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Beaver Dam Locations and Their Effects on Distribution and Abundance of Coho Salmon Fry in Two Coastal Oregon Streams

Abstract

Beaver (*Castor canadensis*) dams and coho salmon (*Oncorhynchus kisutch*) fry were examined for their relationships in two coastal Oregon streams in 1987. Our initial spring survey of 19 km of stream found only one dam still complete after winter. By autumn, the number of dams had increased to 1.1 and 1.2 per km on the two streams. Beaver dams increased summer pool habitat 7 to 14 percent over unmodified conditions. Although density of coho (per m^2 and m^3) was similar among pool types, beaver ponds were larger and contained more coho fry than non-beaver pools; thus, beaver increased rearing habitat for coho during the late summer low flow. Beaver represent a low-cost tool deserving more consideration for stream rehabilitation projects.

Introduction

Although there is evidence that coho salmon fry use beaver ponds as rearing habitat in the Oregon Cascade Mountains (Everest and Sedell 1983; Everest *et al.* 1985) and in southeastern Alaska (Sanner 1987), beaver generally have been considered detrimental to salmonid populations. Dams have been viewed as barriers to migration and so have been removed (Salyer 1935a,b, Bradt 1947, Patterson 1950, Reid 1952, Marston and Jong 1978, Marston and Deming 1979). Much is known about the general effect of beaver on rivers and streams (Naiman *et al.* 1986), but little reserach has been done in the Northwest, especially in the Oregon Coast Range. The impact of beaver dams on streams and their fish populations may be different in the Coast Range relative to that in the Cascade Mountains or southeastern Alaska because of differences in climate, topography, forest types, and forest management. Most beaver dams in coastal Oregon streams are ephemeral, being washed out in heavy winter storms and rebuilt the next summer (Maser *et al.* 1981). Thus, applicability of existing research on beaver-fish interactions to the Oregon Coast Range is uncertain.

Our objectives in this study were to identify characteristics associated with dam location in two coastal Oregon streams and to assess the effect of stream modification by beaver dams on the rearing habitat of coho salmon.

Study Sites

The two study streams in the central Oregon Coast Range, Cummins Creek and Cape Creek (Figure 1), are underlain by basalt and flow directly into the Pacific Ocean. Both are within the *Picea sitchensis* Zone (Franklin and Dyrness 1973) in which mean minimum temperature in January is 0-2.5°C and mean maximum temperature in July is 20-25°C. The zone receives 200-300 cm of precipitation yearly, most of which falls as rain from October through May.

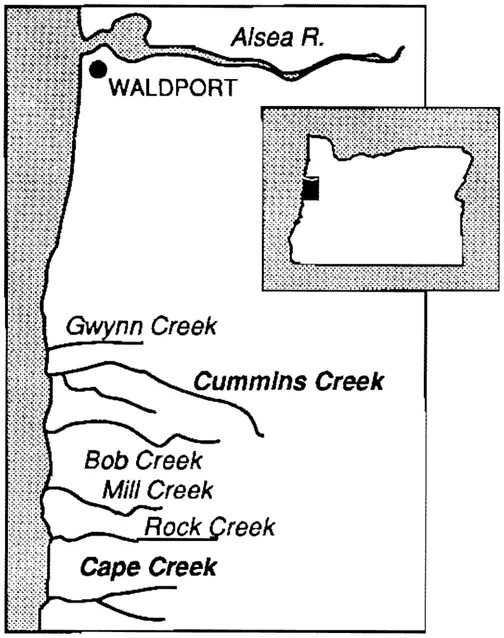

Figure 1. Location of the study sites, main Cape Creek, and Cummins Creek, Oregon.

Cummins Creek

Cummins Creek is a fourth-order 11-km stream draining a watershed encompassing 2,100 ha in a trellis drainage pattern (the main channel being fed by small tributaries that intersect it at approximately right angles). Average active channel width is the summer is 3 m, and average gradient is 3 percent over the sampled length. The pool:riffle ratio is nearly 4:5; summer discharge near the mouth averages 0.28 m^3/s. The floodplain is wide, 5 to 50 m, and the stream is often braided. Spawning gravel, rearing habitat, and aquatic macroinvertebrate production were judged excellent for juvenile salmonids by Marston and Deming (1979). Gravel bars dominate the channel and are usually associated with large woody debris. There are several log jams, and the upper reaches of the stream are structured with log steps. The basin is moderately stable, although debris slides do occur in undisturbed areas.

Except for the lower 0.4 km, the watershed is managed by the U.S. Forest Service as a wilderness area. Hence, Cummins Creek is in an old-growth watershed except for three small clearcuts (adjacent to a total 350 m of stream) created in 1955, 1963, and 1966-67. Overstory vegetation consists of red alder (*Alnus rubra*), Sitka spruce (*Picea sitchensis*), and Douglas-fir (*Pseudotsuga menziesii*); western redcedar (*Thuja plicata*) and western hemlock (*Tsuga heterophylla*) become more abundant in the upper reaches. Understory vegetation is mainly salal (*Gaultheria shallon*) and salmonberry (*Rubus spectabilis*).

Cape Creek

The main stem of Cape Creek is a fifth-order 15.3-km stream that drains a watershed encompassing 3,292 ha in a dendritic stream pattern, with three major tributaries. The average stream width is 4 m, and the average gradient is 3-4 percent over the sampled length. The pool:riffle ratio is 3:4; summer discharge near the mouth averages 1.3 m^3/s.

More than 70 percent of the watershed has been logged since 1948, generally without maintaining any mature forest buffer strips along streams. In addition, the lower 1.9 km of the main stem was mined for gravel in the late 1950's. The stream has long stretches devoid of large organic debris but is punctuated by large debris jams established by mass wasting from hillside clearcuts and midslope roads or by logging debris. There is little opportunity for a steady addition of large organic debris to the stream as most of the streamside overstory vegetation is young alder that has regenerated after clearcutting. Sitka spruce, western redcedar, Douglas-fir, and western hemlock are also present. The understory is mainly salmonberry and thimbleberry (*Rubus parviflorus*).

Methods

We surveyed the lower 7-8 km of each stream (to the upper limit of coho distribution) for beaver dams and for coho salmon use in April-May and September of 1987. We divided the stream into natural habitat units (reaches) and classified each as pool, riffle, or glide (Hankin and Reeves 1988), then visually estimated their average length, width, and depth. Every tenth unit was measured to provide a correction factor for the visual estimates. Corrections were applied in the mathematical analysis. Definitions of the habitat units, from Bisson *et al.* (1982), are based on occurrences during high water flow as follows:

Pool—an area (including beaver ponds) that is scoured

Riffle—an area of deposition

Glide—an area in which neither deposition nor scouring occurs

Because the volume of the streams decreased substantially from high water in the spring to low water in the fall, a relative measure (percent volume) of the stream in each habitat type was used in comparing results of the spring and fall surveys.

As physical variables generally play an important part in determining dam location (Slough and Sadleir 1977, Howard and Larson 1985, Beier and Barrett 1987) and as they may be important to fish populations, we also examined geomorphology and vegetation. Habitat features potentially important to beaver dam construction were measured along 30-m transects on each side of the stream at each dam site ($n = 16$) and at sites located at random distances from the stream mouth but more than 100 m from beaver activity. Variables measured were: proximity to log jams, debris slides, and tributaries; bank slope along a 30-m transect perpendicular to each stream; stream gradient; stream width and depth; and cover by woody plant taxa of the understory (less than 2 m tall), midstory (2-10 m tall), and overstory (greater than 10 m tall). Nonparametric discriminant analysis—the k nearest neighbor method, PROC DISCRIM method = NPAR (SAS Institute, Inc., 1987)—was used to identify habitat features that best separated dam sites from random unused sites.

Divers counted coho salmon fry in each habitat unit in the fall by the method described by Hankin and Reeves (1988). Other fish species were not counted. Number of fry per pool and densities were calculated as the sum of the product of habitat-specific densities and habitat frequencies. Student's *t*-test was used to compare the total number of coho fry in beaver and non-beaver pools and the density of fish in pools with the density in glides and riffles.

Results and Discussion

Beaver Dams

In the spring, Cummins Creek had no beaver dams and Cape Creek only one. Casual observation showed that dam construction began in late June, although most construction was done in July and August. We observed new dams being started as late as September. In the fall, we located eight dams (1.2 dams/km) on Cummins Creek and eight (1.1 dams/km) on Cape Creek, low densities in comparison with those found by Naiman *et al.* (1986) in Quebec, Canada (8.6-16.0 dams/km).

The mean sideslope was significantly different ($P \leq 0.05$) on used sites (dams) and unused sites on Cape Creek, the former having a lower slope (10.5%, SD = 2.8 versus 24.8%, SD = 6.7). Slopes of used and unused sites on Cummins were not significantly different, the mean sideslopes being almost identical (9.2% and 8.3%, respectively). The differences may be largely a consequence of the geomorphological difference between the two streams. Nonetheless, the sideslope on used sites was similar on both creeks, approximately 10 degrees. Cummins Creek has a wider flood plain, so neither used nor unused areas are steep.

The tendency of beaver to avoid steep bank slopes has been shown in two other western studies that have examined this variable (Beier and Barrett 1987, McComb *et al.*, 1990) and may be a general western behavior. In contrast, in the Midwest, Urich *et al.* (1983) found that beaver selected steep banks.

Because the sample size was small, the model for discriminant analysis of physical and vegetation variables important to dam location is not presented here. However, the results are at least indicative of relationships and so have some use. Proximity to logjams, tributaries, and debris slides accounted for 52 percent of the model variation, indicating the importance of pre-existing structures to the location of dams. The dams frequently were built on or in front of logjams, or on large wood in the stream channel. Three vegetation variables accounted for an additional 23 percent of the variation. Midstory and overstory conifer cover had a negative association while midstory vine maple (*Acer circinatum*) was positively associated.

The percent volume of streams in non-beaver pools in the spring and fall surveys was fairly constant (Figure 2); however, beaver pools added 7 percent more habitat in Cummins Creek and 14 percent more in Cape Creek—12 percent and 22 percent of the total fall pool volume, respectively. Beaver ponds, on average, were from 3 to 4 times larger than pools formed by other means (Figure 3). Some beaver dams enlarged present pools, often at the expense of riffle or glide habitat. Other dams created pool habitat from riffles or glides.

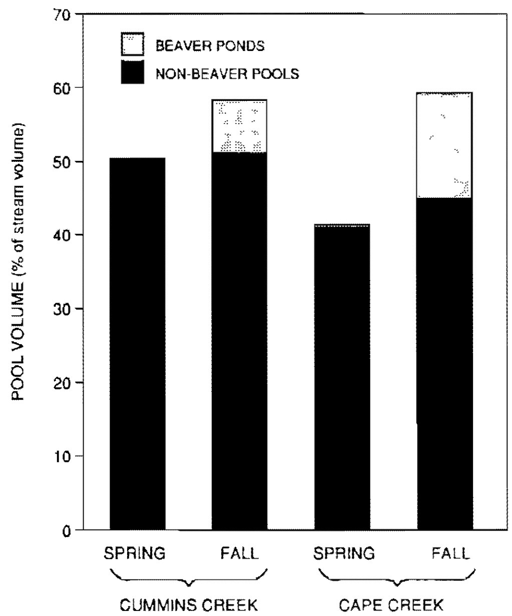

Figure 2. Changes in the percentage of stream volume in pool habitat in Cummins and Cape Creeks, 1987. In the spring survey, no beaver ponds were present at Cummins Creek, and only one small beaver pond at Cape Creek.

Fish-beaver Interactions

The total coho salmon counts of Cape and Cummins Creeks were 8,767 and 3,437, respectively (Table 1). Coho salmon fry were 2 times more abundant in pools than in glides and 40 times more abundant in pools than in riffles, which supports

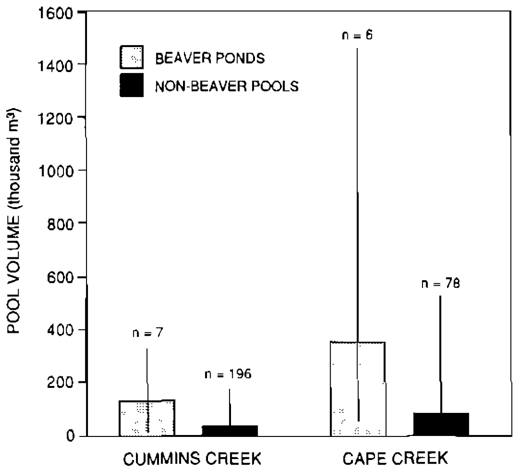

Figure 3. Mean volume and ranges for beaver ponds and non-beaver pools. Cummins and Cape Creek, fall 1987. Number of pools and standard error are shown.

the conclusion that the fry are typically found in pools (Bisson *et al.* 1982, Sedell *et al.* 1984). We also found that coho distribution terminated upstream at a large logjam on Cummins Creek, and that where Cape Creek became very small, beaver dams were not associated with the upstream limit of the coho. The upper limit of coho on Cape Creek appeared to be associated with a continued diminution of stream width and an increase in stream gradient.

The mean number of coho fry in beaver ponds was three times the mean number in non-beaver pools, although the variance was too high to be statistically significant (Table 2). Density of coho fry by area and volume did not differ in beaver ponds and non-beaver pools; thus, it appears that the fry use the habitat created by beaver in these streams. We have no evidence that fry were actively selecting beaver ponds; rather, they were using large pools, and beaver ponds tended to be larger than non-beaver pools.

The presence of beaver in these two coastal Oregon streams seemed to affect coho populations positively by increasing the availability of pools, the preferred coho habitat (Bisson *et al.* 1988). We did not observe the decreases in density that have been reported in the midwestern United States for fish species of that region (Salyer 1935a,b, Patterson 1950, Reid 1952). The coastal streams are steeper, faster, and generally colder in summer than midwestern streams, where large temperature rises and low levels of dissolved oxygen are associated with beaver dams in the low-gradient stream systems. In this coastal environment, the moderate slowing and deepening of

TABLE 1. Total stream length, area and volume in the habitat units, and average coho salmon density in each unit. N is the number of units sampled in fall 1987.

Stream habitat unit	N	Length (m)	Area (m^2)	Volume (m^3)	Average fish density m^{-2}	Average fish density m^{-3}
Cape Creek						
Pool	22	2,307	19,210	8,935	0.554	1.500
Glide	12	2,898	21,321	3,965	0.080	0.387
Riffle	10	3,050	22,527	2,478	0.014	0.143
Cummins Creek						
Pool	42	3,741	22,518	7,430	0.107	0.332
Glide	18	2,322	13,341	2,601	0.036	0.156
Riffle	30	4,856	23,310	2,833	0.000	0.000

TABLE 2. Comparison of coho fry populations in beaver and non-beaver pools, by pool, density per area, and density per volume. Values are for Cape Creek and Cummins Creek combined, fall 1987. Student's *t*-test was used to compare population sizes.

Population	Beaver ponds (n = 14) Average	Beaver ponds (n = 14) (SD)	Non-beaver pools (n = 45) Average	Non-beaver pools (n = 45) (SD)	*P*
Coho/pool	108.43	(179.68)	35.62	(56.76)	0.16
Coho/m^2	0.34	(0.38)	0.26	(0.38)	0.49
Coho/m^3	0.95	(0.75)	0.71	(1.02)	0.43

streams by beaver dams improves the quality of summer habitat by increasing the amount of slow water in pools (Bisson *et al.* 1988). Beaver ponds raise the level of a stream and may also provide access to side channels as the water level decreases, therefore preventing fry from becoming stranded in side-channel ponds.

Our spring survey showed that most dams were destroyed by winter high water; however, they were not always washed entirely away. Remnant ends of dams along banks may provide some slow-water refuge (sensu Sedell *et al.* 1990) during high water events. The side channels, canals, and dams developed at a beaver site also could be important winter habitat for coho fry. Careful study of stream energetics is needed to evaluate if beaver-caused changes in the stream system result in changes in fish productivity or changes in the composition of the fish community.

An important question to ask, but for which answers can only be speculative, is why there are so many more coho salmon in Cape Creek than in Cummins Creek. The streams differ in both small and large ways; any or all of which may contribute to the difference in coho population size. A very significant difference between the streams is their management history, which suggests testable hypotheses on the interactions between coho populations and streamside community structure and disturbance. Off-shore harvest of salmon may also have affected within-stream populations.

Management Implications

Stream enhancement projects instituted in some anadromous fish streams in the Pacific Northwest (Bisson *et al.* 1987) have demonstrated that structures can increase spawning or rearing habitat (Everest and Sedell 1983), but they have also shown that stream enhancement can be expensive (Bisson *et al.* 1987). Costs for placing an individual boulder ranged from $22 to $35. The estimated average cost for an individual gabion was $1200. Installation of gabions to retain spawning gravel in tributaries of the Coos River in Oregon cost $225,000 in 1981, excluding costs of engineering design and roads (Bisson *et al.* 1987). These projects may be more costly than foregoing timber harvest to allow beaver and riparian trees to contribute to stream structure (House and Crispin 1990).

On banks of low-gradient coastal streams that have been extensively harvested and cleaned, beaver offer an alternative to engineered improvements aimed at increasing coho-rearing habitat. While beaver dams are not structurally the same as other accumulations of large woody debris, they can provide some of the same benefits: increased pool area in the stream, slower water, increased productivity in pools (Naiman *et al.* 1986, 1988), and refuge during high water. Hence, maintaining high beaver densities in coastal streams is an additional tool to be considered in the development of management strategies for coho salmon production.

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Literature Cited

Beier, P., and R. H. Barrett. 1987. Beaver habitat use and impact in Truckee River Basin, California. J. Wildl. Manage. 51:794-799.

Bisson, P. A., R. E. Bilby, M. D. Bryant, C. A. Dolloff, G. B. Grette, R. A. House, M. L. Murphy, K. V. Koski, and J. R. Sedell. 1987. Large woody debris in forested streams in the Pacific Northwest: Past, present, and future. *In* E. O. Salo and T. W. Cundy (eds.) Streamside Management: Forestry and Fishery Interactions. Proceedings of a symposium. College of Forest Resources, University of Washington, Seattle. Inst. For Resour. Contrib. 57. Pp. 143-190.

Bisson, P. A., J. L. Nielson, R. A. Palmason, and L. E. Grove. 1982. A system of naming habitat types in streams, with examples of habitat utilization by salmonids during low streamflow. *In* N. B. Armantrout (ed.), Acquisition and Utilization of Aquatic Habitat Inventory Information. Proceedings of a symposium. October 28-30, 1981, Portland, Oregon. American Fisheries Society, Western Division. Pp. 62-73.

Bisson, P. A., R. Sullivan, and J. L. Nielsen. 1988. Channel hydraulics, habitat use, and body form of juvenile coho salmon, steelhead and cutthroat trout in streams. Trans. Amer. Fish. Soc. 117:262-273.

Bradt, G. W. 1947. Michigan beaver management. Michigan Department of Conservation, Lansing. 56 pp.

Everest, F. H., and J. R. Sedell. 1983. Evaluation of fisheries enhancement projects on Fish Creek and Wash Creek, 1982 and 83. *In* Natural Propagation and Habitat Improvement. Vol. 1. Oregon, Suppl. A. Annu. Rep. U.S. Department of Energy, Bonneville Power Admin., Portland, Oregon. Pp. i-x.

Everest, F. H., J. R. Sedell, G. H. Reeves, and J. Wolfe. 1985. Fisheries enhancement in the Fish and Wash Creek Basin—An evaluation of in-channel and off-channel Projects, 1984. U.S. Department of Energy, Bonneville Power Admin., Portland, Oregon. 228 pp.

Franklin, J. F., and C. T. Dyrness. 1973. Natural vegetation of Oregon and Washington. USDA For. Serv. Gen. Tech. Rep. PNW-8. Pac. Northwest Forest Range Exp. Sta., Portland, Oregon. 417 pp.

Hankin, D. G., and G. H. Reeves. 1988. Estimating total fish abundance and total habitat area in small streams based on visual estimation methods. Can. J. Fish Aquat. Sci. 45:834-844.

House, R., and V. Crispin. 1990. Economic analysis of the value of large woody debris as salmonid habitat in coastal Oregon streams. USDI Bureau of Land Management, Oregon State Office, Portland, Oregon. Tech. Note T/N OR-7. 11 pp.

Howard, R. S., and J. S. Larson. 1985. A stream classification system for beaver. J. Wildl. Manage. 49:19-25.

Marston, D., and T. Deming. 1979. Stream assessment surveys. Stream assessment program. USDA, Siuslaw National Forest. Waldport Ranger District, Waldport, Oregon. 376 pp.

Marston, D., and B. Jong. 1978. Stream assessment surveys. Stream assessment program. USDA, Siuslaw National Forest, Waldport Ranger District. Waldport, Oregon. 270 pp.

Maser, C., B. R. Male, J. F. Franklin, and F. T. Dyrness. 1981. Natural history of Oregon coast mammals. USDA For. Serv. Gen. Tech. Rep. PNW-133. Pac. Northw. For Range Exp. Sta., Portland, Oregon. 496 pp.

McComb, W. C., J. R. Sedell, and T. D. Buchholz. 1990. Damsite selection by beavers in an eastern Oregon basin. Great Basin Nat. 50:273-281.

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Naiman, R. J., C. A. Johnston, and J. C. Kelley. 1988. Alteration of North American streams by beaver. BioScience 38:753-761.

Naiman, R. J., J. M. Melillo, and J. E. Hobbie. 1986. Ecosystem alteration of boreal forest streams by beaver (*Castor canadensis*). Ecology 67:1254-1269.

Patterson, D. 1950. Beaver-trout relationships. Wis. Conserv. Bull. 15:9-11.

Reid, K. A. 1952. Effects of beaver on trout waters. Northeast. Logger 1:7,31-32.

Salyer, J. C. 1935a. Preliminary report on the Beaver-Trout investigation. Amer. Game 24(6):13-15.

________. 1935b. A program of beaver management recommended for the maintenance of both beaver and trout in Michigan. Amer. Game 24(3):39,47-48; 24(4):55,62-64.

Sanner, C. J. 1987. Effects of beaver on Coho Salmon habitat, Kenai Peninsula, Alaska. Oregon State University, Corvallis. M.S. Thesis. 81 pp.

SAS Institute, Inc. 1987. SAS/STAT guide for personal computers, Version 6 edition. SAS Institute, Inc., Cary, North Carolina. Pp. 370-371.

Sedell, J. R., G. H. Reeves, F. R. Hauer, J. A. Stanford, and C. P. Hawkins. 1990. Role of refugia in recovery from disturbances: Modern fragmented disconnected river systems. Environ. Manage. 14:711-724.

Sedell, J. R., J. E. Yuska, and R. W. Speaker. 1984. Habitats and salmonid distribution in pristine sediment rich river valley systems: South Fork Hoh and Queets River, Olympic National Park. *In* W. R. Meehan, T. R. Merrell, Jr., and T. A. Hanley (eds.) Fish and Wildlife Relationships in Old Growth Forests. Proceedings of a symposium. American Institute of Fishery Research Biologists, Morehead City, North Carolina. P. 33-46.

Slough, B. G., and R. M. F. S. Sadleir. 1977. A land capability classification system for beaver (*Castor canadensis* Kuhl.). Can. J. Zool. 55:1324-1335.

Urich, D. L., J. P. Graham, and C. C. Cook. 1983. A handbook for habitat evaluation in Missouri. Missouri Department of Commerce. U.S. Soil Conservation Service and U.S. Fish and Wildlife Service, Columbia, Missouri. 148 pp.