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Effects of Riprap Bank Reinforcement on Juvenile Salmonids in Four Western Washington Streams

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Abstract.—Summer and fall juvenile salmonid populations in five pairs of stream sections were estimated shortly before and after construction of flood and erosion control projects. All five projects included bank reinforcement with rock riprap and three included streambed alterations. Juvenile coho salmon *Oncorhynchus kisutch*, juvenile steelhead *Salmo gairdneri*, and cutthroat trout *Salmo clarki* were apparently adversely affected by construction in the three smaller, and most severely altered, stream sections. Numbers of juvenile coho salmon and young-of-the-year trout were reduced somewhat, but those of yearling steelhead and cutthroat trout apparently increased, in the two newly riprapped sections of larger streams. Negative short-term effects of construction appeared to increase with severity of habitat alteration, to decrease with increase in stream size, and to decrease with increasing fish size.

Many streams in western Washington have been channelized for flood control and erosion reduction by the placement of rock riprap against the banks, alteration of the streambed, or both. Previous research regarding the effects of this kind of habitat alteration in western Washington has indicated losses of salmonid production under certain conditions in streams having discharges of less than 10 ft^3/s (Chapman and Knudsen 1980). However, work on larger streams west of the Cascade Range has been limited to that of Cederholm and Koski (1977), who reported large decreases in salmonid production after channelization (but not riprapping) of Big Beef Creek, a medium-size western Washington stream. Most other studies on the effects of channel modification have been conducted on streams outside of western Washington.

Several recent studies have addressed the effects of other habitat changes on salmonids. Bryant (1983) documented the importance of large woody debris as juvenile salmonid habitat in small streams. Elliott (1986) reported that removal of large logging debris from small streams of southeast Alaska caused an initial reduction in large Dolly Varden *Salvelinus malma* due to reduced habitat and the loss of smaller individuals during November freshets thereafter. House and Boehne (1985) demonstrated that enhancement of habitat diversity in a western Oregon stream increased the carrying capacity for young salmonids. Brusven et al. (1986) reported that simulated undercut banks were an important summer habitat component for juvenile chinook salmon. Together, these studies indicate that reduction of habitat diversity, as might occur during the riprapping of a stream bank, may be detrimental to juvenile salmonids.

We studied populations of juvenile salmonids at five locations just before and shortly after rock riprap was placed for bank protection during the summer of 1979. These projects were undertaken as a result of flood damage in 1975 and 1977 and were sponsored by the U.S. Soil Conservation Service (SCS) under the Emergency Watershed Protection Program. Construction at each site was done according to general limitations of hydraulic permits from the Washington Department of Fisheries; consequently, gross effects on the fish resources were prevented. An SCS inspector was present at each site to ensure adherence to permit restrictions. The objective of this research was to determine whether a stream's carrying capacity for juvenile salmonids was reduced shortly after common flood control practices were conducted.

Study Areas

The five study sites were on four streams in central western Washington. Big Mission Creek and the Deschutes River drain into Puget Sound, and Decker and Beaver creeks drain into the Chehalis River, which flows into the Pacific Ocean (Figure 1). All five of the study sites were accessible to anadromous salmonids and would generally be considered as good-to-excellent spawning and rearing habitats. The streams flow through mixed coniferous and hardwood forests in a climate of cool rainy winters and dry summers.

At each of the five sites, we chose two study sections—an upstream control section and a test

TABLE 1.—Study sites, 1979 sampling dates, mean discharge at time of sampling, and type of flood-control construction.

Study stream	Sampling dates	Mean discharge (m^3/s)	Type of construction: Streambank relocation	Riprap placement	Streambed alteration
Decker Creek	28 Jun–6 Jul	6.40	No	Yes	No
	28 Aug–5 Sep	6.42			
Big Mission Creek	10 Jul–13 Jul	0.64	Yes	Yes	Yes
	18 Sep–27 Sep	0.56			
Beaver Creek	18 Jul–31 Jul	0.40	Yes	Yes	Yes
	28 Sep–4 Oct	0.43			
Lower Deschutes River	1 Aug–10 Aug	4.90	No	Yes	No
	16 Oct–24 Oct	11.58			
Upper Deschutes River	9 Aug–21 Aug	2.40	Yes	Yes	Yes
	3 Oct–11 Oct	1.53			

section at the construction site. Selections of upstream control sections were based on similarities to the construction site and on accessibility. In no case were the upstream control sections less than 300 m nor more than 1,000 m from the construction section. We attempted to encompass the boundaries of the proposed bank alteration when selecting the construction site test sections. The type of flood-control construction, dates of sampling, and mean discharges of the study streams are shown in Table 1.

Methods

We sampled the paired study sections by identical methods insofar as possible. We electrofished the previously designated section, usually using 400 V DC from a Coffelt pulsator powered by a 115-V generator onshore or in a small boat. Each section was sampled just prior to construction and then 1–3 weeks after construction was completed.

Fish were collected during two or three passes with the electrofishing gear and, where possible, the area was thoroughly seined. At Beaver Creek, which was smaller than the other creeks, fish were collected with a backpack shocker. Fish were separated into four categories; coho salmon *Oncorhynchus kisutch*, young-of-the-year (age-0) trout (steelhead *Salmo gairdneri* and cutthroat trout *Salmo clarki* less than 70 mm long), yearling and older steelhead, and yearling and older cutthroat trout. We found it was necessary to combine age-0 trout because we were unable to separate small steelhead from small cutthroat trout in the field. Individuals in a subsample were weighed to the

TABLE 2.—Salmonid population estimates (±95% confidence limit) at five pairs of test and control stream sections in western Washington before and after flood control construction. Petersen estimates were made from electrofishing data only, except where noted.

Study stream	All salmonids: Before	All salmonids: After	Coho salmon: Before	Coho salmon: After	Age-0 trout: Before	Age-0 trout: After
Test sites						
Decker	1,532±593	1,954±632[a]	98±108[a]	256±108[a]	1,306±516	1,045±379[a]
Big Mission	2,382±677	817±60	1,795±555	628±54	521±175	132±20
Beaver	26±8[b]	14±2[b]	13±21[b]	5±1[b]	13±6[b]	0
Lower Deschutes	332±112[a]	724±184[a]	0	0	87±47[a]	0
Upper Deschutes	588±190	209±51	359±125	113±34	22±16	3±4
Control sites						
Decker	372±137	450±242[a]	42±27	52±43[a]	358±176	299±211[a]
Big Mission	1,299±339	827±105	1,159±336	714±94	149±59	51±17
Beaver	20±2[b]	42±1[b]	16±3[b]	27±1[b]	2±0[b]	0
Lower Deschutes	374±134[a]	281±113[a]	73±39[a]	38±25[a]	70±38[a]	0
Upper Deschutes	327±128	535±93	234±98	321±59[a]	11±11	3±4[a]

[a] Petersen estimate from combined electrofishing and seining data.

[b] Removal method.

nearest 0.1 g. All fish were marked, in a manner similar to that described by Fay and Pardue (1985), with a freeze-brand specific for that study section, date, and capture technique. Fish were recaptured 2–4 d later by electrofishing and by seining (if possible).

Field experience indicated that the best Petersen estimates of population size could be derived by including fish caught by both electrofishing and seining. To test the validity of this, we applied Seber's (1973) methodology for evaluating stratified mark and recapture data. We tested for random mixing, tagging, and recovery between species and gear types at tagging and recovery, and we found that data from shocking and seining could be combined to derive a single Petersen estimate.

We obtained population estimates based on Seber's (1973) equation for the simple Petersen estimate, with a 95% confidence interval, for all salmonid species combined and for separate species for which the numbers of recaptured marked fish exceeded seven. Seber's equation for estimating a subpopulation, which has its own estimate of a 95% confidence interval, was used when less than seven fish were recaptured. For the smaller Beaver Creek, we used Seber's two-sample removal method for estimating the population of each species.

The population estimate for each species category was multiplied by the average fish weight to estimate the biomass. The combined biomass of salmonid species in each section was estimated by proportioning the estimated population according to the percentage of each species in the catch, multiplying by the average weight of fish of that species, and summing the biomass for all species.

TABLE 2.—Extended.

Steelhead		Cutthroat trout	
Before	After	Before	After
Test sites			
42±32	459±179[a]	0	16±16[a]
66±35	37±12	7±10	14±7
1±0[b]	9±1[b]	3±0[b]	2±0[b]
246±94[a]	695±180[a]	4±5[a]	28±17[a]
128±57	61±21	22±16	15±10
Control sites			
5±6	89±69[a]	0	3±7[a]
0	28±18	29±19	19±10[b]
3±1[b]	15±3[b]	0	0
174±78[a]	222±112[a]	28±19	30±21[a]
50±33	102±31	13±13	23±4

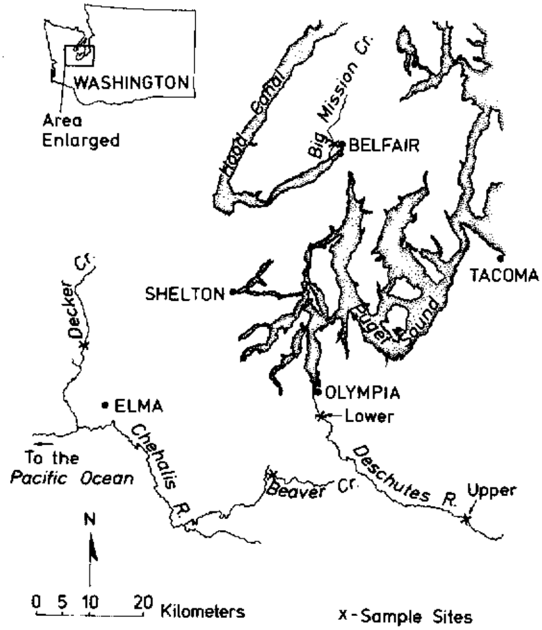

FIGURE 1.—Locations of the five stream study sections in western Washington.

The length of each study section was measured along the center to the nearest 0.1 m. Width was measured at the center of, and at the boundaries between, each pool, riffle, and glide. These measurements were used to calculate the area of the study section.

The biomass for each species and for all salmonid species combined was divided by the area of the section to estimate standing stock, which we accepted as an index of the ability of that section to support juvenile anadromous and resident salmonids. This statistic was then used for the comparisons of study sections before and after stream alteration.

Because discharges were approximately an order of magnitude higher at Decker Creek and the lower Deschutes River than at the other study areas, we decided to analyze results from those two sites separately from those of the smaller streams. Then, following a method of presentation used by Hartzler (1983), we compared the standing stocks for each species category at the small- and large-stream test sections before and after construction. The Wilcoxon two-sample test (Sokal and Rohlf 1981) was used to determine whether densities had changed significantly for the small-stream sections; there were too few observations to test for statistical differences at the large-stream sections. Because several months had elapsed between preconstruction and postconstruction sampling, changes in standing stocks were probably influenced by growth, emigration, or immigration, as well as by the effects of construction. Consequently, we made similar comparisons of standing stocks for the control sections before and after construction. Our assumption was that standing stock changes due to natural phenomena would occur similarly in the test and control sections if there were no effect of the habitat alteration.

Results

Population estimates are shown in Table 2. Comparisons of biomass in the small-stream test and control sections before and after construction showed that the total biomass of all salmonids decreased, although not significantly, in the combined test sections, but increased in the combined control sections, after construction (Table 3). In large-stream sections, however, the biomass increased substantially after construction, more so in the altered than in the control sections. Explanations for this outcome probably reside in differences in habitat usage among species and in the severity of habitat alteration at each study location.

Biomass of coho salmon decreased somewhat in the small-stream combined test sections, but increased slightly in the combined control sections (Table 3). Coho salmon biomass increased more in the large-stream control sections after construction than it did in the test sections, indicating that construction may have reduced the carrying capacity of the test sections. These results led us to believe that juvenile coho salmon were negatively affected by the stream alterations. There were no coho salmon in the lower Deschutes test section either before or after construction.

Age-0 trout biomass decreased equally in the combined small-stream test and control sections (Table 3). Large-stream biomass of age-0 trout decreased slightly in the test sections and increased somewhat in the control sections, perhaps indicating a reduction in large-stream habitat quality.

Juvenile steelhead biomass increased significantly at the combined small-stream control sites and decreased at the combined test sites, indicating that the habitat alterations had negative effects on juvenile steelhead (Table 3). Juvenile steelhead biomass increased dramatically in the large-stream combined test sections after construction compared to those in the control sections. Much of the increase occurred at the lower Deschutes section and may be attributable to the section's pool-like characteristic, both before and after construction, and to the movement of juvenile steelhead downstream as they grew.

Cutthroat trout biomass in the small streams was apparently negatively affected by construction (Table 3). Standing stocks increased at control sections but decreased somewhat in the test sections. Large-stream cutthroat biomass increased substantially in the test sections but decreased in control sections, indicating improvement of cutthroat trout habitat.

Stream Habitat Management Implications

Flood control construction activities appeared to have affected summer and fall salmonid carrying capacity in various ways that depended on (1) size of the stream, (2) size of the juvenile salmonids, and (3) severity of habitat alterations. The small-stream sections apparently suffered more serious reductions in carrying capacity than did the larger streams. Whitney and Bailey (1959) found drastic reductions in numbers and biomass of trout after alteration of a small Montana stream for highway construction. Chapman and Knudsen (1980) found dramatic decreases in juvenile salmonid biomass in a small western Washington stream 10 d after streambed alteration. They also reported significantly reduced biomass of cutthroat trout and juvenile steelhead in channelized sections of small streams at least several years after channelization. Salmonids use somewhat different habitat structure in small streams than they do in large streams. Recent studies have demonstrated the need for diverse habitat structure in small salmonid streams (Bryant 1983; Elliott 1986; Heifetz et al. 1986). The alterations to small-stream test sections in our study were drastic enough to eliminate many of the pools and much of the streamside cover, which partially explains the more serious reduction in biomass there than in the large-stream sections.

In larger streams, smaller salmonids may be more seriously influenced by habitat alteration than larger salmonids. Coho salmon exhibited reductions in test sections of both small and large streams and age-0 trout were reduced in the larger streams. Again, the loss of natural fish habitat features such as undercut banks, log snags, and streamside hanging vegetation may be more detrimental to smaller than larger salmonids in larger streams just as it is to all salmonids in small streams. Marzolf (1978)

TABLE 3.—Estimated salmonid standing stocks (g/m²) before and after flood control construction at small- and large-stream test and control sections, western Washington.

Fish group and stream	Test sections: Before construction	Test sections: After construction	Test sections: Change	Control sections: Before construction	Control sections: After construction	Control sections: Change
Small-stream sections						
All salmonids						
Big Mission	7.09	6.39	–	6.49	7.07	+
Beaver	0.66	0.87	+	0.35	0.79	+
Upper Deschutes	3.61	1.19	–	1.29	4.67	+
Total	11.36	8.45	–26%	8.13	12.53	+54%
Coho Salmon						
Big Mission	3.91	3.80	–	5.60	4.14	–
Beaver	0.16	0.16	0	0.21	0.40	+
Upper Deschutes	1.62	0.56	–	0.93	2.91	+
Total	5.69	4.52	–20%	6.74	7.45	+10%
Age-0 trout						
Big Mission	0.69	0.73	+	0.28	0.26	–
Beaver	0.16	0.00	–	0.03	0.00	–
Upper Deschutes	0.04	0.00	–	0.02	0.02	0
Total	0.89	0.73	–18%	0.33	0.28	–15%
Steelhead						
Big Mission	2.27	1.36	–	0.00	1.23	+
Beaver	0.01	0.44	+	0.14	0.38	+
Upper Deschutes	0.87	0.49	–	0.23	0.93	+
Total	3.15	2.29	–27%	0.37	2.54	+586%[a]
Cutthroat Trout						
Big Mission	0.12	0.64	+	0.79	1.74	+
Beaver	0.36	0.56	+	0.00	0.00	0
Upper Deschutes	0.94	0.05	–	0.06	0.14	+
Total	1.42	1.25	–12%	0.85	1.88	+121%
Large-stream sections						
All salmonids						
Decker	4.74	9.01	–	0.30	1.11	+
Lower Deschutes	2.47	14.60	+	3.23	3.47	+
Total	7.21	23.61	+227%	3.53	4.58	+30%
Coho Salmon						
Decker	0.26	0.34	+	0.07	0.15	+
Lower Deschutes	0.00	0.00	0	0.28	0.60	+
Total	0.26	0.34	+31%	0.35	0.75	+114%
Age-0 trout						
Decker	3.14	3.09	–	0.16	0.51	+
Lower Deschutes	0.24	0.00	–	0.21	0.00	–
Total	3.38	3.09	–8%	0.37	0.51	+38%
Steelhead						
Decker	1.18	5.52	–	0.07	0.36	+
Lower Deschutes	2.15	13.95	+	1.03	2.79	+
Total	3.33	19.47	+485%	1.10	3.15	+186%
Cutthroat Trout						
Decker	0.00	0.17	–	0.00	0.02	+
Lower Deschutes	0.12	0.42	+	1.29	0.36	–
Total	0.12	0.59	+392%	1.29	0.38	–70%

[a] Significant difference ($P < 0.10$).

and Hortle and Lake (1983) reported that loss of habitat structure was detrimental to fish standing stocks. Larger salmonids may be better able to use nonstructural habitat features in large streams, such as depth, for cover. Small salmonids may also decrease in such habitats acceptable to larger salmonids because of predation by the larger salmonids.

We subjectively judged the severity of the test section habitat alterations to be, in order of decreasing severity, those of the upper Deschutes, Big Mission, Beaver, Decker, and lower Deschutes. This was based on how much of the streambed was graded and leveled by bulldozers working in the stream, the amount of natural streamside cover that was replaced by riprap, and the degree to which machinery operated within the streambed to place the riprap. The severity of habitat alterations in this study coincided with the sizes of the streams; the three most severely altered sections were on the three smallest streams and those sections exhibited the most detrimental effects on salmonid biomass from habitat alteration. This may be due to the impracticality of heavy equipment working directly in the deeper water of the larger streams and the resultant placement of the riprap by equipment working from shore. Whitney and Bailey (1959) and Chapman and Knudsen (1980) also reported substantial salmonid reductions in severely altered stream channels. Lund (1976) indicated that standing stocks in totally altered Montana stream sections were reduced below densities in the unaltered control sections but that standing stocks in partly altered areas sometimes exceeded those of unaffected controls.

We believe that short-term and localized detrimental effects of bank reinforcement may be less serious in large streams than in small streams. Future studies of this type should attempt to determine the long-term effects of incremental additions to the total length of riprapped streambanks on salmonid productivity.

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