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Channelization and Livestock Impacts on Salmonid Habitat and Biomass in Western Washington

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Abstract

We examined salmonid habitat and biomasses in 50–70-m pairs of altered and control sections of small (discharges less than 0.3 m^3 $second^{-1}$) streams around Puget Sound in western Washington in 1978–1979. Altered sections had been channelized or used by livestock. Channelization significantly reduced overhead cover, sinuosity, wetted area, and woody bank cover while increasing bank grasses. Total habitat area declined in altered areas. These impacts most damaged the quality of habitat for cutthroat trout (*Salmo clarki*) over 70 mm in length. Biomass of coho salmon (*Oncorhynchus kisutch*) did not decline significantly in altered sections except in areas severely damaged. Zero-age trout (cutthroat and steelhead, *Salmo gairdneri*) suffered no loss of habitat quality, although larger trout did, except in areas of severe physical impact. Short-term effects of machinery operation in the one stream for which data were obtained included biomass depletions of all salmonid species and size classes. Channelization and livestock use appeared to reduce quality of winter habitat for salmonids. In altered sections with stable bottoms, no recent damage history, relatively little silt and sand, and adequate riffle areas, the reduction in overhead cover appeared to lead to higher standing crops of salmonids, suggesting that fish production in many streams of the Puget Sound area may be light-limited.

Channelization for flood control, stream clearance, urban construction, agricultural convenience, and highways has altered thousands of stream kilometers in western Washington (Washington Department of Fisheries 1974) with assumed deleterious effects on anadromous salmonids. Livestock grazing and trampling have altered many additional areas. We assessed the effects of these activities on habitat and biomass of salmonids in 36 streams (Fig. 1) around Puget Sound.

The United States Bureau of Indian Affairs and the United States Fish and Wildlife Service supported the study in preparation for litigation concerning degradation of fish habitat in western Washington since 1855, when the United States of America negotiated treaties with various Indian tribes.

Methods

We sampled channelized and livestock-impacted streams in three periods: June 1 to July 30, 1978; August 1 to September 30, 1978; and in midwinter, 1978–1979. In addition, to assess immediate effects of channel modification, we sampled one stream before, and shortly after, machinery disrupted it. We worked almost exclusively in streams with flows of less than 0.3 m^3 $second^{-1}$.

Channelized sections included stream areas that machinery had altered in the previous 10 years for flood control, urban construction, agriculture, or for highway rights-of-way. Sections altered by livestock lay in pastures used currently or very recently.

We selected for study those sections to which coho salmon (*Oncorhynchus kisutch*) appeared to have access, according to the Catalog of Washington Streams and Salmon Utilization (Washington Department of Fisheries 1974) or our field observations. The streams studied lie in the lowlands of Puget Sound and foothills of the Cascade Range. When relatively undisturbed by man, they meander through thickets of brush or stands of red alder (*Alnus rubra*). Presence of very large stumps in most drainages indicates that the original canopy consisted of conifers with a very light understory of ond pass did not equal at least 40% of the first-pass catch. We maintained fish from each pass in separate buckets or live cages. We could not separate 0-age cutthroat trout (*Salmo clarki*) from 0-age steelheads (*Salmo gairdneri*) in the field, hence classified both as "0-age trout." The terms "cutthroat trout" and "steelhead" thus refer to yearling or older fish.

After measuring and counting fish from each pass, we calculated salmonid population sizes, by species, with the two-removal method (Zippen 1958). Occasionally the catch on the second pass exceeded that during the first pass. In these cases a principal assumption of the catch-removal method became invalid: that of equal probability of capture of each fish on each pass. To overcome this difficulty we estimated populations with the second and third passes, then added the first-pass catch to the estimated population. We assumed that after the first pass, fish behavior did not change and each fish had an equal probability of capture on second and third passes.

Once populations had been estimated, we used length tallies of the catch for each species to prepare a mean or median length by species (we used medians where the sample size exceeded 30 fish), and then converted the mean or median lengths to mean weight with a length-weight curve for juvenile coho salmon and cutthroat trout. We converted lengths for the few steelheads in our samples to weights with the curve for cutthroat trout. With mean fish weight and population estimates by species we estimated total biomass of salmonids in the section by species and biomass per unit of habitat.

We used the nonparametric Wilcoxon signed-rank test (Hollander and Wolfe 1973) to compare biomasses in tests and controls. Possible differences in fry recruitment in different stream pairs, as well as nonrandom selection of sections, precluded use of normal methods such as a *t*-test of differences between pairs. We first compared total biomass of coho salmon, cutthroat trout, 0-age trout, and all salmonids in altered and control sections of equal (or corrected to equal) straight-line length. This statistic incorporated elements of habitat quantity and quality because it encompassed losses of habitat caused by lost sinuosity as well as any detrimental effects of alteration such as siltation and cover loss. Secondly, we examined mean biomass per square meter in test and control sections, a statistic which more directly measures habitat quality because it eliminates effect of lost sinuosity.

We use the term "significant" for any statistical probability level equal to or less than 0.10.

Habitat Characteristics

Channelization of 24 test sections that we examined from June 1 to July 30 significantly decreased sinuosity by a mean of 10%, wetted stream area by 20%, and overhead cover by 89% compared with control sections (Table 1). Bank cover tended toward grasses and away from woody vegetation in test sections. We found no difference between test and control reaches in the volume of pools and glides, or in percentages of riffles and fine sediments.

We found similarities and differences between test and control reaches during the second half of the summer (Table 1).

In each of the two summer sampling periods, stream reaches used by livestock had significantly less wetted area and overhead cover, and more bare or grassy bank area than control reaches (Table 1). Other variables did not differ significantly between test and control reaches. Reduction in stream areas, coupled with no reduction in the volume of pool and glide, indicates that in pastures streams tend to narrow and deepen.

Our information shows the reduction in total habitat area caused by channelization and, to a lesser extent, livestock-related impacts. Channelization reduced stream area largely by reducing sinuosity. Livestock occasionally reduced stream width by trampling in the stream margin, usually on the gently sloping side of the stream, breaking up the bank and creating a mud morass which encroached on the channel. In some instances, grasses encroached on the channel in lightly grazed pastures, causing the deepening and narrowing noted by White and Brynildson (1967).

Salmonid Biomass

In the first half of the summer we found that 24 channelized sections did not have significantly altered mean biomass per square meter for coho salmon or for 0-age trout, but had significantly less mean biomass per square meter for cutthroat trout and for all salmonids combined (Table 2). Channelized sections did

TABLE 2.—*Biomass of salmonids per unit area in channelized and livestock-altered reaches, compared with respective control sections, western Washington, 1978.*

Variable	Channelized streams				Livestock-altered streams			
	Coho salmon	Cutthroat trout	0-age trout	All salmonids	Coho salmon	Cutthroat trout	0-age trout	All salmonids
				June 1–July 30				
Numbers of pairs	22[a]	23[a]	24	24	12	12	12	12
Habitat area (m^2)								
Test sections	3,800	3,874	4,423	4,423	2,323	2,323	2,323	2,323
Control sections	4,843	5,017	5,515	5,515	2,879	2,879	2,879	2,879
Mean biomass (g/m^2)								
Test sections	0.78	0.80	0.48	2.12[b]	1.33	0.78	0.68	3.05[b]
Control sections	0.66	1.52	0.37	2.61[b]	0.71	1.42	0.33	2.65[b]
Probability	NS	0.10	NS	0.10	NS	NS	0.10	NS
Total biomass (g)								
Test sections	2,973	3,080	2,105	9,357[b]	3,090	1,823	1,579	7,080[b]
Control sections	3,211	7,606	2,025	14,397[b]	2,041	4,099	961	7,638[b]
Probability	NS	0.10	NS	0.10	NS	NS	0.10	NS
				August 1–September 30				
Numbers of pairs	19[a]	20	20	20	10	10	10	10
Habitat area (m^2)								
Test sections	3,019	3,110	3,110	3,110	1,621	1,621	1,621	1,621
Control sections	3,576	3,584	3,684	3,684	1,979	1,979	1,979	1,979
Mean biomass (g/m^2)								
Test sections	1.30	0.52	1.23	3.15[b]	1.26	1.02	2.14	4.45[b]
Control sections	1.35	1.21	0.71	3.59[b]	1.68	1.75	1.04	4.63[b]
Porbability	NS	0.10	0.10	NS	NS	0.10	NS	NS
Total biomass (g)								
Test sections	3,915	1,625	3,839	9,797[b]	2,041	1,649	3,466	7,356
Control sections	3,211	7,606	2,025	14,397[b]	3,319	3,457	2,057	9,157[b]
Probability	NS	0.10	NS	0.10	NS	0.10	NS	NS

[a] Pairs were excluded if they did not contain this species in the control.

[b] Estimates to the left do not sum to this total because the latter includes some steelhead. Biomasses of steelhead can be found by subtraction.

and control sections, total biomass provides the best measure of the total effect of channelization and livestock-related impacts on populations residing within the sections. The total biomass statistic incorporates possible effects of such diverse features as substrate composition, overhead cover, sinuosity, and wetted area. Our information shows significant reduction in total habitat area in channelized and livestock-altered sections in comparison with paired controls. Channelized and livestock-altered reaches contained less mean biomass per square meter and less total biomass for cutthroat trout. Cutthroat trout prefer pool habitat with cover overhead (Nickelson 1975) and often with pockets under cutbanks or logs. One or more of these features disappear with channelization or livestock use.

Young-of-year trout suffered no loss of biomass in altered sections. In fact, mean biomass of 0-age trout in channelized sections in the latter half of the summer exceeded that in control reaches. We noted the same phenomenon in livestock-altered reaches in the first half of the summer. This may relate to relatively low abundance of large cutthroat trout in altered sections, a factor which tends to make the environment somewhat more congenial for newly emerged trout fry. In all sets of comparisons (all test sections compared with all controls for both parts of the summer), presence of lower cutthroat trout biomass per square meter correlated with higher 0-age trout biomass (see section on canopy reduction, below). Whatever the cause for the correlation (habitat alteration or associated reduction in predator biomass), spurred on by the observation of field crews that "more light means more fish in the sections."

These somewhat exceptional stream sections appeared to differ from other impacted reaches in that they had not recently been seriously disrupted, and had relatively low quantities of silt and sand, little or no overhead cover, and obvious crops of periphyton.

We compared the 10 channelized or livestock-altered sections in which total and mean fish biomass substantially exceeded that in controls with 40 other test sections. The exceptional sections had significantly larger percentages of their area in riffle, less overhead cover, and less substrate consisting of sand or finer particles than did the other 40 test sections. They differed from their control reaches only in having less overhead cover. We infer that light is an important limiting factor for salmonid biomass in summer in many streams.

Mean biomass in the 10 altered sections equalled 1.32, 1.95, and 1.51 g/m^2 for 0-age trout, coho salmon, and cutthroat trout, respectively. In their control sections the mean biomass equalled 0.49, 0.60 and 1.11 g/m^2 for 0-age trout, coho salmon, and cutthroat trout, respectively. Thus for all three major components of the salmonid biomass, the mean biomass index was greater in altered sections. Because mean biomasses of 0-age trout and coho salmon in the 10 exceptional sections exceeded substantially the mean biomasses of these salmonid groups in associated control reaches even though cutthroat trout biomass in the altered sections also exceeded that in controls, we infer that in at least these exceptional sections, the effects of increased light outweighed predator-prey relationships influencing biomass of 0-age trout. Hall et al. (1977) demonstrated that canopy removal in small streams of the Cascade Range in Oregon resulted in increased biomass of cutthroat trout. Several authors have stressed the importance of streamside vegetation in maintaining moderate stream temperatures in streams of the intermountain west (Gunderson 1968 and Platts 1978). The latter authors studied streams strikingly different from those in western Washington. But even in a few streams examined in our Puget Sound study, removal of the canopy and streamside vegetation over substantial reaches apparently caused very low salmonid biomasses and proliferation of threespine sticklebacks (*Gasterosteus aculeatus*) which prefer higher water temperatures than do salmonids. Hence one should approach vegetation management cautiously, perhaps leaving alternating reaches of canopied stream to cool the water. But it is clear that careful studies of canopy removal in western Washington could yield information useful in the study of limiting factors and possibly of utility in stream management for habitat improvement.

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