

EFFECTS OF FINE SEDIMENT ON SALMONID REDDS IN PRAIRIE CREEK,
A TRIBUTARY OF REDWOOD CREEK, HUMBOLDT COUNTY, CALIFORNIA

by

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ABSTRACT

We studied the impacts of sedimentation from a highway construction site on salmonid redds in Prairie Creek, which flows through Redwood National Park and Prairie Creek State Park, California. Using infiltration bags, permeability standpipes, and colander mesh baskets filled with gravel and eyed steelhead (Oncorhynchus mykiss) eggs, we measured changes in percent fine sediment, permeability, dissolved oxygen, and egg survival-to-hatching in artificially constructed redds. Infiltration bag results indicated percent fines were greatest in an impacted Prairie Creek tributary, next greatest in Prairie Creek mainstem, and the least in the control stream. Percentages of fines in the egg-containing baskets were low (< 8% by volume) and did not differ significantly between the mainstem and control stream, however. Factors other than fines appeared to be affecting redd gravel permeability and dissolved oxygen concentrations. Survival of steelhead eggs to hatching was not significantly affected. These results were obtained during a low rainfall year. Stream flows were too low to move sediment into the cleaned gravels of the redds; consequently, egg survival was probably less adversely affected than it would have been in a year of more normal streamflow. Similar studies will be conducted in future years to document effects of higher flows.

Key Words: Salmonid, Egg Survival, Redd, Dissolved Oxygen, Gravel Permeability

INTRODUCTION

In October 1989, a storm delivered tons of fine sediment from an unprotected highway construction site into Prairie Creek and many of its tributaries. A layer of silt- and clay-textured sediment settled on the surface of the streambed and infiltrated into subsurface gravels of this relatively pristine salmonid stream system (Redwood National Park 1991). Infiltration of large amounts of fine sediment into salmonid redds can reduce reproductive success (Everest et al. 1987). Sediment can reduce gravel permeability and intragravel water flow (Cooper 1965) and, thus, availability of dissolved oxygen (Coble 1961). Low dissolved oxygen can cause direct egg mortality (Alderice et al. 1958). The objective of this study was to determine if the fine sediment reduced gravel permeability, dissolved oxygen, and salmonid egg survival in Prairie Creek. The results of the first year of this multi-year study are presented. During this first year, we specifically addressed the impact on survival to hatching of eyed steelhead eggs.

STUDY AREA

Prairie Creek is located in Redwood National Park and Prairie Creek Redwoods State Park near the town of Orick in northern California. Prairie Creek, tributary to the coastal stream, Redwood Creek, is 22 km long. In the study area, the average stream gradient is 1%, and the creek drains 35 km² at the downstream end. Much of the Prairie Creek watershed vegetation is

old-growth redwood forest. The creek and its tributaries have supported large runs of anadromous chinook salmon (*Oncorhynchus tshawytscha*), coho salmon (*O. kisutch*), and steelhead trout (*O. mykiss*). Anadromous and resident stocks of cutthroat trout (*O. clarki*) are common (Anderson 1988).

A four-lane highway was constructed upslope and parallel to Prairie Creek on the east side for 10 creek km in second-growth redwood forest. The terrain of the highway alignment is steep and highly erodible. During the October storm, sediment was delivered into Prairie Creek from the tributaries, Ten Tapo, Brown, Big Tree, Boyes, and May Creeks. The study area included the affected Prairie Creek reach, the affected Brown Creek tributary, and a control stream, Lost Man Creek (Fig. 1). Lost Man Creek is a large tributary to Prairie Creek that was unaffected by highway sediment inputs. This stream is not an ideal control because it has been affected by some logging, and it is somewhat dissimilar geologically. However, it is identical climatologically, has supported successful salmonid spawning, and was the best control available.

METHODS

To test (1) permeability, (2) fine sediment infiltration, and (3) egg survival, we constructed artificial salmonid redds and measured the cumulative effect of subsequent storms on those 3 parameters. To simulate a redd, we sifted pockets of gravel to clean out the fine sediment using a shovel or sieve at potential

spawning sites. We mimicked the shape and pot of a natural redd for the egg survival experiment. Prairie Creek water and sediment discharge were recorded near the sites during the study period (Fig. 1).

Fine Sediment Infiltration in Redds

In December 1989, we placed 3 infiltration bags on Prairie Creek, 1 on the control stream, and 3 on Brown Creek, a sediment-impacted tributary to Prairie Creek. These collapsible, water-proof bags with floats were placed beneath columns of stream gravel sieved of all fines < 4 mm in Prairie Creek and < 2 mm in Brown Creek. All bags were removed with a winch and tripod by June 1990 and sieved to determine percent of the total sample weight in various particle size classes < 4 mm. Sample size was only 1 in the control stream due to time constraints, so little could be inferred statistically. Differences found were interpreted only as apparent trends.

Redd Gravel Permeability and Dissolved Oxygen

In January 1990, we placed 4 clusters of 4 permeability standpipes, modelled after those of Gangmark and Bakkala (1958), in shovel-cleaned artificial redds in Prairie Creek. The most upstream cluster was located in the least impacted section of Prairie Creek, which was above the Brown Creek confluence; the other 3 were located downstream of Brown Creek and other tributaries known to have contributed large amounts of sediment (Redwood National Park 1991) (Fig. 1).

Permeability testing procedures followed those of Terhune (1958). Pipes remained in the streambed throughout the winter, and subsurface gravel inflow rates were measured 3 times from January to July, 1990. Beginning in February, we also lowered a dissolved oxygen (DO) probe into the standpipes to measure DO concentrations in the subsurface gravels. DO was measured in the adjacent surface water at the same time.

Inflow rate was used as an index of permeability. Differences in inflow rate and DO between the standpipe clusters and over time were tested using 2-way analysis of variance. One-way analysis of variance and Tukey's multiple range tests (Neter et al. 1990) were performed to determine which groups differed significantly (at the 0.05 level). We used paired t-tests to test differences between intragravel and surface water DO.

Egg Survival

We constructed 10 artificial steelhead redds in Prairie Creek and 8 in the control stream. Three enamel-coated colander baskets (0.31-cm mesh), filled with shovel-cleaned stream gravel and eyed steelhead eggs, were covered with a fiberglass screen mesh and buried in each redd. The eggs were incubated between mid-February to April 1990, similar to the natural incubation period. After eggs were expected to have hatched, we removed the baskets and counted the number of alevins.

During removal, baskets were slid into a dishtub underwater to minimize loss of fine sediment. Basket gravel was wet-sieved to determine percent volume of fines < 1.0 mm. Differences in survival and fines between Prairie Creek and the control stream were tested using analysis of variance. To reduce non-normality, all percent estimates were converted by an arcsine transformation. Additionally, percent egg survival was regressed on percent basket fines.

RESULTS

Peak streamflows following artificial redd construction were very low. The highest flows to which the permeability and infiltration redds were subjected were 1/5 and 2/5 of the stream's 2-year recurrence interval (RI), respectively (2-yr RI = 17 m³/sec just below Brown Creek confluence). The egg-survival redds were exposed to even lower flows, the highest being 1/10 of this RI.

Fine Sediment Infiltration in Redds

Brown Creek infiltration bags received a greater proportion of fine sediment than bags in Prairie Creek or the control stream. The control sample had the lowest percent fines (Fig. 2). Mean percent fines < 1.0 mm by weight ranged from 4.9% (SE = 1.9) in Brown Creek to 2.9% (SE = 0.28) in Prairie Creek to 1.9% (n = 1) in Lost Man Creek.

Redd Gravel Permeability and Dissolved Oxygen

One standpipe in the third downstream cluster was damaged and not included in the results. Inflow rate decreased in all but 1 of the 15 pipes from January to July. Mean inflow rate significantly decreased over this period ($P < 0.001$) and varied between clusters ($P < 0.001$). Two-way interactions were insignificant ($P > 0.05$). Means were lower in pipe clusters below Brown Creek confluence (clusters 2 - 4) than above during both sampling months (Tukey's Test, $P < 0.05$). However, the winter decrease in the upstream cluster did not differ significantly from downstream clusters ($P > 0.05$) (Table 1).

DO decreased in all but 2 standpipes from February to July. Mean DO significantly decreased over this period ($P < 0.001$) and varied between clusters ($P < 0.01$). Two way interactions between time and location were significant ($P < 0.001$). In February, the lowest mean concentration was in the cluster just downstream of Brown Creek confluence (Tukey's test, $P < 0.05$), but this cluster had the highest mean concentration in July (Table 1). Average decrease over time did not significantly differ between intragravel water ($x = 12\%$, $SE = 3$) and surface water ($x = 15\%$, $SE = 1$). Surface DO ranged from 0.1 to 1.0 ppm greater than intragravel DO. Intragravel DO never dropped below 7.7 ppm in any of the pipes.

Egg Survival

Egg survival to hatching was relatively high for all but two redds (Fig. 3). Mean percent survival was 71% ($SE = 12.0$) in Prairie

Creek and 85% (SE = 2.5) in the control stream. This difference was not statistically significant ($P > 0.05$). Two redds on Prairie Creek had 0% survival. These two redds were heavily infested with oligochaete worms. Fines < 1.0 mm in the baskets of these two redds fell within the range of the other redds, 1.2 to 8.1% by volume. Mean percent of basket fines was 2.6% (SE = 0.6) for Prairie Creek and 3.7% (SE = 2.8%) for the control stream; those values did not significantly differ ($P > 0.05$). Basket fines did not explain much of the variance in egg survival ($r^2 = 0.06$).

DISCUSSION

The winter of 1989-1990 was a low rainfall year, averaging 114 cm at Prairie Creek Redwoods State Park compared to the 19-year average of 170 cm. Stream discharge was low during all experiments. Scour and fill studies showed that very little of the streambed was mobilized during this period (Redwood National Park 1991). Consequently, flows were insufficient for scouring and moving much sediment into the cleaned artificial redds. This accounts for the low mean value of percent fines found in the redds toward the end of the winter.

Infiltration bag results indicated that fines were greatest in the Brown Creek tributary, least in the control stream, and intermediate for Prairie Creek. This was expected because eastern tributaries such as Brown Creek received direct inputs of sediment from the highway alignment. Surface and subsurface fines were

Infiltration bag results indicated that fines were greatest in the Brown Creek tributary, least in the control stream, and intermediate for Prairie Creek. This was expected because eastern tributaries such as Brown Creek received direct inputs of sediment from the highway alignment. Surface and subsurface fines were found in greatest amounts in the tributaries (Redwood National Park 1991) and would, therefore, provide a larger source of infiltrating sediment upon mobilization.

In contrast, levels of fine sediment in the egg survival redds in the impacted stream were similar to the control stream. These redds, however, were subjected to smaller flows than redds with infiltration bags, which may explain the different results. Levels of fines reported to be deleterious to salmonid egg survival have varied (Chapman 1988), but are generally higher (usually at least 10%) than levels found during this study.

At the end of the winter, permeability was lower in Prairie Creek redds exposed to sediment inputs from the Brown Creek tributary than an upstream redd, but this difference was also present immediately after installing the pipes and cleaning the gravel. Factors other than fines appear to be affecting permeability. DO similarly decreased over the winter; but this appeared to be a function of decreasing surface water DO, which, in turn, was probably caused by increasing water temperature. DO concentrations were above those reported in the literature as causing egg mortality (generally < 5 ppm, Alderice et al. 1958), although decreases below 11 ppm have restricted embryonic growth

(Chapman 1988). Finally, steelhead egg survival to hatching was largely unaffected by fines or changes in permeability; instead, worm infestation appeared to be responsible for the two cases of high mortality. Further investigation is needed to determine if presence of worms is related to fine sediment.

We suspect these results would have been different if the rainfall year had been near or above normal. Most of the fine material in the system was not mobilized and was still present at the end of the winter (Redwood National Park 1991). In following years, this material will still be available for a large storm to move and deposit into incubating salmonid redds. Following such an event, we would expect percent fines in redds to be much higher, reducing permeability to a greater extent, which could, in turn, adversely impact egg survival. Even during this 1989-1990 winter, species such as coho and chinook salmon, which spawn earlier in the season and are exposed to more storms, may not have had as high egg survival as steelhead trout. For these reasons, we recommended repeating a refined version of this study. We plan to address the effect of sedimentation on artificial redd physical parameters and coho salmon egg survival and emergence in the next two years, in hopes of documenting the effects of larger storms.

ACKNOWLEDGMENTS

We thank D. Anderson, R. Coey, J. O'Brien, H. Eberwine, R. Sonnevil, V. Ozaki, C. Jones, V. Vrell, and F. Levitan for field and laboratory assistance and data analysis. We are grateful to T. Hofstra, M. Moore, and J. Meyer for their advice and support. We also thank S. Bowman and T. Lisle of the U.S. Forest Service for collecting data on Brown Creek. This work was supported by the California Department of Transportation.

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Table 1. Mean inflow rates and dissolved oxygen concentration measured from clusters of 4 standpipes placed in artificial salmonid redds, which were constructed on Prairie Creek in January, 1990. Pipe clusters are ordered from upstream to downstream. Similarly superscripted values in the same column did not differ significantly at the 0.05 level (Tukey's test).

Pipe cluster	January		July		% Decrease	
	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
<u>Inflow rate (cm/sec)</u>						
1	108 ^a	7	87 ^a	10	-20 ^a	5
2	57 ^b	9	35 ^b	3	-32 ^a	12
3	47 ^b	8	35 ^b	5	-22 ^a	13
4	67 ^b	5	54 ^b	3	-19 ^a	10
<u>Dissolved oxygen (ppm)</u>						
1	10.4 ^a	0.3	8.2 ^{a,b}	2.5	-20 ^a	3
2	8.6 ^b	0.4	9.1 ^a	0.1	+ 3 ^b	5
3	10.7 ^a	0.3	9.0 ^a	0.1	-16 ^a	2
4	10.5 ^a	0.1	8.7 ^b	0.1	-17 ^a	2

Figure 1. Study area showing Prairie Creek, its tributaries, the highway bypass alignment, water and sediment discharge gaging stations, and location of artificial redds containing clusters of permeability pipes (●), egg baskets (A), or infiltration bags (B).

Figure 2. Distribution of fine particle sizes in redds artificially constructed in Prairie, Brown, (affected streams) and Lost Man (control stream) Creeks, northern California, in late May and early June 1990. In December 1989, these redds were cleaned of fines < 4 mm in Prairie and Lost Man Creeks, and < 2 mm in Brown Creek.

Figure 3. Percent of eyed steelhead eggs (200 eggs/redd) that survived to hatching when incubated in artificial redds from February to April on Prairie Creek (affected stream) and Lost Man Creek (control stream) in northern California, 1990.

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