishery trend of decreasing vegetative cover.

Purpose of the habitat rehabilitation and protection program

With the recognition of the importance of the streambank habitats for fish and the increasing damage to rearing habitat associated with streambanks, there has been increased effort to design and implement streambank rehabilitation and protection measures for fish habitat. The Alaska Department of Fish and Game initiated two programs in 1995: 1) the "State/Federal Joint Matching Funds Kenai River Rehabilitation and Protection Program" provides cost-share funding to public and private landowners to restore and protect salmon habitat damaged by land development and streambank trampling (funding was provided by the State of Alaska, Senate

Bill 183 and the National Marine Fisheries Service); and, 2) ADF&G also co-managed an *Exxon Valdez* Oil Spill Trustee Council restoration project, "Kenai River Habitat Rehabilitation and Recreation Enhancement", that was designed to rehabilitate damaged riparian habitat on public lands of the Kenai River (Hughes 2000).

The purpose of the "State/Federal Joint Matching Funds Kenai River Rehabilitation and Protection Program" streambank rehabilitation and protection projects is to remove structures that are considered detrimental to juvenile salmon, to protect areas that naturally provide good fish habitat and to rehabilitate human-induced impacted fish habitat (Hughes 2000). A total of 180 projects on private and public property was funded between 1995 and 1998. These accounted for 5,764 m of cabled spruce and walkways for bank protection, 1,467 m of bulkheads, barriers and jetties removed and 3,869 m of rehabilitated streambank. Liepitz (1994) reported that there was a total of 267,508 m of Kenai River frontage; of which, an estimated 29,693 m had been damaged or altered. The streambank rehabilitation and protection projects were designed to function at the "ordinary high water" stage of stream discharge which typically occur during July and August. These projects are intended to restore fish habitat, however some are intended to minimize erosion and loss of productive fish habitat.

This project, the Kenai River Rehabilitation and Protection Program: Assessment of Streambank Habitat Treatment, was designed to determine whether rehabilitation of damaged riverbanks has resulted in increased fish habitat or whether juvenile salmon, particularly chinook salmon, use that habitat. This project did not evaluate if erosion control was accomplished, however, Hughes (2000) did assess the status and success of those projects. In addition, this project was not designed to evaluate habitat requirements of juvenile salmonids; but rather, to compare different habitats and fish use of those habitats.

Purpose of this study

The objectives of this study were:

a) to compare and evaluate streambank fish habitat variables among rehabilitation and protection projects, disturbed, and undisturbed habitats in the Kenai River, and
b) to compare and evaluate the use of undisturbed, disturbed and rehabilitated streambank habitat by juvenile salmonids.

The results from this study will be used to improve the design of future projects in the Kenai River and to apply the methodologies in other watersheds.

STUDY SITES

Five riverbank treatments were evaluated; three of the five represented rehabilitation or protection project sites. The five habitat treatments were: 1) Undisturbed, 2) Disturbed, 3) Cabled Spruce, 4) Bioengineered and, 5) Bioengineered–plus. The Undisturbed treatment consisted of natural riparian and instream woody debris and vegetation with little or no physical human disturbance (Figure 1). The Disturbed treatment consisted of human-induced impacted sites that could be considered candidates for a bank rehabilitation or protection project (Figure 2). Cabled Spruce treatment sites were protected with lengths of spruce trees that were anchored with cables to the bank parallel with the water flow (Figure 3). Bioengineered treatments were riverbanks that were rehabilitated and protected with coir or coconut fiber logs with some brush layering (Figure 4). Bioengineered-plus were treatments where rehabilitated banks were protected with root wads and/or cabled spruce trees in addition to brush layering (Figure 5). Streambank rehabilitation techniques used on the Kenai River to protect or rehabilitate riverbanks are described in detail by Muhlberg and Moore (1998) and Hughes (2000).

Thirty-two sites were selected within a 48 river-km (30 river-mi) reach beginning upstream from the tidally influenced portion of the river. We selected sites that were representative of channel morphology, e.g. left and right river banks (Table 1, Figure 6).

Table 1. Locations and numbers of study sites for the assessment of streambank habitat treatments on the Kenai River, 1999.

		Number of study sites within each treatment					
River km	River mi	Un-disturbed	Disturbed	Cabled Spruce	Bioengineered	Bioengineered-plus	All
16.1 to 32.2	10 to 20	2	3	4	2	3	14
32.2 to 48.3	20 to 30	4	2	1	2	1	10
48.3 to 64.4	30 to 40	2	1	3	1	1	8
	Total	8	6	8	5	5	32

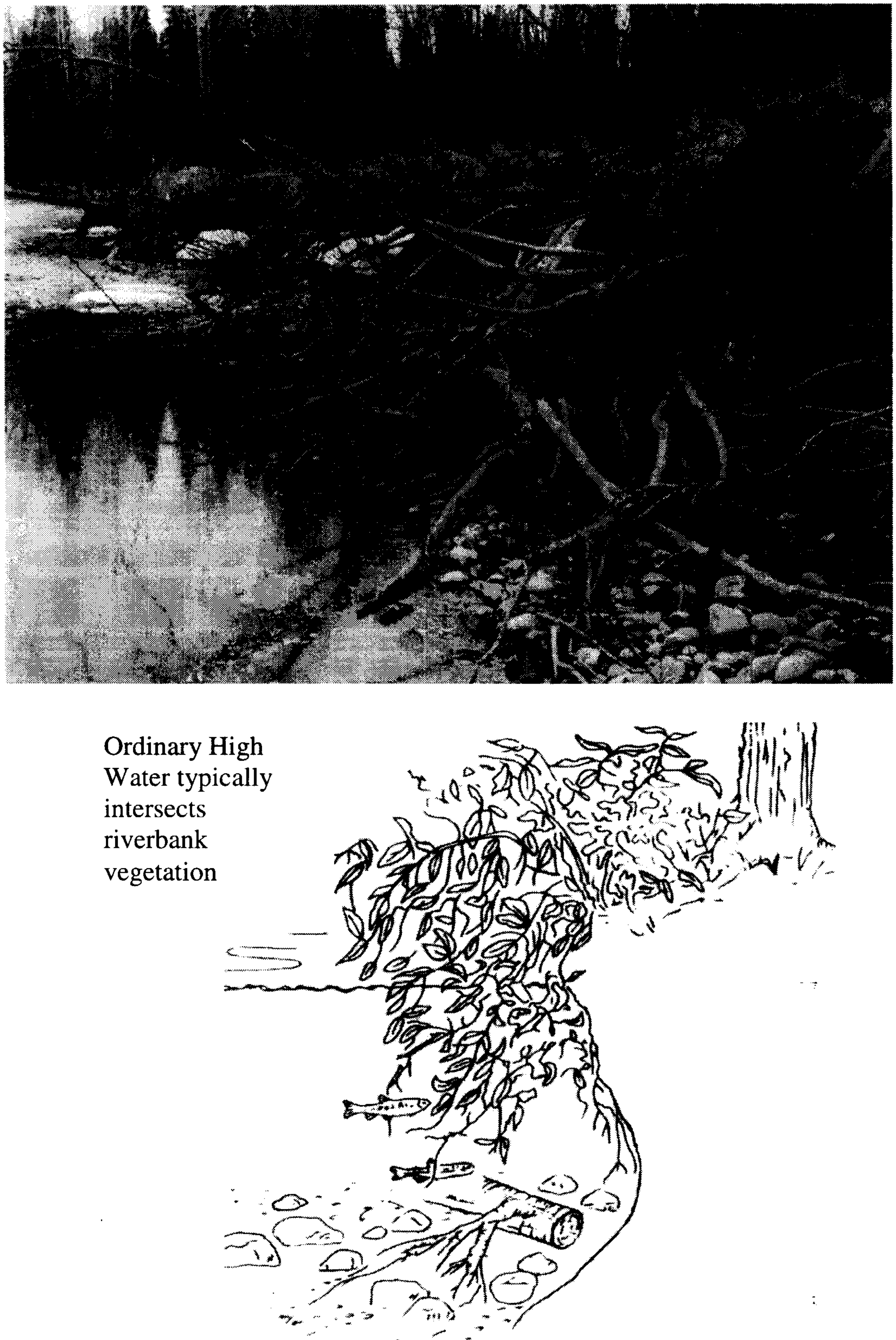
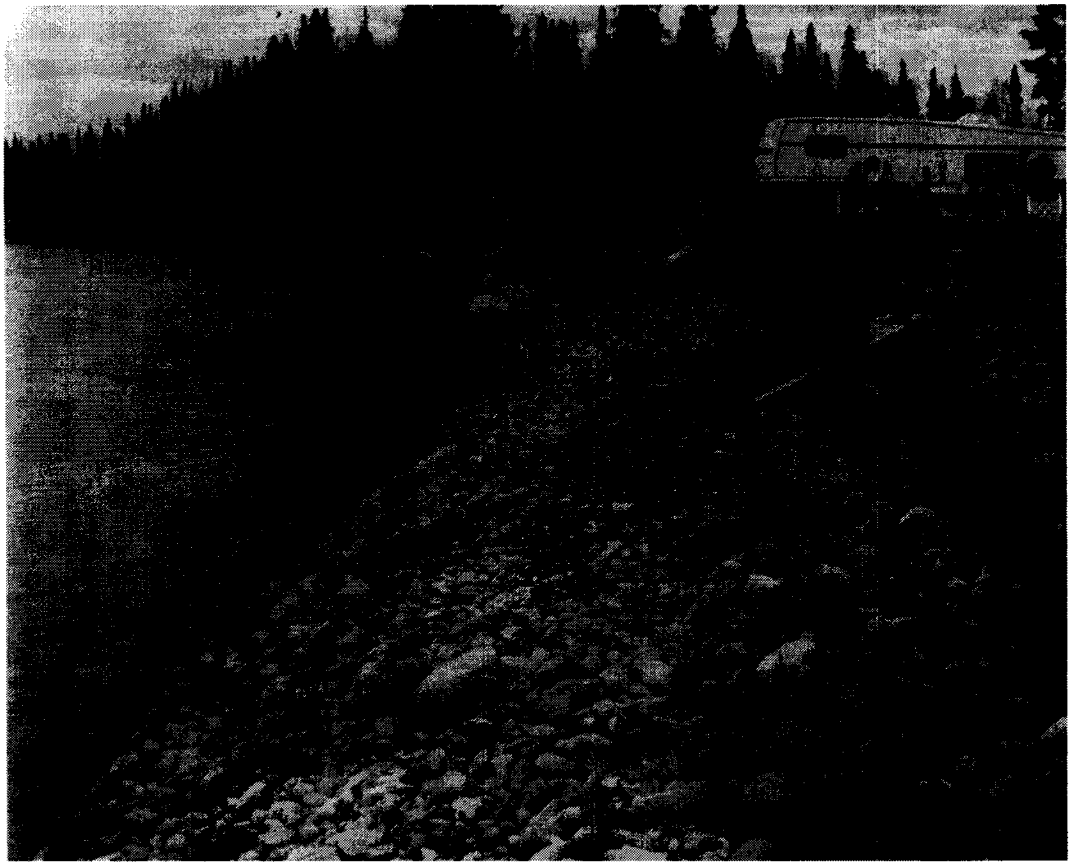


Figure 1. Photograph (Kenai River, May, 1999) and schematic diagram (Muhlberg and Moore 1998) of an Undisturbed riverbank. (Water level in photograph is approximately 1 m below Ordinary High Water.)



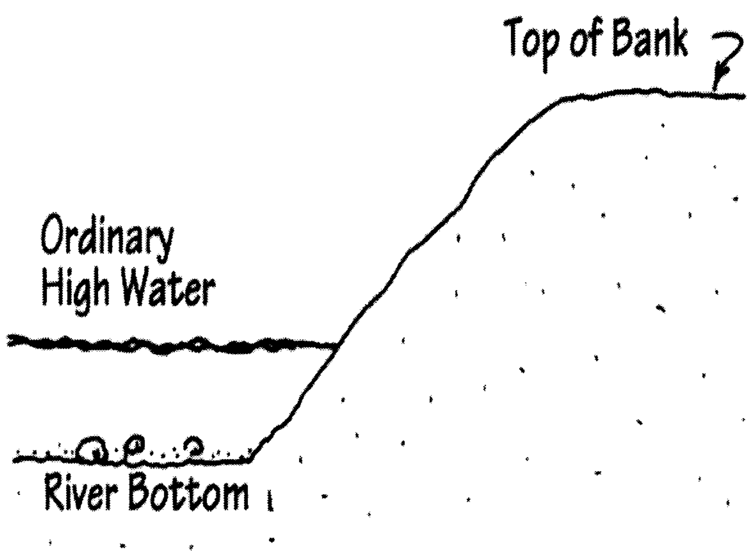
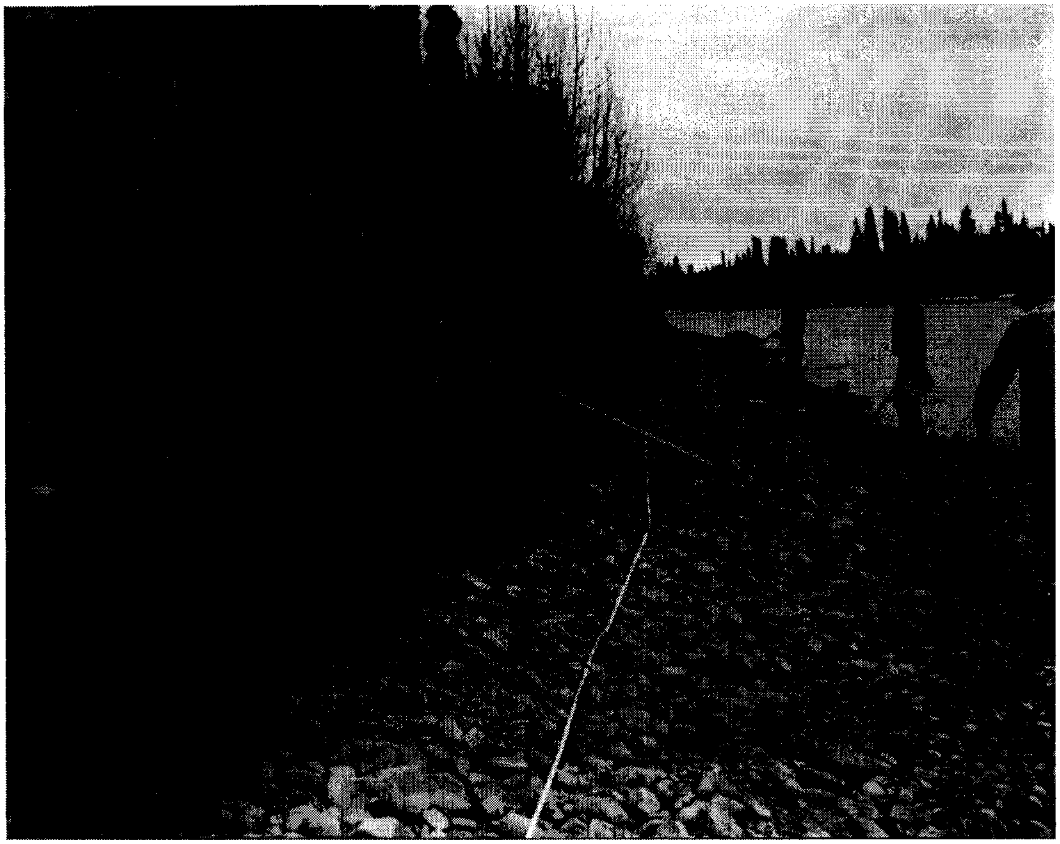


Figure 2. Photograph (Kenai River, May, 1999) and schematic diagram (Muhlberg and Moore 1998) of a Disturbed treatment site. (Water level in photograph is approximately 1 m below Ordinary High Water.)



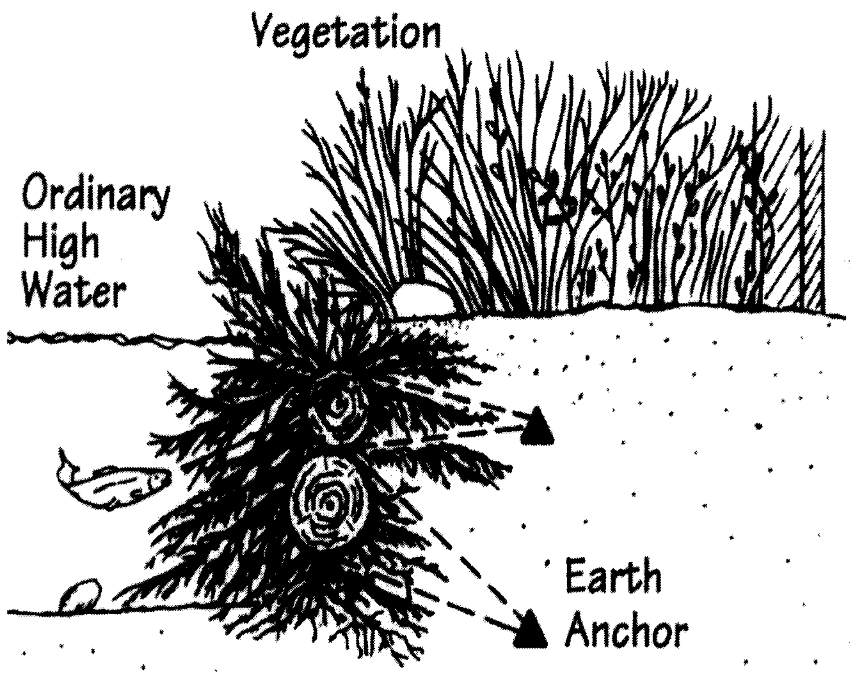
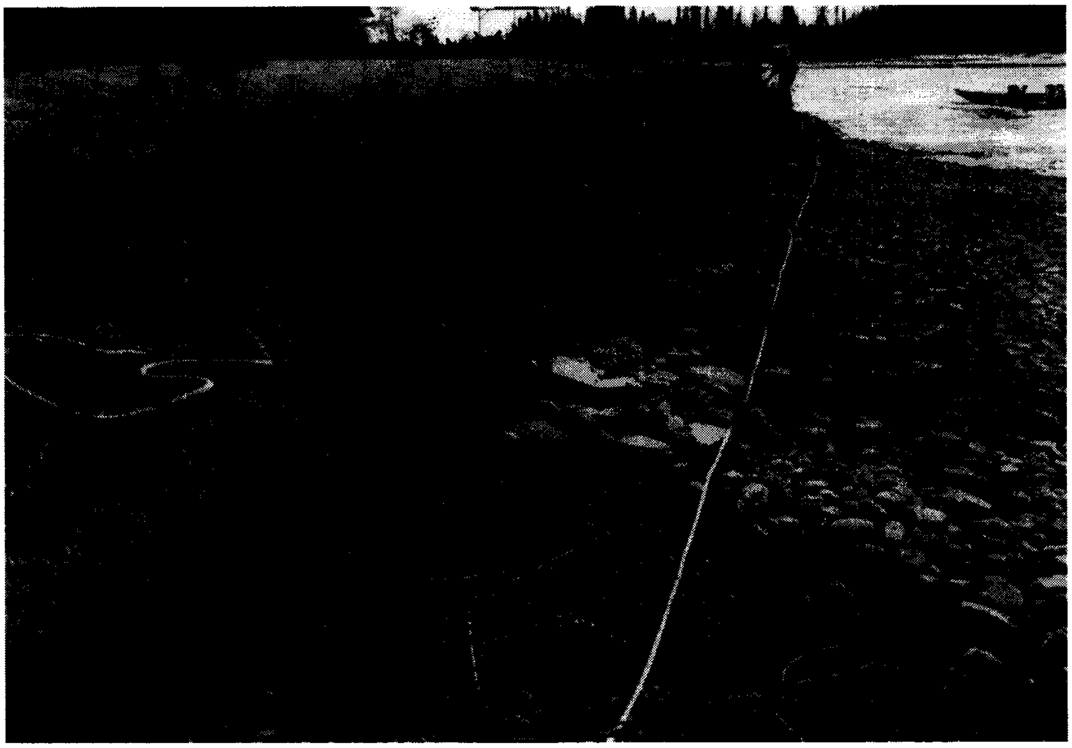


Figure 3. Photograph (Kenai River, May, 1999) and schematic diagram (Muhlberg and Moore 1998) of a streambank that has been rehabilitated using a Cabled Spruce Tree treatment. (Water level in photograph is approximately 1 m below Ordinary High Water.)



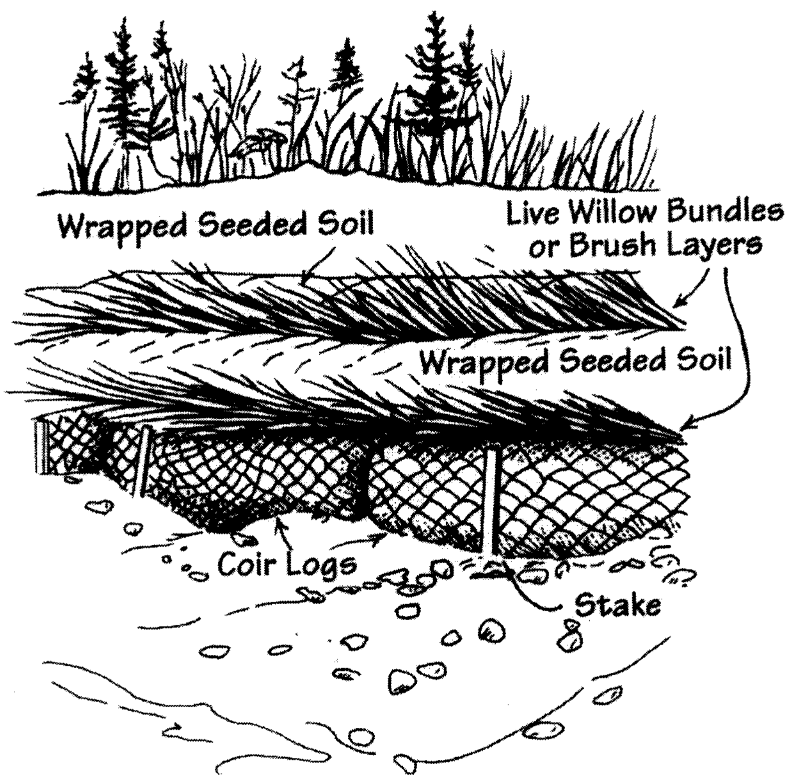


Figure 4. Photograph (Kenai River, May, 1999) and a schematic diagram (Muhlberg and Moore (1998) of a streambank that has been rehabilitated using Bioengineering treatment. (Water level in photograph is approximately 1 m below Ordinary High Water.)

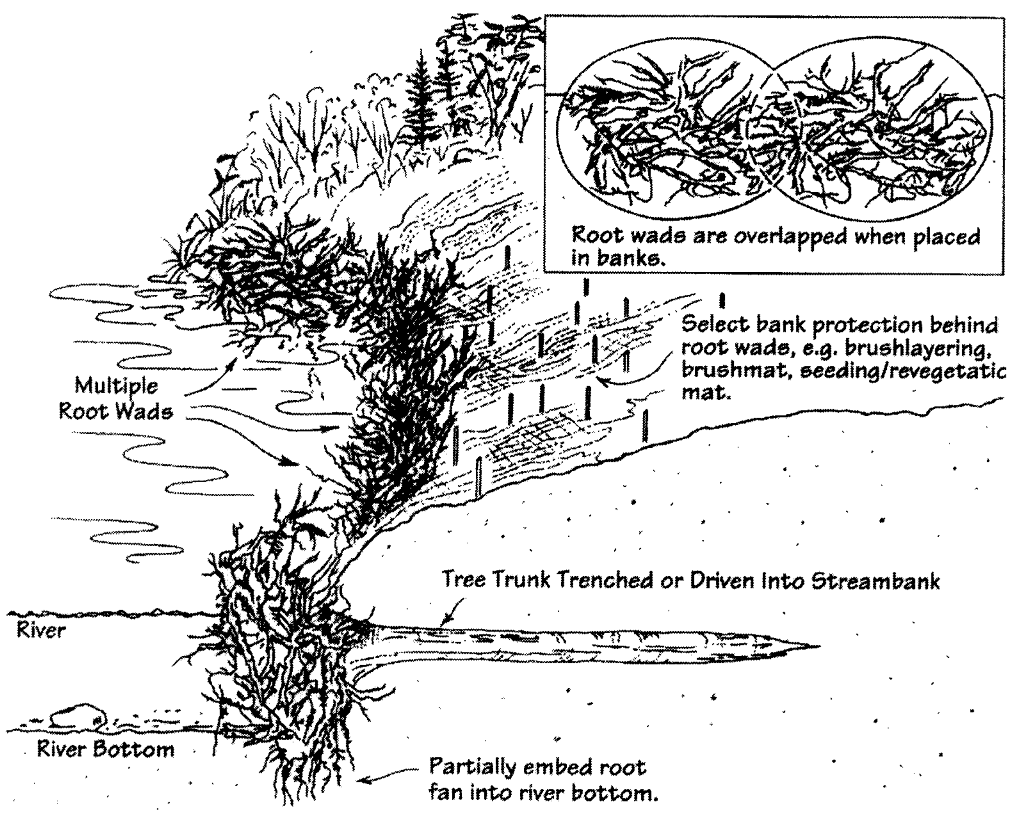


Figure 5. Photograph (Kenai River, May, 1999) and schematic diagram (Muhlberg and Moore 1998) of a streambank that has been rehabilitated using a Bioengineered-plus Treatment that includes addition of rootwads and/or cabled spruce. (Water level in photograph is approximately 1 m below Ordinary High Water.)

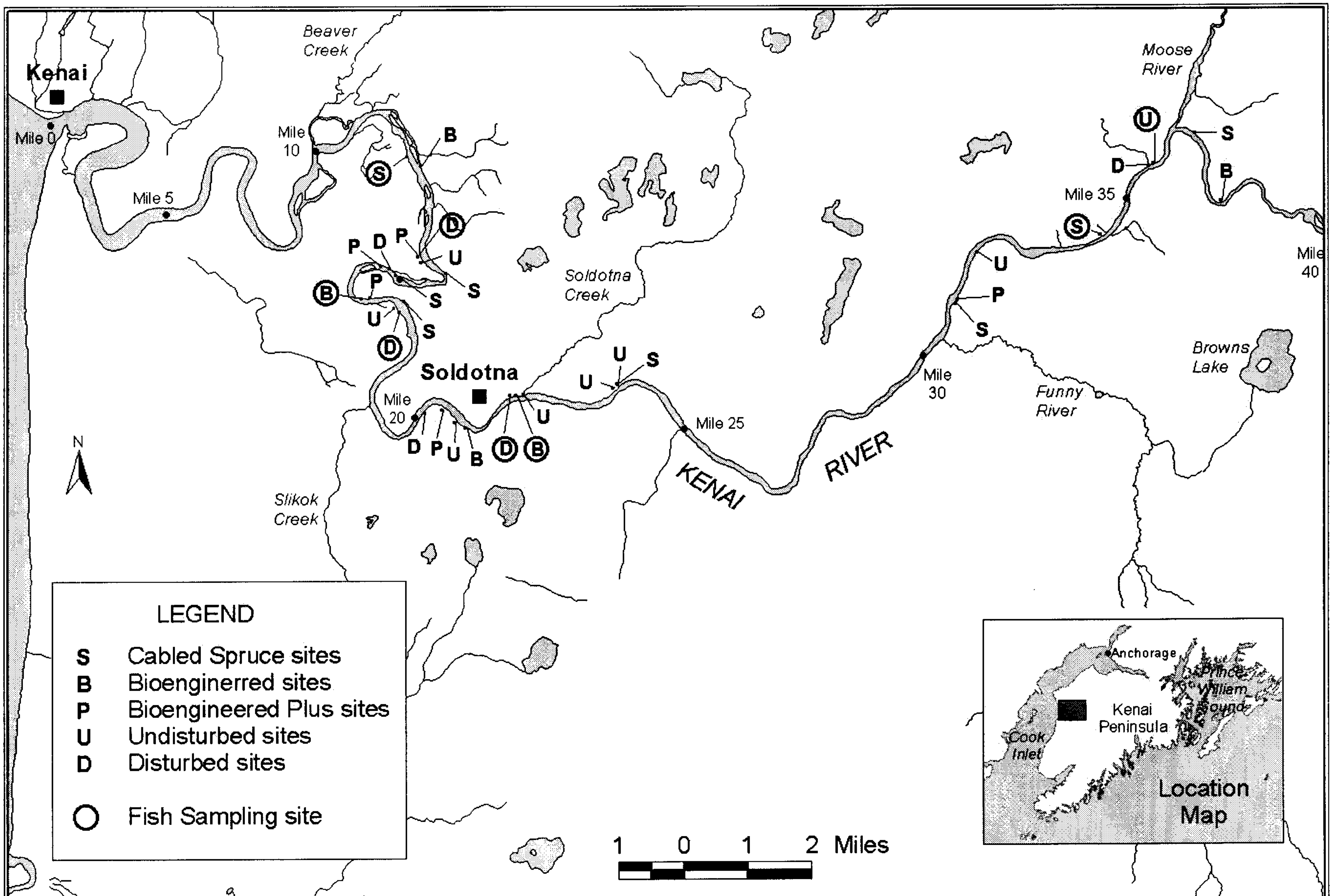


Figure 6. Location of habitat survey and fish sampling sites on the Kenai River, 1999.

METHODS

We evaluated the Kenai River rehabilitation and protection projects by measuring fish habitat variables at the study sites during two different water discharge stages. Vegetative cover below ordinary high water, shoreline complexity, and undercut bank were measured in late spring during low discharge conditions when they were not inundated by silt-laden water. Water velocity and overhanging vegetation were measured in early August under approximately ordinary high water conditions. A modified depletion method was conducted to estimate fish abundance at selected study sites the week after habitat measurements were collected in August.

Data collection

Fish Habitat Variables:
Measurements of fish habitat variables were made along each of five transects that were located at 5, 10, 15, 20, and 25 m upstream from the downstream end of each 30-m study site. A metal stake marked the approximate ordinary high water level at both ends of the study site. The downstream end was designated the zero transect. Each transect began from the streambank at the ordinary high water level and extended offshore approximately perpendicular to the flow of the water. We measured the cross-sectional areas of vegetative cover below ordinary high water, depth of undercut bank, and shoreline complexity during low discharge conditions on 10-17 May, 1999. The cross-sectional area of water velocity less than 18 cm/sec and the width of overhanging vegetation were measured from 2-6 August, at a discharge stage at approximately ordinary high water. The observations for each habitat variable from all transects at that study site were combined to obtain the average value for that variable for each study site. Average values for each study site were combined to obtain average values for each variable within a treatment.

Vegetative cover below ordinary high water was described as a "Fine Stem Debris Cluster" or "Other Woody Debris" (modified from Platts et al.1987). A Fine Stem Debris Cluster was defined as two or more stems less than 10 cm in diameter that are within 10 cm of other stems. Other Woody Debris was defined as individual stems greater than 10 cm in diameter or that are separated by more than 10 cm from another stem. If a woody stem that was larger than 10 cm in diameter was found within a Fine Stem Debris Cluster (e.g., the bole of a spruce tree), it was treated as part of that Fine Stem Debris Cluster.

We measured the width of the Fine Stem Debris Cluster and Other Woody Stem below ordinary high water beneath each transect using a graduated 2-m rod that was leveled with an attached line level and held perpendicular from the riverbank at the ordinary high water mark. The height of the Fine Stem Debris Cluster above the substrate was measured at the midpoint of the width of each cluster. The product of the two measurements represented the cross-sectional area under each transect.

The width of an undercut bank was defined as the greatest horizontal distance measured from a line that is vertical to the upper, outer margin of the opening (Platts et al.1987). If more than one undercut bank was encountered under a transect, each was measured separately and all were summed for that transect.

Shoreline complexity was defined as the ratio of the actual length of the shoreline at ordinary high water to the transect length of 30 m. The length of shoreline was measured with a calibrated 29-cm diameter measuring wheel.

We measured the cross-sectional area of water with an average water velocity less than 18 cm/sec to determine the size of the water cell available to juvenile salmon at each transect. Bendock and Bingham (1988) reported that 18 cm/sec was the optimal velocity for juvenile chinook salmon, and Burger et. al. (1983) observed 75% of juvenile chinook salmon were found where the water velocity did not exceed 18.3 cm/sec and Murphy et al. (1989) found juvenile chinook salmon where the average water velocity was 3 to 15 cm /sec. We measured the average water velocity using a Marsh-McBirney velocity meter and top-down wading rod. We recorded the velocity at two-thirds the depth of the water (Platts et al. 1987). At a point where the average water velocity exceeded 18 cm/sec, we measured the width of the cell from shore and the depth of the cell at that velocity threshold. The depth of the water column was also measured at the water's edge and at the midpoint between the water's edge and the velocity threshold. The cross-sectional area (A_T) was then calculated from the width and depth of each of the two trapezoid cells using the formula:

$$A_T = T_1 + T_2 : \quad \text{Where T is the area of each trapezoid; } T_i = \tfrac{1}{2} \text{ (width x depth)}$$

If the flow was disrupted and there was more than one cell of water slower than 18 cm/sec and separated by more than 50 cm, each cell was measured separately and all were summed to obtain the total cross-sectional area for that transect.

Overhanging Vegetation was defined as overhead cover that extended continuously from the water's edge within 30 cm of the water surface and where the water velocity was less than 18 cm/sec. Discontinuous portions of overhanging vegetation were measured individually if separated by more than 50 cm. Debris that was clinging to vegetation was included as continuous overhanging vegetation.

Fish Abundance Estimates:

We attempted to estimate the relative abundance of juvenile salmonids and other fish at nine study sites with a modified depletion method (Seber 1982) using baited minnow traps. Instantaneous catches with minnow traps were expected to be highly variable and would not represent indices of abundance (Bloom 1976; Elliott and Reed 1973; Lorenz 1984; Shepherd 1998; Swales 1987).

Several assumptions are inherent with this sampling method: 1) the population is stationary or closed, except for the removals; 2) catchability is the same in each event and for each individual in the population; and, 3) all individuals have the same probability of being caught (Seber 1982; Zippin 1956). We attempted to satisfy the first assumption by applying an intensive trapping effort while quickly repeating the sampling events. In addition, we expected that juvenile fish that might enter the sampling area from upstream or downstream would be attracted to the first trap that they encountered; therefore, we ignored the catches from the farthest upstream and downstream traps.

Fish were captured using standard minnow traps (42 cm long by 22 cm in diameter) which were baited with fresh-frozen salmon roe before each deployment. Traps were typically fished between 0.5 and 1.0 m from the water edge, but some were fished farther out from shore to assure that the end rings of the traps were submerged. The standard sampling procedure consisted of fishing 11 traps at 3-m intervals in each 30-m sampling site. Each sampling event consisted of 30 min of soak time and sampling events were repeated as quickly as all traps were rebaited and redeployed; generally, within five to seven min. Sampling events were repeated at least five times or until the catch for the last sampling event was 1/3 that of the first sampling event.

Catches from the middle-nine traps (i.e., trap numbers two through ten) were pooled and treated as if the nine traps functioned as one trap. Catches from the farthest upstream and downstream traps were tabulated separately. Fish were identified according to species and counted. Trapped and counted fish were held in oxygenated water in insulated coolers until they could be released after sampling was complete.

The sampling protocol was modified and evaluated at several sampling locations. The soak time at one location was 15 min for each sampling event. At another sampling location, the sampling effort was doubled by fishing 2 (paired) traps at 3-m intervals in a 15-m reach that was approximately 15 m downstream from a location where the standard sampling technique was employed at the same time. Of the nine locations that were sampled, three had more than five sampling events. Two had six sampling events, one had eight.

The sampling locations for fish abundance estimates included all treatments: one site each at Undisturbed and Bioengineered treatments, two at Cabled Spruce and four at Disturbed. The 15-m sampling location was a Cabled Spruce treatment.

Data analyses

Fish Habitat Variables:

We tested the hypothesis that there was no significant difference in the mean habitat variables among the five riverbank treatments. We determined that the observed values for the habitat variables were not normally distributed. Consequently, we used a ranked transformation of the observed average values to determine the mean ranked values at a total of 32 study sites. Analysis of variance with a nested treatment arrangement (ANOVA) was used to test for significant differences among treatments. The following model was used for each habitat variable:

$$Y_{ijk} = \mu + \tau_i + \gamma_{ij} + \varphi_{ijk}$$

where:

$\mu =$ the overall mean rank

τ_i = Effect of the i^{th} treatment
γ_{ij} = Effect of the j^{th} site within the i^{th} treatment
φ_{ijk} = Effect of the k^{th} transect within the j^{th} site within the i^{th} treatment

Treatments were considered fixed effects and both site and transect were considered random effects. When significant differences were detected with the ANOVA, we applied a Duncan's Multiple Range Test to group similar treatments.

Between and within observer variability was measured for each habitat variable at two study sites within each of the treatments (Appendix A). Data for determining within observer variability at a specific study site were not collected on the same day as the initial data collection. The intent was to reduce the ability of observers to remember characteristics at a site that they had previously used to identify habitat variables for measurement.

Fish Abundance Estimates:
Estimates of abundance for juvenile chinook and coho salmon were made using the program CAPTURE (White et al. 1982) with model M(bh), and the validity of these estimates was evaluated with a Goodness of Fit test ($\alpha = 0.05$). The abundance estimates were based only on the pooled catches from the "middle" traps and catches from each of the end traps were disregarded. Because of the small sample size, we did not compare between sites or treatments.

RESULTS

Fish habitat variables

Observed average fish habitat variables within each of the treatments are shown in Table 2. and the transformed mean ranked values for each treatment are shown in Table 3 and Figure 7. Results from the non-parametric ANOVA indicated that there were among-treatment significant differences only for Fine Stem Debris Cluster and Overhanging Vegetation (Table 4).

The Cabled Spruce, Bioengineered-plus, and Bioengineered treatments had statistically significant more cross-sectional area of Fine Stem Debris Cluster than the Disturbed treatment (Table 5). Of these treatments, the cross-sectional area of Fine Stem Debris Cluster was significantly higher in the Cabled Spruce Treatment than in the Bioengineered-plus treatment, which had significantly more than the Bioengineered treatment (Table 5). The cross-sectional area of Fine Stem Debris Cluster in the Undisturbed treatment was not statistically distinguishable from that of Disturbed or Bioengineered treatments (Table 5).

Table 2. Average values for habitat variables within treatments, Kenai River, 1999. (Number in parentheses is the total number of transects that were measured for that treatment.)

Treatment (n)	Fine-stem debris cluster cross-sec area (sqcm)			Other woody stem cross-sec area (sqcm)			Undercut bank width (cm)			Overhanging vegetation width (cm)			Optimal velocity cross-sec area (sqcm)		
	Medi-an	Mean	Variance	Medi-an	Mean	Variance	Medi-an	Mean	Vari-ance	Medi-an	Mean	Vari-ance	Medi-an	Mean	Variance
Bioengineered (22)	191	546	454,902	0	8	1,372	7	10	83	11	19	506	3,358	11,974	196,400,000
Bioengineered - plus (25)	2,436	2,189	2,905,648	0	183	156,990	8	9	71	62	61	1,848	6,350	7,914	22,531,495
Cabled Spruce (39)	4,132	5,505	19,854,814	0	126	88,897	0	6	115	56	67	2,516	6,781	23,739	1,968,400,000
Disturbed (30)	0	40	8,577	0	29	13,926	0	8	178	1	19	1,932	2,647	4,708	41,310,514
Undisturbed (39)	0	1,604	28,493,939	0	46	13,174	9	16	370	58	72	3,544	3,468	7,193	97,637,534

Table 3. Mean ranked values for habitat variables within treatments, Kenai River, 1999. (Number in parentheses is the number of sites within a treatment.) (Error +/- is the range that includes 90% of the values.)

	Fine-stem debris		Other woody stem		Undercut bank		Overhanging vegetation		Optimal velocity	
Treatment (n)	**Mean rank**	**Error (+/-)**	**Mean rank**	**Error (+/-)**	**Mean rank**	**Error (+/-)**	**Mean rank**	**Error (+/-)**	**Mean rank**	**Error (+/-)**
Bioengineered (5)	72.2	8.9	66.0	12.7	85.1	11.3	45.0	15.4	69.5	16.1
Bioengineered - plus (5)	101.4	10.1	83.8	16.9	85.3	17.8	92.5	16.4	98.8	12.7
Cabled Spruce (8)	125.9	5.0	80.2	10.7	59.9	9.6	92.7	11.8	90.7	10.7
Disturbed (6)	34.1	7.1	65.3	11.1	70.7	10.0	39.0	9.3	57.5	17.5
Undisturbed (8)	52.1	12.5	87.4	12.3	94.7	13.6	98.8	11.0	74.2	14.4

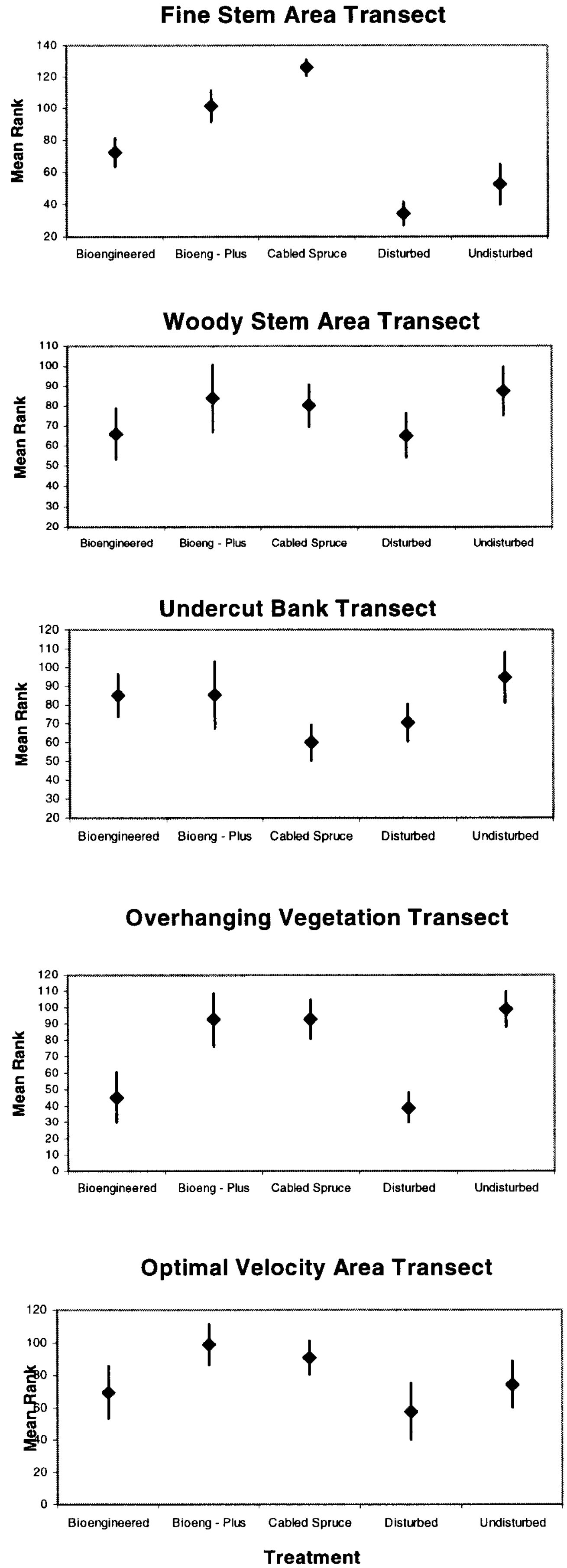


Figure 7. Mean values (ranked data) of habitat variables within each treatment, Kenai River, 1999. Error bars represent range where 90% of values occur.

Table 4. Analysis of variance for differences in mean ranked values for habitat variables, Kenai River, 1999.

Habitat variable	Source	Degrees of freedom	Mean Squares	P>F
Fine stem debris cluster	among treatments	4	46,805.91	0.0001
	within treatments	27	2,019.83	
Other woody debris	among treatments	4	3,085.65	0.2996
	within treatments	27	2,396.55	
Undercut bank	among treatments	4	6,975.21	0.3323
	within treatments	27	5,798.02	
Overhanging vegetation	among treatments	4	24,165.93	0.0014
	within treatments	27	4,049.48	
Optimal velocity	among treatments	4	8,264.91	0.2328
	within treatments	27	5,545.29	

Table 5. Duncan's Multiple Range Test for differences in mean ranked values for Fine Stem Debris Cluster and Overhanging Vegetation, Kenai River, 1999. (No significant differences were detected within other habitat variables.)

Habitat variable	Treatment	Sample Size	Mean Rank	Duncan Grouping*
Fine stem debris cluster	Cabled Spruce	8	125.92	A
	Bioengineered-plus	5	101.42	B
	Bioengineered	5	72.17	C
	Undisturbed	8	52.11	D C
	Disturbed	6	34.13	D
Overhanging vegetation	Undisturbed	8	98.80	A
	Cabled Spruce	8	92.73	A
	Bioengineered-plus	5	92.48	A
	Bioengineered	5	45.02	B
	Disturbed	6	39.03	B

* Different letters indicate statistically significant different groupings.
Two letters on one line indicate groupings that overlap.

The width of Overhanging Vegetation was not significantly different among the Undisturbed, Cabled Spruce and Bioengineered-plus treatments, but the width of Overhanging Vegetation in these treatments was significantly greater than in the Bioengineered and Disturbed treatments (Table 5).

The differences in measurements between observers were normally distributed with a mean of zero. The calculated between-observer variability for Fine Stem Debris Cluster was 33% (Appendix A).

We attempted to measure Shoreline Complexity, but encountered two problems. First, we had difficulty in actually measuring the bank contour at mean high water as originally intended because at some sites the actual contour was often obstructed by woody debris, especially, at the Cabled Spruce and Bioengineered-plus treatment sites. Second, one of the measuring wheels malfunctioned and the wheel did not roll smoothly. This caused us to question the reliability of distances from at least 11 study sites. Consequently, although we consider this an important component of streambank habitat (Burger et al. 1983; Estes and Kuntz 1986), we could not adequately evaluate this habitat variable and we cannot include any further discussion based on our measurements.

Fish abundance estimates

A total of 16,696 fish was caught; of these, chinook salmon comprised 77.1% and coho salmon comprised 17.3% (Table 6). The catch of chinook salmon for one 30-minute sampling event, totaled from all traps, ranged from 32 to 523 individual fish. We trapped a total of 4,471 fish at one Bioengineered site, before we terminated the trapping effort after 8 sampling events.

Juvenile chinook salmon were generally more abundant and were caught at all sites and all treatments that were sampled. Juvenile coho salmon were not as widely captured and they were not as abundant as chinook salmon. Abundance estimates of juvenile chinook salmon were obtained for seven sampling locations (Table 7). Of these, two passed the Goodness of Fit Test ($\alpha = 0.05$). The estimated abundance of juvenile chinook salmon at these sites was 137 (95% CI of 117 to 190) fish and 1,394 (95% CI of 1,193 to 1,796) fish. Abundance estimates of juvenile coho salmon were obtained for five sampling locations (Table 7). Of these, two passed the Goodness of Fit Test. The estimated abundance of juvenile coho salmon at these sites was 157 (95% CI of 157 to 157) fish and 173 (95% CI of 161 to 221) fish.

Table 6. Total numbers of fish caught at selected study sites in the Kenai River, August, 1999.

Treatment:	**Bioengi-neered**	**Bioengi-neered**	**Dis-turbed**	**Dis-turbed**	**Dis-turbed**	**Cabled Spruce**	**Cabled Spruce**	**Cabled Spruce**	**Undis-turbed**	
Study Site:	**1**	**2**	**3**	**4**	**5**	**6 - 15 m**	**6 - 30 m**	**7**	**8**	
Trapping Events:	**6**	**8**	**5**	**5**	**6**	**5**	**5**	**5**	**5**	**Total Catch**
Chinook salmon	189	4,187	2,390	1,525	414	1,985	1,582	244	356	12,872
Coho salmon	158	263	210	8	216	7	0	958	1,072	2,892
Rainbow trout	0	0	0	0	1	0	0	0	0	1
Dolly Varden	14	15	15	15	2	0	15	19	15	110
Slimy sculpin	511	6	35	33	72	35	35	55	35	817
Threespine stickleback	1	0	0	0	3	0	0	0	0	4
All fish:	873	4,471	2,650	1,581	708	2,027	1,632	1,276	1,478	16,696

Table 7. Abundance estimates for juvenile chinook and coho salmon at selected study sites in the Kenai River, August, 1999. (Abundance estimates are with end traps excluded.)

		Chinook salmon				Coho salmon			
Study site	Treatment	Abundance estimate	95% Confidence Interval	P Value	Pass Goodness of Fit Test	Abundance estimate	95% Confidence Interval	P Value	Pass Goodness of Fit Test
1	Bioengineered	137	117-190	0.9137	Yes	105	96-129	0.017	No
2	Bioengineered	25,861	7,254-12,4401	0.001	No	173	161-221	0.2764	Yes
3	Disturbed	no estimate			No	157	157-157	0.9888	Yes
4	Disturbed	917	874-984	0.037	No	no estimate			No
5	Disturbed	565	321-1941	0.0075	No	no estimate			No
6 -15m	Cabled Spruce	1,394	1,193-1,796	0.752	Yes	no estimate			No
6 -30m	Cabled Spruce	1,418	1,227-1,774	0	No	no estimate			No
7	Cabled Spruce	273	229-365	0.0091	No	942	836-1127	0.0216	No
8	Undisturbed	no estimate			No	2,704	1,580-5,870	0.0024	No

DISCUSSION

We detected few differences among treatments. There may have been few differences; however, more likely, differences among treatments may have been difficult to detect because of high natural variability within habitat features that we measured, as well as, observer measurement error.

Fish habitat variables among treatments

The Cabled Spruce and the Bioengineered-plus treatments had significantly more Fine Stem Debris than other treatments (Table 5). This was not unexpected because spruce trees were installed along the ordinary high water level to provide fish cover habitat and reduce erosion. All treatments had similar amounts of Other Woody Stems, but the Undisturbed and Bioengineered-plus treatments had the highest ranked values (Table 3, Figure 7). Other Woody Stems are a natural occurrence in Undisturbed treatments but Bioengineered-plus treatments often incorporate rootwads and cabled spruce as part of their design to reduce erosion and provide fish habitat. The ranked mean and range of values of Other Woody Stems in the Bioengineered-plus treatment approximates those values in the Undisturbed treatment. In addition, the lower rankings of the amount of Fine Stem Debris Cluster and Other Woody Debris in the Bioengineered treatment imply that the brush layering that is incorporated below ordinary high water for temporary fish habitat in the Bioengineered treatment (Muhlberg and Moore 1998) may not be as durable as expected.

We had speculated that the Undisturbed treatment would rank higher for Fine Stem Debris Cluster than it did, however, it is noteworthy that the range of mean values is broad (Table 3, Figure 7). We did not attempt to evaluate the complexity or irregularity of the instream vegetated habitat, but the range of values may suggest that Fine Stem Debris and Other Woody Debris are more irregular within the Undisturbed treatment than within most other treatments. Instream cover used by juvenile salmonids often is typified by large, irregular pieces of woody debris (e.g., Dolloff and Reeves 1990; Harvey 1998; Harvey et al. 1999; summarized by Healey 1991; Quinn and Peterson 1996; Sanderdock 1991). Spalding et al. (1995) concluded that larger pieces of woody debris that can affect water flow were used more and were more important for juvenile coho salmon than the small brushy debris.

Cabled Spruce, Bioengineered-plus and Undisturbed treatments had similar and high values for the widths of Overhanging Vegetation (Table 5). Our data records did not distinguish live or dead vegetation, however, we observed that most of the overhanging vegetation in the Bioengineered-plus and Cabled Spruce treatments were from woody debris and spruce tree branches that had been installed and extended above the water surface. These results and observations, and the lower ranking of the width of Overhanging Vegetation in the Bioengineered treatment compared to the Undisturbed, Cabled Spruce, and Bioengineered-plus treatments (Table 5) suggest that the live vegetation that is installed in the Bioengineered and Bioengineered-plus treatments may not be growing as well as expected (Muhlberg and Moore

1998). Although the Bioengineered treatments may function as desired for other aspects of the projects (Hughes 2000), our observations suggest that they generally provide less fish habitat than Bioengineered-plus or Cabled Spruce treatments.

Undisturbed, Bioengineered and Bioengineered-plus treatments may have more undercut banks than other treatments (Figure 7), however, we only measured the width of undercut banks and we did not evaluate the "quality" or volume of the undercut banks. Small undercut banks are created between the layers of coir logs (Figures 4 and 5) as they are installed in Bioengineered and Bioengineered-plus treatments, however, we noted that these usually have low height and small cross-sectional areas which may be less useful for fish compared to natural undercut banks in Undisturbed treatments. Brusven et al. (1986) demonstrated that undercut banks were very important to juvenile chinook salmon when other cover was not available.

The Disturbed treatment had among the lowest average values and usually small ranges for habitat variables, however, values for the Bioengineered treatment were also low (Table 3, Figure 7). This suggests that the amount and irregularity of habitat features are low in the Bioengineered and Disturbed treatments. Disturbed treatment sites are often completely denuded streambanks, but many Bioengineered treatment sites included temporary woody debris for fish habitat that was lost sooner than expected. This resulted in Bioengineered treatment sites that were regular in shape and included a small amount of woody debris and undercut banks and, provided meager fish habitat.

Fine Stem Debris Cluster was much more abundant but the range of values was smaller in the rehabilitated treatments than in the Undisturbed treatment (Table 3, Figure 7). This suggests that the spruce trees which were installed in these study sites were quite uniform and densely branched. Although these were not designed or installed to mimic conditions of undisturbed reaches, less dense and more open or irregularly-shaped trees or deployment pattern may provide greater benefit for the rearing fish. Alternatively, it appears that the mean values for all habitat variables in the rehabilitated sites are higher than in the disturbed sites (Table 3) although some values overlap, particularly with the Bioengineered treatments (Figure 7).

Although our method to measure Shoreline Complexity failed, our observations suggest that shorelines in the Undisturbed treatment are commonly complex and irregular (Figure 1), particularly, compared to Bioengineered (Figure 4) and Disturbed (Fig 2) treatments. Estes and Kuntz (1986) and Burger et al. (1983) reported that these irregular-shaped streambanks were important as rearing areas for juvenile chinook salmon. The shoreline of the Bioengineered-plus treatment resembled that of the Bioengineered treatment, however, when rootwads are incorporated in the design, irregularity and complexity is created (Figure 5). Cabled spruce, in some bank protection projects, may also have low shoreline complexity (Figure 3).

The Cross-sectional Area of Optimal Velocity is an important habitat variable because this represents the volume of water that is within the optimal velocity that can be utilized by juvenile chinook salmon (Bendock and Bingham 1988; Bjornn and Reiser 1991; Burger et al. 1983; Murphy et al. 1989) and probably by other similar-sized salmonids as well. Bjornn and Reiser (1991) rated water velocity as one of the most important factors that limits rearing space for salmonids and Burger et al. (1983) reported that water velocity appeared to be the greatest limiting factor for juvenile chinook salmon in their utilization of Kenai River habitat. The Bioengineered-plus and Cabled Spruce treatments ranked highest for this habitat variable (Table 3, Figure 7), however, we suggest that the average value at any particular location probably depends on the flow characteristics along that reach of shoreline rather than the habitat variables associated with the specific location. In other words, at a particular study site, it appears that the distance from the shoreline to the optimal velocity of 18 cm/sec is influenced more by the hydraulic features and configuration of the shoreline upstream from that study site than by habitat features within the site.

Collectively, these results suggest that for the habitat variables we evaluated, the Undisturbed treatment is resembled more closely by the Cabled Spruce and Bioengineered-plus treatments, and that the Bioengineered treatment resembles the Disturbed treatment more closely than other treatments.

Fish habitat variables – methodology

Although fish habitat observations are typically highly variable and it is often difficult to detect statistically significant differences (King and Hansen 1999), we may have detected more significant differences with slightly modified data collection procedures. Improved strategy to mark and relocate individual transect end points and to identify ordinary high water level would minimize search activities and increase accuracy during subsequent data collection events.

We believe that shorelines become smoother, less complex and less valuable as fish habitat as they are modified by anthropogenic processes such as trampling and development and it would be informative to evaluate this habitat variable. Our intended method to measure shoreline complexity would be improved if each instrument was calibrated daily. However, when woody debris was added to a streambank, it often became difficult to accurately trace the actual shoreline with the measuring device that we used.

Within-treatment variability, particularly for Disturbed and Undisturbed treatments, may be reduced if study sites and/or treatments that were selected were stratified according to streambank characteristics; e.g., the riparian vegetation at some Undisturbed treatment sites consisted of upland vegetation and trees on steep banks but some consisted of grassy vegetation on low-angle banks. Some Disturbed treatment sites were wooded, some were grassy and some were denuded of vegetation.

Fish abundance estimates

Statistically-valid comparisons were not possible with our data to evaluate the use of different streambank habitat treatments by juvenile salmonids. Juvenile chinook salmon, however, were generally abundant among all study sites (Table 6). This observation is consistent with results from other juvenile salmon studies in the Kenai River (Bendock and Bingham 1988; Burger et al. 1983; Estes and Kuntz 1986, Litchfield and Flagg 1986). Although we caught more juvenile coho than chinook salmon at two of our study sites (Table 6), they are generally less abundant and less widely distributed than juvenile chinook salmon in the Kenai River (Bendock and

Bingham 1988; Burger et al. 1983). We did note, however, that the sampling locations where we found the most juvenile coho salmon were located just downstream from a tributary which has good coho salmon rearing habitat. We could not attempt to detect any correlation between abundance of juvenile salmon and habitat variable or treatment with our sampling design or sample size.

Fish abundance estimates – methodology

Our inability to develop statistically significant estimates of abundance may be related, in part, to our sampling method. We were not aware of any previous reported description of this application of this sampling and evaluation method; consequently, our intent with this application was to determine its feasibility as a useful sampling method. We believe that this depletion method may have some promise, with modifications, as a means to assess relative abundance of juvenile salmonids.

We did not expect to capture so many fish at so many study sites. This method may yield more suitable results in locations where the population density is lower. Before we attempted to apply this method in the Kenai River, we evaluated it with favorable results, but that experiment was done on a small, clearwater stream that had a much smaller density of juvenile salmonids. Either the abundance of juvenile salmonids – especially chinook salmon – is high in the Kenai River or, as fish were removed, others quickly replaced them from the adjacent streambanks or farther offshore. We concluded that our rate of removal during this study was not sufficient to accommodate the numbers of fish or their rate of replacement.

We had hypothesized that, if juvenile salmonids would be drawn from the habitat adjacent to the study sites, they would enter the first traps that they encountered so the catches from those traps were disregarded from the analyses. Casual observation of those data, however, does not suggest that catches from those traps remained high while catches in the "middle" traps declined.

We recommend that future attempts to evaluate this method should test the effectiveness of installing block nets at the upper and lower limits of the study site. Block nets should be installed as "instantaneously" and with as little disturbance as possible. For example, posts may be placed at the outer margin of the block net and a small seine with a heavy lead line could be deployed as a drop net with a remote release. The block net probably needs to operate effectively from the edge of water to the distance where the water velocity exceeds 30 to 50 cm/sec. Another net may be deployed parallel with the current and shoreline between the posts to completely isolate the study site if there is evidence that fish are skirting the outer edge of the block net during the fishing interval or if there is evidence of fish moving in from offshore locations.

The objective of this method is to successively trap and remove the fish as quickly as possible. Where the density of juvenile salmonids is high, it may be important to increase the fishing effort. We doubled our trapping effort at one study site while we employed the standard method at an adjacent, upstream site. We were unable to make an abundance estimate where the standard method was used, but the abundance estimate from the more intensively-fished site passed the Goodness of Fit Test. In study sites such as those we trapped, at least twice as many traps may be needed. We suggest that a study site should be fished with at least 12 traps per 15 m of shoreline (i.e., two traps per three m).

Juvenile salmonids and streambank habitat interactions

This study was not adequate to determine statistically significant differences in fish use among treatments, however, we observed considerable numbers of chinook salmon and, to a lesser amount, coho salmon, in rehabilitated, disturbed and undisturbed study locations.

Some of these locations had minimal values for habitat variables, including woody debris. Many authors have discussed the importance of woody debris as complex, irregular instream cover for juvenile salmonids (e.g., Dolloff and Reeves 1990; Harvey 1998; Harvey et al. 1999; summarized by Healey 1991; Quinn and Peterson 1996; Sanderdock 1991). Water velocity less than 18 cm/sec is also important as a limit of the volume that may be occupied by young chinook salmon (Bendock and Bingham 1988; Bjornn and Reiser 1991; Burger et al. 1983; Chapman and Associates 1989; Murphy et al. 1989). Locations that are preferred by young chinook salmon are adjacent to faster currents which transport food items near the fish as they rest and wait in the slower water (Brusven et al. 1986; Chapman and Associates 1989; Everest and Chapman 1972). Published reports suggest that complex cover, usually in the form of instream woody debris, is an important component in rearing habitat because rearing fish compete for available food and cover provides focal sites for territorial fish so they can minimize energy loss while awaiting food and avoiding risk of predation (Angradi 1992; Chapman 1966; Dill and Fraser 1984; Dill et al. 1981; Dolloff and Reeves 1990; Everest and Chapman 1972; Fausch 1984; Harvey 1998; Johnsson 1993; Martel 1996; McNicol and Noakes 1984; Puckett and Dill 1985; Sundbaum and Näslund 1998).

Burger et al. (1983). performed limited food habit studies of juvenile salmon in the Kenai River, but they did not report evidence that these fish fed on salmon carcasses and offal. Observations and reports from other river systems, however, document heavy reliance by rearing chinook and coho salmon on salmon eggs and flesh from salmon carcasses (Bilby et al. 1996; Bilby et al.1998; Cederholm et al. 1999; Eastman 1996; Piorkowski 1995;) and the importance of carcasses to stimulate production of other food items (Bilby et al. 1996; Cederholm et al. 1999; Eastman 1996; Fisher Wold and Hershey 1999; Piorkowski 1995; Schuldt and Hershey 1995; Wipfli et al.1998; Wipfli et al.1999). The abundant food source from carcasses of spawning salmon, eggs and offal may be one possible explanation for why large numbers of juvenile salmon were observed at most study locations in the Kenai River during our study. In addition, with an abundant food supply, in both time and space, the reliance by juvenile salmon on streambank cover for feeding territories may also be reduced and they can utilize more of any available rearing water volume.

Functions of instream cover

Various roles or "functions" have been assigned to instream bank cover, including:

- increase visual isolation and partition the habitat and provide more "focal points" for territorial juvenile fish (Chapman 1966; Chapman and Associates 1989; Dolloff and Reeves 1990; Sundbaum and Näslund 1998);

- trap organic matter and prevent carcasses from being washed out of the river (Cederholm and Peterson 1985; Cederholm et al. 1989; Robison and Beschta 1990);
- slow the water velocity and increase optimal rearing areas (Fausch and Northcote 1992; Shirvell 1990; Robison and Beschta 1990);
- provide substrate for food for invertebrates (Bilby et al. 1998; Cederholm et al. 1999; Fisher Wold and Hershey 1999; Wipfli et al. 1998; Wipfli et al. 1999);
- create a refuge for the young fish during high water events (Harvey et al. 1999; Pearsons et al.1992; Shirvell 1990; Taylor 1988) and from predators (Harvey et al 1999; Holierhoek and Power 1995); and,
- influence channel morphology and shoreline features and control erosion (Fausch and Northcote 1992; Olson and West 1989; Hilderbrand et al. 1998; Robison and Beschta 1990; Rosenfeld et al. 2000).

Most of these functions are performed by some form of irregularity or roughness associated with streambank features below the water surface. Our study was not designed to evaluate which habitat variable is most important. We suggest, however, that the habitat variable which performs these functions most reliably in the Kenai River is woody debris below ordinary high water that is associated with the streambank. Another more subtle role of streambank cover in the Kenai River entails maintenance and enhancement of water flows that are favorable for rearing and movement of juvenile salmon. This may be particularly important to expedite any upstream movement by fry (Bendock 1989).

At various times, one or several of these functions may be more or less important to the young fish and not all can be expected to be equally important at all times. During 1999, for example, salmon escapement in much of the Kenai River drainage was good and ample numbers of salmon carcasses were deposited in the mainstem as a result of both spawning and angling activities. Under such conditions, decomposing carcasses not only stimulate invertebrate production but also provide food directly for the rearing salmon (Bilby et al. 1996; Bilby et al 1998; Cederholm et al. 1999; Eastman 1996; Piorkowski 1995) as well as for predators and competitors of juvenile salmon (Cederholm et al. 1989; Cederholm et al. 1999; Eastman 1996; Piorkowski 1995). Therefore, the importance for cover to provide focal points to enhance territorial defense and to produce invertebrate food items may be diminished. Woody debris below ordinary high water, however, is very important to retain carcasses and create slow water velocity for rearing space.

Conversely, during years when salmon carcass deposition is poor, the importance of cover to retain carcasses is greatly increased and the importance of territorial focal points, invertebrate food production, and refuge from predators is also increased. Streambank cover is important to help stabilize the banks, reduce erosion and increase the volume of slow water rearing areas. During high water events, streambank cover becomes imperative to help stabilize the banks and reduce erosion. In addition, under flood conditions, streambank cover is an important survival refuge for the young fish. If conditions are extreme, young fish may become dispersed onto the floodplain and lost. We speculate that those young salmon which find a refuge in streambank habitat are more likely to survive the extreme conditions than those which are dispersed onto the floodplain.

Under ordinary high water conditions, the Kenai River is usually slightly turbid from glacial runoff (Bendock and Bingham 1988; Burger et al. 1983; Dan Bosch, Division of Sport Fish Management, Anchorage, personal communication). This also provides some measure of protection for the rearing salmon from potential predators (Gregory 1993; Gregory and Levings 1998; Gregory and Northcote 1993; Reid et al. 1999; Vogel and Beauchamp 1999).

Implications for streambank treatments

We speculate that under usual summer conditions in the Kenai River; that is, under conditions of ordinary high water, ample recruitment, and ample carcass deposition, juvenile salmon have a reduced reliance on streambank cover and can fully utilize the available volume of optimal-velocity rearing water. However, the undisturbed and rehabilitated streambank cover is important to maintain a migration corridor, a complex streambank and to minimize erosion. Under extraordinary conditions; e.g., high water events or during periods of inadequate carcass deposition, streambank cover becomes more important for rearing salmon to avoid predation, to compete for available food, and to avoid being flushed downstream and to protect the streambank.

Recommendations

Cabled Spruce and Bioengineered treatments would probably provide better fish habitat than they do now with any installation design that will increase irregularity and complexity; e.g., with other woody debris designed and constructed as part of the project; or, by deploying spruce trees more diagonal or perpendicular to the water flow.

Additional studies to relate which habitat variables may be most important to juvenile salmon and design future rehabilitation and protection projects to maximize the installation of those variables; e.g., if slow velocity water and irregular woody debris is important, bioengineering projects should incorporate root wads into the foundation layer or the toe should include cabled spruce trees to provide those functions. Cabled spruce tree projects can limit the impact of erosion on natural banks which may need protection. However, if spruce trees were installed perpendicular to the bank at irregular intervals in addition to the traditional installation, cells of slow-velocity water and predator refuges may be increased.

Studies to evaluate the effectiveness of rehabilitation and protection projects to provide important habitat functions (e.g., slow water, predator or flood refuge) may be helpful rather than to simply measure the amount of each habitat variable. Studies may be devised, for example; to measure how the treatment affects the cross-sectional area of optimal water velocity, to evaluate if carcasses are retained, to determine that these treatments do provide refuge from predators and floods. Other studies may evaluate if the habitat variables in the treatments change before and after construction and over several years. We believe that Shoreline Complexity is an important habitat variable and a reliable method should be devised to measure it.

We believe that the modified depletion method and sampling procedure using baited-minnow traps does have merit as a quantitative measure of fish abundance. In the Kenai River, blocking nets to minimize immigration and emigration may be required and should be evaluated. Blocking nets may also be useful to reduce the number of sampling events. The more intensive trapping effort also seemed useful. In other systems, where the density of rearing fish is less, the method may be acceptable without modification.

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APPENDIX A.

Evaluation of Observer Measurement Error

Measurement of habitats or habitat variables is very difficult due to bias associated with observer errors which are further affected by normal fluctuations in physical and biological conditions. The inability to repeat a procedure or method for measurement reduces precision in the data collected (Platts et al. 1983). In our study, we attempted to evaluate observer error or variability for the following habitat variables: a) Fine Stem Debris Cluster, b) Other Woody Debris, c) Undercut Bank, d) Shoreline Complexity, e) Overhanging Vegetation, and f) Optimal water velocity. Final calculations were completed for Fine Stem Debris Cluster, Other Woody Debris and Undercut Bank.

METHODS

Observer error was minimized by employing two measures. First, one person from each data collection team was designated as the observer. The designated observer was the only person from that team who made data observations. Second, all observers practiced together before data were collected to provide quality assurance and consistent methodology for each variable measurement.

Between and within observer errors were measured at two study sites within each of the five treatments, totaling 10 replicate study site observations for each designated observer. A replicate observation for each of the variables at a study site was made at the 10 m and 20 m transects, only. An observation for determining within observer error at a specific study site was not made on the same day as the initial data collection. The intent was to reduce the ability of observers to remember characteristics at the site that they had previously used to identify habitat variables for measurement. Measurement error between readers was estimated as:

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

where:

BR = Between reader variability

R_{ij} = measurement by reader i at site j

$\overline{R}_j$ = average measurement by i at site j

n_j = number of measurements at site j

Measurement error within a reader was measured as:

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

where:

- WR = Within reader variability
- N_j = Number of measurements at site j
- R_{ijk} = Measurement by reader i at site j on trial k
- $\overline{R}_{ij}$ = Average measurement by reader i at site j
- N_k = Number of trials by reader i at site j

RESULTS

The difference between observers 1 and 2 for habitat variables measured in May, 1999, Fine Stem Woody Debris, Other Woody Debris, Undercut Bank, and habitat variables measured in August, 1999, Optimal Velocity, and Overhanging Vegetation was normally distributed with a mean of zero. Between reader variability was estimated to be:

Variable	Mean Relative Precision	Sample Size
Fine Stem Debris Cluster (area/transect)	29%	33
Undercut Bank (total width)	19%	33
Other Woody Debris (area/transect)	9%	33
Optimal Velocity	17%	28
Overhanging Vegetation	56%	28

Within observer variability was estimated to be:

Variable	Relative Precision	
	Observer 1	Observer 2
Fine Stem Debris Cluster (area/transect)	35%	27%
Undercut Bank (total width)	16%	14%
Other Woody Debris (area/transect)	1%	21%
Optimal Velocity	83%	80%
Overhanging Vegetation	76%	71%

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