U.S. Fish & Wildlife Service

Salmonid use of the Bioengineered Revetment at the Maplewood Golf Course on the Cedar River, Washington

Western Washington Office
Aquatic Resources Division

Lacey, Washington
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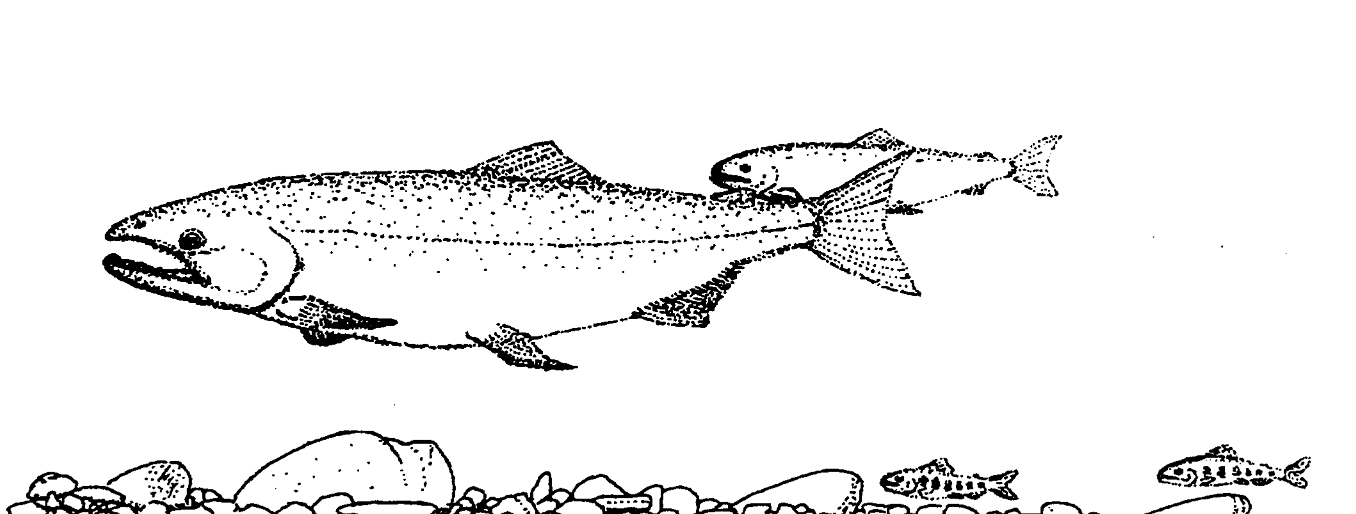

Salmonid Use of the Bioengineered Revetment at the Maplewood Golf Course on the Cedar River, Washington.

Report to the Army Corps of Engineers

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Abstract.-This study was conducted to determine what influence modifying a riprap revetment in the Cedar River had on seasonal fish densities and habitat complexity. The riprap revetment was modified to a revetment consisting of rock deflectors and large woody debris (LWD). We compared bi-weekly fish densities at the new revetment to a control area just upstream. The control area was a natural bank and was considered representative of other un-reveted banks in the Cedar River. We also compared winter and spring fish densities observed at the new revetment during 1999 to those observed at this revetment during 1997, prior to its modification.

Relative densities of salmonid parr, sculpin, and total salmonids were consistently greater at the new revetment than the control during almost all surveys. Chinook salmon fry densities were generally less at the new revetment than the control during winter, but were generally greater at the new revetment than the control during spring.

Relative densities of salmonid parr, sculpin and total salmonids at the new revetment location were greater during the winter of 1999, after the revetment was modified than 1997, prior to revetment modification. However, relative densities of chinook salmon fry were less in 1999 than 1997. No fish were observed during spring surveys in either year.

Habitat complexity increased at the new revetment with the placement of instream LWD and rock deflectors. The combination of materials created a series of diverse secondary habitat units (backwaters and dead-water pools) that were absent in the riprap revetment. The placement of LWD and rock deflectors created deeper pools, more instream cover, and more backwater and dead-water pools than in the riprap revetment.

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Introduction

The Cedar River is important in the life history of several populations of Pacific salmonids. Sockeye salmon (*Onchorynchus nerka*), chinook salmon (*O. tshawytscha*), coho salmon (*O. kisutch*), steelhead trout (*O. mykiss*), and cutthroat trout (*O. clarki clarki*) utilize various sections of the river during their life cycle. One of the key factors affecting salmonids is lack of suitable rearing habitat. The lower Cedar sub-basin has a comprehensive system of levees and revetments that provide limited salmonid habitat features.

The Army Corps of Engineers (Corps) recently modified the Maplewood Golf Course revetment on the Cedar River. The historic method of bank protection in this location was riprap, but in 1998, the Corps re-constructed the site into a bio-engineered revetment incorporating a combination of large woody debris (LWD) and rock deflectors for fish habitat.

A study conducted by the U.S. Fish and Wildlife Service (Service) showed that juvenile salmonid densities were greater at bank stabilization sites that incorporated large woody debris (Peters et al. 1998). That study also showed that salmonid densities were lower at riprapped banks. One of the Service's study locations was the riprap revetment at the Maplewood Golf Course on the Cedar River. Snorkel surveys were conducted at this location during spring 1997 and 1998, summer 1997, and winter 1998 (December 1998 - March 1999). Since the Service has background data on this site, the Corps requested that the Service monitor fish densities during 1999 and compare them to the background data.

The objectives of this study were: 1) compare relative densities at the new revetment to the control; 2) compare relative densities at the new revetment to the old revetment; and, 3) compare habitat complexity at the new revetment to the old revetment.

Study Area

The Maplewood Golf Course revetment is located on the Cedar River at river kilometer (Rkm) 6.9. The Cedar River is one of five major rivers in King County and is the largest tributary to Lake Washington. The river drains an elongated basin of 486.9 square kilometers that extends westward from the crest of the Cascade Mountains to the southern shore of Lake Washington in the City of Renton. The lower Cedar River watershed is heavily urbanized and has a comprehensive system of revetments and levees that, in combination with a dam, protect residents in the valley, as well as homes and commercial property in downtown Renton (Figure 1).

The bio-engineered revetment consists of a series of LWD structures, rock deflectors, a rock toe, and native vegetation (Figure 2). The revetment study reach is 62 meters(m) long and 5 m. wide. The control site is approximately 200 m. upstream of the revetment, directly across from the sockeye salmon spawning channel constructed by King County. The control site dimensions were 63 m. long by 3.5 m. wide and were representative of natural river banks within the system.

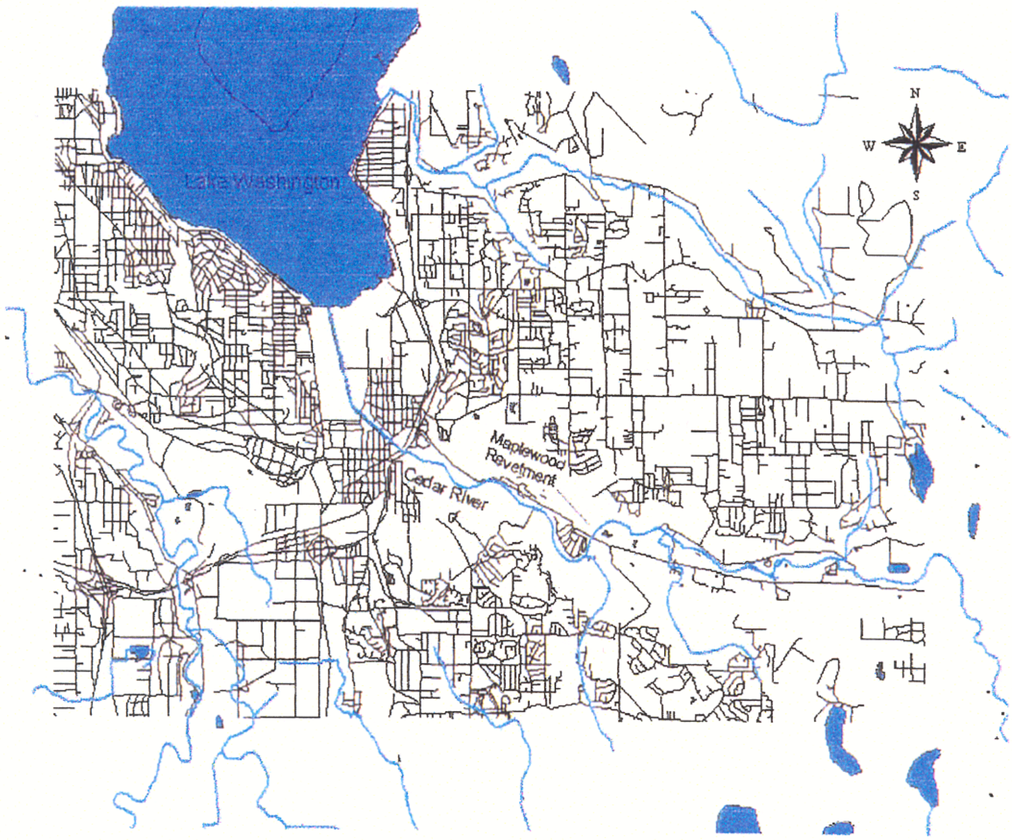

Figure 1. Lower Cedar River Watershed

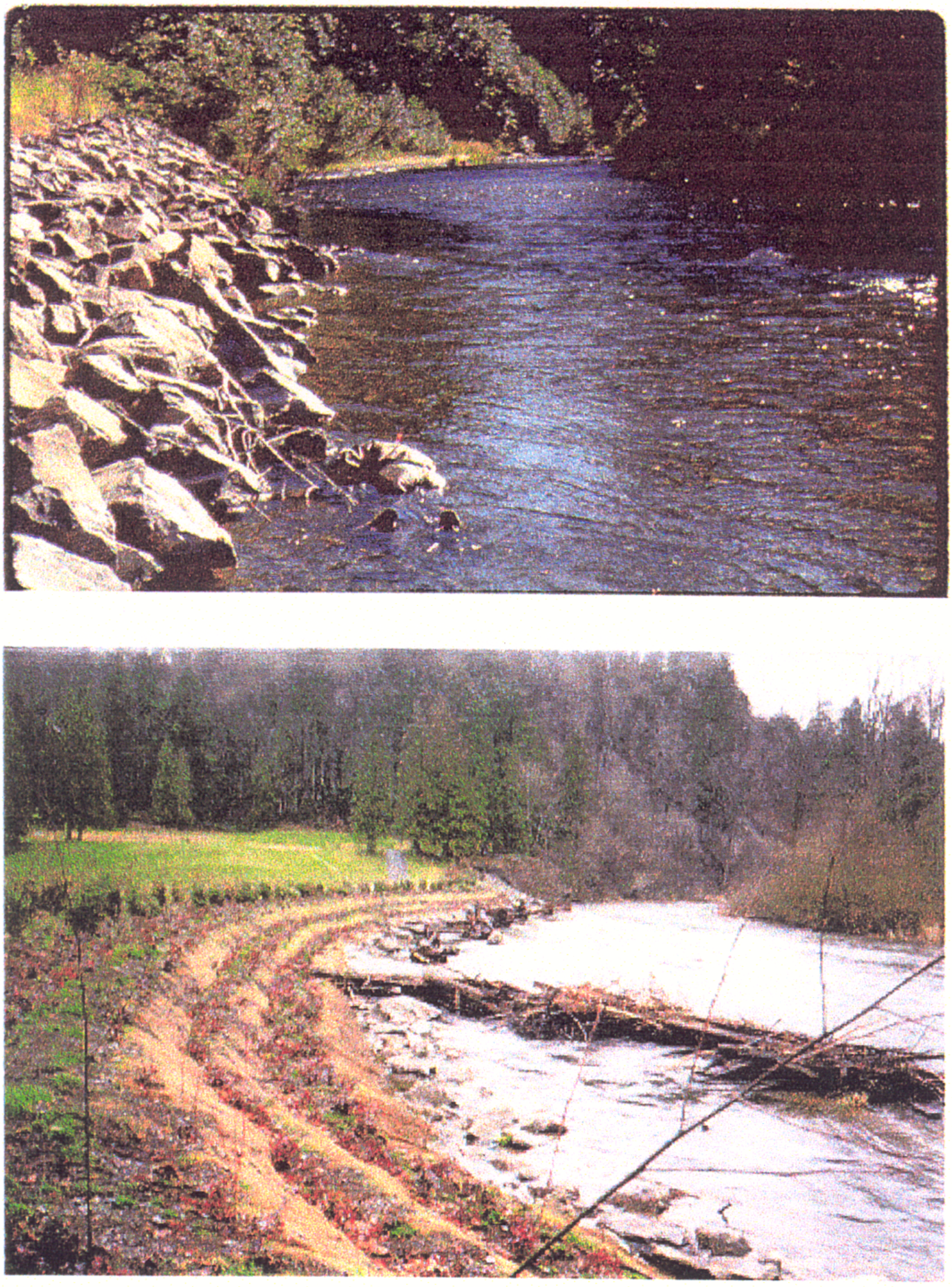

Figure 2. Top: Maplewood riprap revetment pre-reconstruction, summer 1997. Bottom: Reconstructed revetment with rock deflectors and LWD, winter 1998.

Methods

For this study, we conducted two separate comparisons. We compared relative fish densities from multiple observations collected on a bi-weekly basis at the new LWD and rock deflector revetment to those at the control area. The control site selected for comparison was a naturally stable area similar in river morphology and meso-habitat features to the study reach. We also compared relative fish densities from a single winter and a single spring survey from 1997/1998 (riprap revetment) to a single winter and spring survey from 1999 (LWD and rock deflector revetment). We selected the winter and spring dates from 1999 surveys to match as closely as possible to the date we conducted the 1997/1998 surveys.

Fish Densities

Snorkel surveys commenced on February 11, 1999, and were conducted bi-weekly until June 28, 1999. Surveys were separated into winter and spring time periods. Winter surveys were conducted from February 11, 1999, to March 22, 1999, whereas spring surveys were conducted from April 4, 1999, to June 28, 1999. Surveys were conducted at night during both sample periods and commenced at least 1 hour after sunset. Surveys were conducted at night because the literature suggests that many fish, especially salmonids, seek refuge during the day and emerge at night during the winter (Heggenes et al. 1993; Riehle and Griffith 1993; Contor and Griffith 1995). However, we conducted one daytime survey in spring of 1999 to compare counts to those of 1997, in which the survey was conducted during the day. All surveys were conducted when river flows were between 450 cubic feet per second (cfs) and 1300 cfs. Surveys were not conducted at flows above 1300 cfs due to poor visibility and safety concerns.

Three snorkelers started at a downstream reference point and snorkeled slowly upstream. All salmonids were counted, and identified to species when possible. Fish counts were recorded on slates attached to the snorkeler's arm. Due to a low species abundance, our analysis was conducted on chinook salmon fry (30-90 millimeters (mm)), salmonid parr (50-100 mm), sculpin, and total salmonids. Non-chinook salmonids and trout (50-100 mm) were grouped into one category (parr) because of the difficulty distinguishing between salmon parr and trout parr at night. A large portion of fish moved away from the light, which made identification difficult. Larger trout and salmon were grouped into 100-200 mm and 200+ mm categories. All non-salmonid species were counted and identified to family or species when possible.

Fish abundance was estimated using the bounded-count methodology (Regier and Robson 1967) as follows:

$$N=2N_{m} - N_{m-1}$$

where N is the estimate of fish abundance, N_m is the largest of the three counts, and N_{m-1} is the second largest count. The lowest count is not included in the estimate.

Densities for comparison between the revetment site and control site were calculated as follows:

Revetment density (D_r) = fish bounded count/revetment length

Control density (D_c) = fish bounded count/control length

We then calculated relative densities for winter and spring comparison of the old revetment to the new revetment as:

Revetment relative density = $(D_r - R_d)/R_d$

Control relative density = $(D_c - R_d)/R_d$

Where:

Reach density (R_d) = $C_r + C_c / L_r + L_c$

and where C_r and C_c are the revetment counts and control counts, respectively; L_r and L_c are the revetment length and control lengths, respectively.

The relative density value is between -1 and infinity. The negative value would indicate lower than average density, and a positive value would indicate greater than average densities.

Habitat

We measured riverine and secondary habitat at both locations during a variety of flows. Habitat measurements were taken if flows were greater or less than 20% of the previous time we measured habitat. Riverine habitats were classified as pools, riffles, glides, or runs, following Bisson et al. (1982) and Helm (1985). Pools were further classified as lateral scour, straight scour, backwater, or dead-water following Bisson et al. (1982). We also classified and measured meso or secondary habitats within the project site. Secondary habitats are sub-units of the main-stem habitat that fish would use for rearing, such as backwater and dead-water pool. Secondary habitats were classified using the same criteria as the riverine habitats. We measured length, width, maximum and average depth, current velocity, substrate composition and embeddedness, percent overhanging vegetation (within 30 centimeters (cm) of the water surface), and instream woody debris for each secondary habitat.

Length and widths of secondary habitats were measured using a laser range-finder or stadia rod. Depths were measured using a stadia rod and current velocities were measured with a Swoffer Model 2100 current meter. Substrate composition was recorded during the snorkel surveys. We recorded the size and percent of the dominant and subdominant substrates visually, based on Cummings (1962) (Table 1).

Table 1. Substrate classifications used for this study (Cummings 1962)

Substrate	Description/particle size range (mm)
Silt/sand	0.0039 - 2
Gravel	2 -64
Cobble	64-265
Boulder	>256
Bedrock	Exposed underlying rock not distinguishable as a boulder
Debris	Bottom covered with terrestrial debris such as leaf litter and/or small woody debris

Woody debris was counted, classified by type, measured for length and width, and visually classified with regards to complexity. Woody debris type was classified as log, tree, log jam, rootwad, or small woody debris. The complexity of the woody debris structure was classified as sparse, medium, or dense. Single logs without branches were classified as sparse, logs with some branches as medium, and complex log jams, rootwads, or trees were classified as dense.

We compared secondary habitat features by calculating the weighted variable means using the following formula:

$$(L_1*V_1)+(L_2*V_2)+(L...*V...)/PL$$

where L is the length of an individual secondary habitat, V is the habitat feature (i.e., flow, depth, etc.) for that particular habitat, and PL is the length of the project.

Results and Discussion

Fish Densities

Relative densities of chinook salmon fry were generally less at the new revetment site than the control during the 1999 winter surveys. However, relative densities were generally greater at the new revetment than the control during the 1999 spring surveys (Figure 3). Increased chinook salmon relative densities later in the year may be associated with changes in habitat preferences with fish size and/or reduced avoidance of potential predators (sculpins and parr). In un-revetted sections of the Cedar River, chinook salmon fry appear to prefer habitats near the river bank that

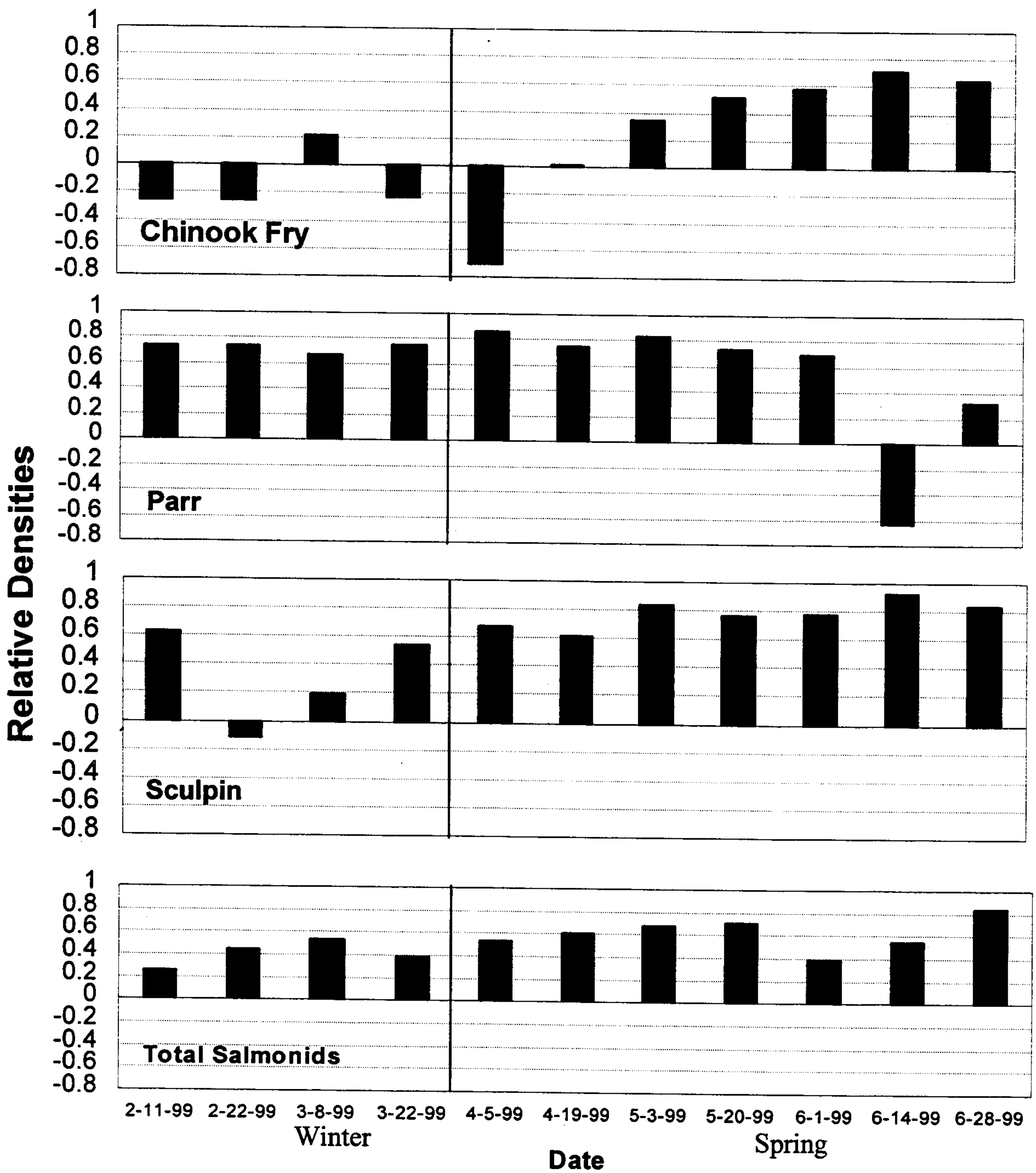

Figure 3. Relative densities of chinook salmon fry, parr, sculpins and total salmonids at the new revetment. The control site relative densities would be opposite (+/-) in sign from the revetment densities. Relative densities range between -1 and infinity.

have shallow water (5-9 cm), low current velocity, and gradual slopes (less than 20^0) (authors' personal observations, 1999). These habitat types were lacking at the new revetment where toe rock created a nearly vertical wall from the toe to the water surface at most discharges.

Potential predators of chinook salmon fry (sculpins and parr) were very abundant (parr density range: 95-1790 fish km^{-1}; sculpin density range: 161-5967 fish km^{-1}) at the new revetment. The combination of LWD and rock deflectors created a series of slow-water, backwater, and dead water pools allowing predators to find food (that tends to congregate in backwater and dead water pools) without expending much energy. This may have resulted in avoidance of the site by chinook salmon fry until later in the year when they reached a size where predation by these predators was no longer a threat. Relative densities of chinook salmon fry were less at the reconfigured revetment site in winter 1999 than the old revetment site in winter 1997 (Figure 4). No chinook salmon fry were observed during the day at the revetment site during spring surveys in either year. Two potential reasons why chinook salmon were not observed are: 1) the surveys were conducted during the day, when fry were hiding, and 2)chinook salmon fry were absent from the site because the lack of overhead cover makes the habitat unsuitable at both revetment sites. Moreover, these comparisons were inconclusive because we only surveyed the old revetment once during each sample period.

Relative densities of salmonid parr (50-100 mm) during the 1999 surveys were consistently greater throughout both periods at the new revetment than the control (Figure 3). Relative densities were consistent throughout the survey period except on the June 14 sample date, when densities were lower. Slow-water refuge habitat created by the LWD and rock deflectors in the revetment, and juvenile salmonid foraging opportunities (sockeye fry tend to seek out slow-water for refuge), are two potential reasons why parr were more common at the reconstructed revetment. Unlike chinook salmon fry, relative densities of salmonid parr were greater at the new revetment during winter 1999 surveys than at the old revetment during winter 1997 surveys (Figure 4). No parr were observed at the revetment or control site during spring surveys in either year, again, possibly because lack of overhead cover or the time of day when the surveys were completed.

Relative densities of sculpin were greater at the new revetment than the control throughout the 1999 survey period, except on the February 22 sample date, when relative densities were slightly lower (Figure 3). More sculpin were observed at the revetment than the control most likely because of the availability of slow-water refuge habitat and cover provided by the rock toe. Sockeye fry also took refuge in these slow-water areas during periods of higher light levels, which created feeding opportunities for sculpin preying on sockeye fry (R. Tabor, USFWS, Pers. Comm.). Sculpin relative densities were greater in winter 1999 at the new revetment than the old revetment in winter 1997, but the increase was not as great as that observed for salmonid parr (Figure 4). No sculpin were observed during spring surveys in 1999 or 1997, probably because the surveys were conducted during the day, when sculpin were hiding.

Relative densities for total salmonids were consistently greater at the new revetment than the

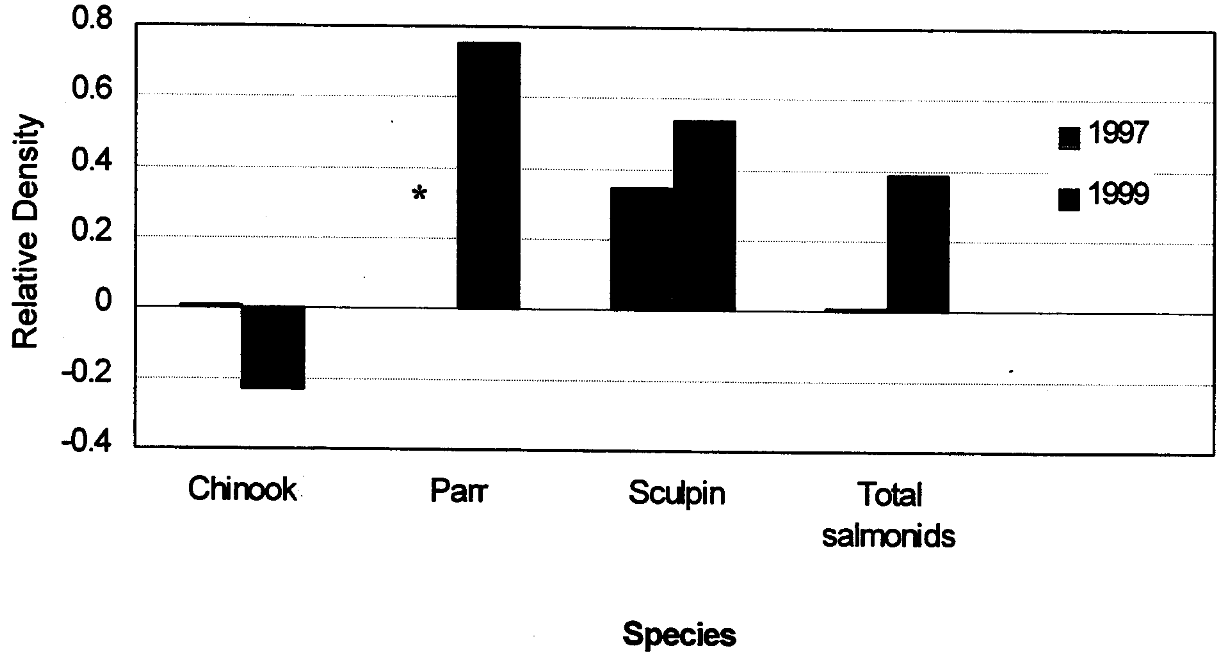

Figure 4. Comparison between the new (1999 winter) and old (1997 winter) revetments. Asterisk denotes zero fish observed, n=1.

control throughout the 1999 survey period (Figure 3). Relative densities were greater at the new revetment in winter and spring 1999 compared to densities at the old revetment in winter and spring 1997 (Figure 4).

Habitat

A change in the number of secondary habitats in 1999 was observed in both the revetment and control during a single survey conducted under high flow conditions. According to U.S. Geological Survey real-time data, the flows during this single survey were 1260 cfs. At 1260 cfs, the hydraulic complexity of the reach is different, causing a change in secondary habitats. The new revetment changed from three to five secondary habitats, and the control changed from six to four secondary habitats. However, the number of secondary habitats remained consistent at flows below 1260 cfs. The placement of LWD and rock deflectors in the new revetment created the change in hydraulic complexity and secondary habitats observed at 1260 cfs. We speculate that the combination of LWD and rock deflectors provides better habitat under high flow conditions. However, at some point, the flows may be high enough to overtop the structure, and may not provide sufficient cover, but we did not observe any flows of this magnitude.

Characteristics of secondary habitats also changed between 1999 and 1997. Weighted mean water column velocities decreased during both sample periods in 1999 compared with 1997.

Table 2. Comparison of habitat features for spring and winter 1997 and 1999.

	Winter		Spring	
	1997	1999	1997	1999
Discharge	1170	1260	575	750
No. secondary habitats	2	5	1	3
Flow (cm s^{-1})	34.4	14.3	46.6	5.8
Depth (m)	0.52	0.72	0.95	0.63
Large woody debris (m^2)	0	48.21	0	72
Primary substrate (%)	gravel (70%)	silt (64%)	cobble (80%)	silt (59%)

Weighted mean depth increased in winter 1999, but decreased in spring 1999 compared with 1997. Substrate composition changed from gravel/cobble in 1997 to sand/silt in 1999 (Table 2).

Secondary habitat complexity increased substantially at the new revetment (1999) compared to the old revetment (Table 2). During both winter and spring sample periods there were more secondary habitats in the new revetment (1999) than the old revetment (1997). Secondary habitat at the riprap revetment was primarily a lateral scour pool with fairly uniform depth and velocity along the length of the project. In comparison, secondary habitats in the reconstructed revetment were much more diverse, including backwater, dead-water, and lateral scour pools with a variety of depths and flows. Mean velocities at the old revetment were greater than 30 cm s^{-1}, while those at the new revetment were much less than 30 cm s^{-1} (Table 2). Juvenile salmonids generally prefer velocities less than 30 cm s^{-1} (Murphy et al. 1989; Beecher et al. 1993), suggesting that, strictly from a velocity perspective, habitat availability was much greater at the new revetment than the old revetment.

LWD

Large woody debris surface area was higher in the new revetment (1999) than the old revetment (1997) (Table 2); no LWD was present in the revetment prior to re-construction. Placement of LWD in the new revetment created more habitat complexity than the riprap in the old revetment. Peters et al. (1998), found that juvenile salmonid densities were directly related to LWD surface area because LWD created a series of slow-water and backwater refugia that fish prefer for rearing. Large woody debris is also responsible for the change in substrate from gravel/cobble to silt/sand. As the water velocity at the revetment slowed (due to the hydraulic roughness provided by LWD), the river was able to release finer elements of its sediment load, thereby changing the substrate in the revetment to one dominated by sand and silt.

Peters et al. (1998), also found lower fish densities at combination LWD and rock deflector projects similar to the Maplewood revetment than at their controls. The placement, size, and presence of complex rootwads characteristic of the LWD in the Maplewood project may have contributed to the greater relative densities of fish compared to its control, where LWD was (mostly) absent.

Large woody debris is very important to juvenile salmonids in larger rivers, such as the Cedar River, because salmonids, and other fish, benefit from slow-water habitat and overhead cover provided by LWD (Peters et al.1998). Placement of LWD in the re-constructed Maplewood Golf Course revetment appears to have created a net gain in salmonid habitat in a system that is lacking suitable salmonid habitat. The Service recommends that as long as bank stabilization projects are going to be constructed or re-constructed, that complex LWD with rootwads intact (roots and all) be incorporated in the projects. The rootwad network provides small interstitial spaces that allow salmonid fry to escape from predation, and high flows, providing important refuge habitat.

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