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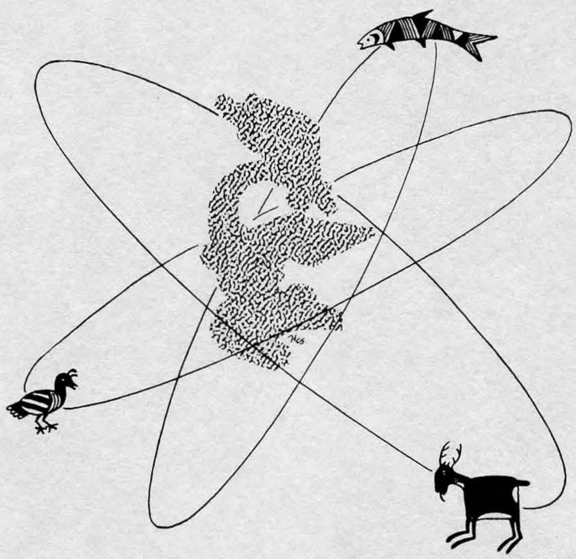

A STUDY OF THE EFFECT OF LOGGING ON AQUATIC RESOURCES, 1960-66

A STUDY OF THE EFFECT OF LOGGING ON AQUATIC RESOURCES, A PROGRESS REPORT 1960-66

by

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THE EFFECT OF LOGGING ON AQUATIC RESOURCES

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INTRODUCTION

The overall study is designed to measure the effect of logging on the production and yield of coho salmon, coastal cutthroat, and steelhead trout in small coastal streams. The principal objective of this segment is to determine the influence of logging on salmonid survival from egg deposition to fry emergence. Three main areas of investigation are being pursued. These are: (1) to determine the influence of the gravel environment on survival; (2) to determine the influence of logging on the gravel environment and (3) to develop methods for the direct measurement of the survival to emergence[1/] of salmonids.

Related areas of study have included the investigation of coho salmon, cutthroat trout, and reticulate sculpin numbers and biomass, and inquiry into the potential predatory role of *Cottus perplexus* and *Acroneuria pacifica* on salmonids developing within the intragravel environment of the three study streams.

The study area includes three tributaries of Drift Creek, a tributary of the lower Alsea River (Figure 1). The streams and their respective drainage areas are: Deer Creek, 750 acres; Flynn Creek, 502 acres; and Needle Branch Creek, 175 acres. The undisturbed watersheds

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[1/] Throughout this report, the term "survival" means the survival of salmonids from egg deposition to the emergence of fry from the gravel (ie. survival-to-emergence).

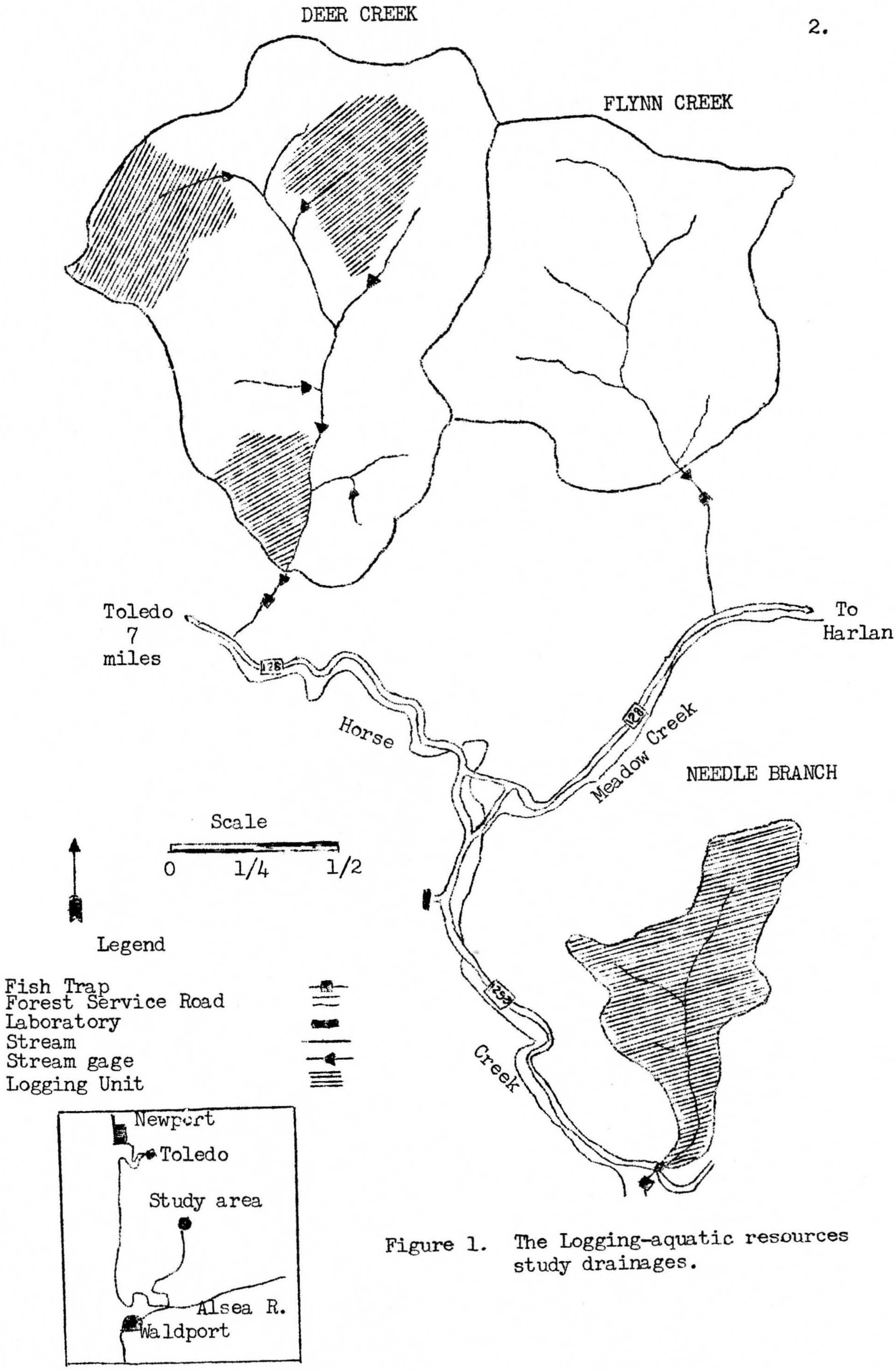

Figure 1. The Logging-aquatic resources study drainages.

are covered mainly by stands of mixed Douglas fir and red alder. Understory attendant species include salmonberry, vine maple, and swordfern.

The project has been designed to compare physical and biological characteristics before and after logging on two streams while a third stream, Flynn Creek, will remain unlogged as a control for the duration of the study. Initial research began in 1959, providing a six-year pre-logging calibration period. Road building was accomplished in 1965 and logging commenced on schedule in March, 1966. By building roads in one year and logging the next year, an assessment of the effect of each might be possible. The Needle Branch drainage was entirely clear-cut while only a portion of the Deer Creek drainage was clear-cut by a staggered setting pattern leaving vegetative strips along the stream.

METHODS AND TECHNIQUES

In order to measure the effect of logging on the aquatic environment, information was needed on: (1) the dissolved oxygen content of intragravel and surface water; (2) gravel permeability; (3) gravel erosion; and (4) salmonid survival in natural redds. Pre-logging values will be compared with post-logging values to measure changes.

The dissolved oxygen concentration of the intragravel water was determined systematically at each permanent standpipe[2/] from September to June of each year. The unmodified Winkler method and the Alsterburg modification of the Winkler method were used. Concurrent measurements of surface water dissolved oxygen content were made. Surface water values

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[2/] Terhune, L. B. D., 1958.

remained high throughout the sampling period. Values recorded from Needle Branch (Table 1) illustrate the oxygen concentration found in the intragravel environment.

Table 1

Mean dissolved oxygen concentration of intragravel water (mg/l) at permanent standpipes in Needle Branch

	Location (in feet above USGS stream gauge)									
Season	335	995	1,450	1,555	1,875	1,970	2,060	2,490	2,595	Surface
1962-63	9.3	10.3	10.2	9.0	11.3	10.1	11.1	11.0	9.6	11.7
1963-64	10.0	9.2	10.0	5.0	11.2	11.0	11.0	11.6	11.6	11.7
1964-65	10.9 1/	7.7 2/	10.0	4.8	11.1	10.1	11.0	9.3	11.2	11.9
1965-66	10.0	5.1	10.5	8.4	10.2	10.2	11.1	10.5	11.0	12.3

1/ Salmon spawned at this location thereby increasing dissolved oxygen.
2/ Standpipe location moved upstream about 50 feet.

Gravel permeability was also measured systematically at the 40 permanent standpipes situated in the three study streams. Permeability is the inherent ability of gravel or any other porous media to pass water. Needle Branch gravel permeabilities (Table 2) provide an example of the values found in the three study streams.

The major freshets of the 1964-65 season did not materially affect gravel permeability and dissolved oxygen concentration at the permanent standpipes (see Tables 1 and 2).

One of the possible effects of logging on the aquatic environment is an increase in the amount of stream gravel shift. As a means of measuring the relative amount of disturbance, 40 gravel-erosion index stations were established in the three study streams at sites containing what appeared to be good spawning gravels. Each station consists of a vertical column of marked, perforated ping pong balls. Six of the 1-1/2-inch balls, each coded in relation to depth of placement, are buried in a column (within a special driving pipe) at each index station.

Table 2

Mean gravel permeability (cm/hr) at permanent

standpipes in Needle Branch

	Location (in feet above USGS stream gauge)								
Season	335	995	1,450	1,555	1,875	1,970	2,060	2,490	2,545
1962-63	156	0	2,260	380	11,820	16,970	3,812	11,180	4,188
1963-64	628[1/]	178	1,464	406	16,640	9,640	2,156	9,740	5,740
1964-65	6,377[1/]	1,083[2/]	1,706	1,144	21,471	4,581	1,670	1,306	2,450
1965-66	1,655	1,286	1,367[1/]	2,474[1/]	21,840[1/]	2,573[1/]	1,398	440[1/]	2,067

1/ Salmon spawned here thereby increasing permeability.
2/ Standpipe location moved upstream about 50 feet.

The balls are buried in the fall prior to spawning, and unearthed in the summer after the incubation period. The letter and number on the balls remaining at a particular site indicates the depth to which erosion occurred. Gravel deposition over a station can also be quantified by this method. The amount of erosion measured at the index stations is summarized in Table 3.

Table 3

Mean depth (inches) of gravel erosion in the

Drift Creek study streams

	Stream		
Season	Deer Creek	Flynn Creek	Needle Branch
1961-62	1.9	1.7	1.1
1962-63	0.6	0.0	0.3
1963-64	3.9	2.8	4.2
1964-65	4.3	6.2	4.7
1965-66	3.4	2.0	—[1/]

1/ Data could not be obtained because of logging operations on Needle Branch in May and June, 1966.

A trap was developed in 1963 to hold salmonid fry as they emerge from natural redds. The device provides a means for determining directly the influence of logging on survival to emergence by comparing pre-logging and post-logging estimates.

Briefly, the trap consists of a cap of nylon netting placed on top of individual salmon redds with its edges tucked 6 to 8 inches into the gravel (Figures 2 and 3). The fry are prevented from leaving their natal area until they can be counted.

The efficiency of the trap in terms of total catch was questioned when laboratory tests of lateral movement indicated that the possibility for escape existed. An experiment conducted in the spring of 1966 indicated that the trap can be 100 percent efficient when installed to a depth of 6 to 8 inches around the redd. The test involved the installation of a double set of traps with a large trap (8' by 12') installed over a smaller one (6' by 8') (Figure 4). One hundred coho fry were introduced into the gravel to a depth of 10 inches via a plastic standpipe installed under the small trap. Two installation depths were used to determine differences which might occur should fry be escaping under the edges of a shallow installation. Table 4 summarizes the results of the nylon fry trap efficiency test.

When the emergence was complete, each of the sites was excavated in an attempt to recover fry which had not emerged. Excavation of the six sites revealed that approximately 70 percent of the fry that did not emerge were dead close to the fry chamber. Counts were difficult to make because of deterioration of some fry.

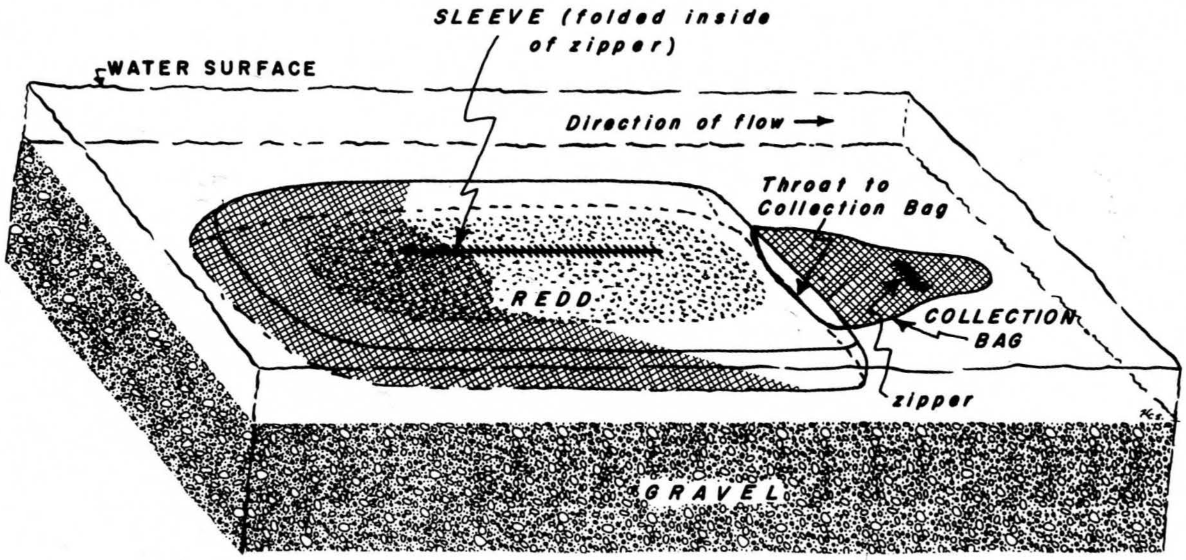

Figure 2. Schematic of a nylon fry trap installed over a redd.

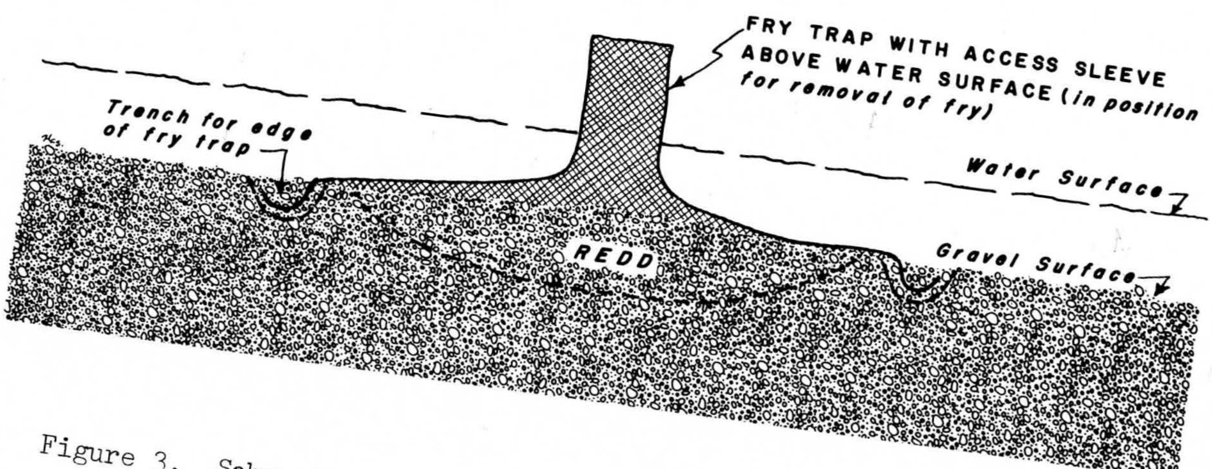

Figure 3. Schematic of a nylon fry trap with access sleeve above the water surface.

Table 4

Results of the nylon fry trap efficiency test, Deer Creek, 1966

	Trap location (feet above USGS weir)											
	2,985		3,880		4,350		4,510		4,625		5,650	
Trap size	Sm	Lg	Sm	Lg	Sm	Lg	Sm	Lg	Sm	Lg	Sm	Lg
Installation depth	5-6 in.		7-9 in.		5-6 in.		5-6 in.		7-9 in.		7-9 in.	
Percent emergence	8	0	45	0	76	1	0[1]	0	25	0	0[2]	0

1/ Mortality here attributed to low intragravel dissolved oxygen.
2/ Fry chamber was silted-in prior to fry introduction.

THE AQUATIC ENVIRONMENT BEFORE LOGGING

A. Physical

Efforts to determine the effect of the gravel environment on survival under natural, unlogged conditions have centered on three factors: (1) dissolved oxygen concentration of intragravel water; (2) gravel size; and (3) permeability. Experiments designed to determine the survival of salmonids were conducted in the field and at the laboratory (Figure 5). Measurements of survival are considered to be meaningful indices to change in the aquatic environment that affect salmonids.

Dissolved oxygen content of intragravel water was directly related to the survival of coho salmon fry. Generally, emergence was not markedly reduced until mean oxygen concentrations fell below about 5 mg/l. Laboratory experiments are summarized in Figures 6, 7, and 8.

A test for interaction between dissolved oxygen and gravel size on survival was significant (p=.05). Thus, the larger gravel sizes tested, since the interstices are less confining, provide a more suitable environment for salmonid emergence. Where gravel size becomes confining,

Figure 4. Nylon fry traps installed to test their efficiency.

Figure 5. Gravel troughs used to test the effects of dissolved oxygen, gravel size, and predation on survival-to-emergence of coho salmon and steelhead.

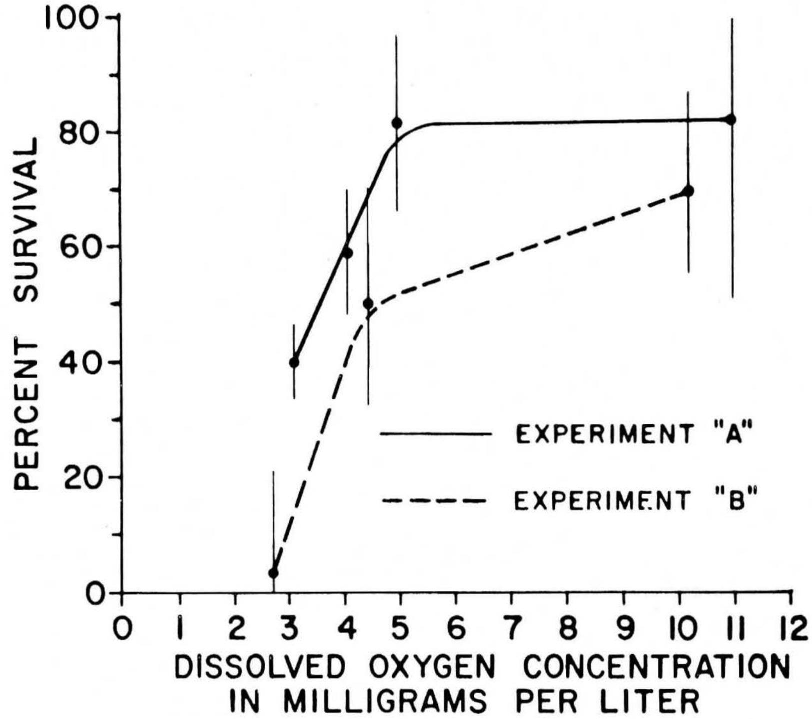

Figure 6. Influence of dissolved oxygen on survival-to-emergence of coho salmon fry.

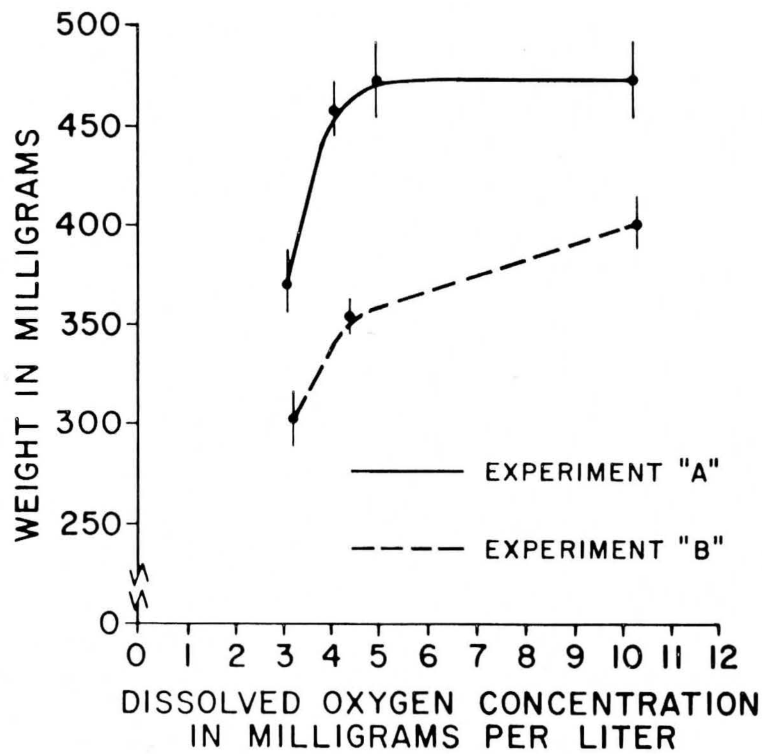

Figure 7. Influence of dissolved oxygen on wet weight (mg) of coho salmon fry preserved in Bouin's fluid following emergence from gravel.

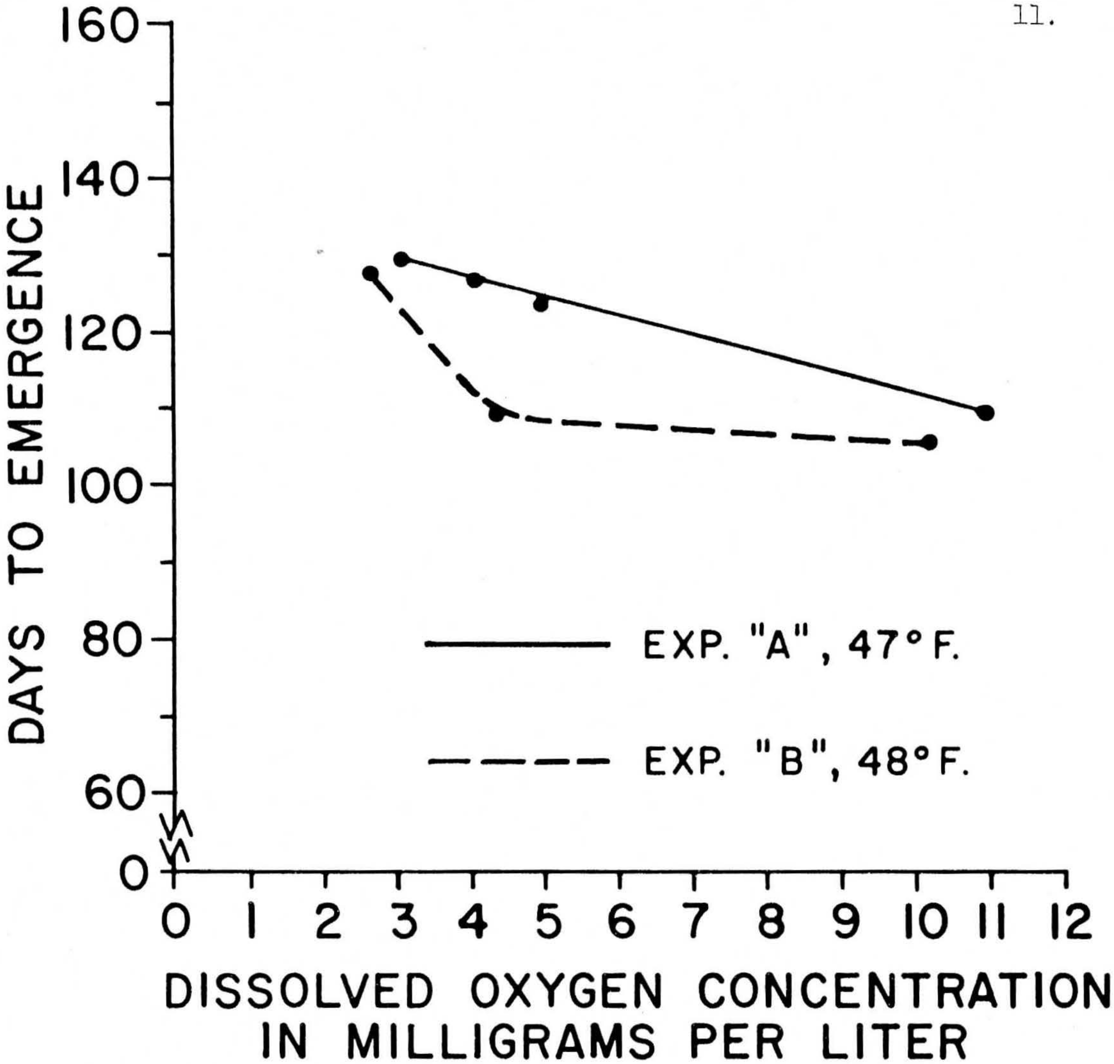

Figure 8. Influence of dissolved oxygen concentration on the number of days to emergence for coho salmon fry in gravel-filled troughs.

higher dissolved oxygen concentrations yield healthier and more vigorous fry, which are better able to make their way through the gravelly matrix. Figures 9, 10, and 11 summarize the results of these experiments.

Gravel size was directly related to survival-to-emergence. In early laboratory experiments, four gravel diameter sizes were tested ranging from 1/4 to 1-1/4 inches in one-quarter inch increments. Survival of coho ranged from 83 percent downward to zero, with a significant decrease in survival occurring in gravel sizes less than 1/2-inch in diameter (Figure 9). The survival of steelhead embryos to emergence followed a similar pattern. Later field experiments showed decreased survival to be directly related to the proportion of fine materials occurring in the gravel of a size less than 0.83 mm in diameter.

Experiments testing the effects of various percentages of fine materials (1-3 mm in diameter) on emergence of coho salmon and steelhead were initiated. The size of fine materials tested allows an analysis of the mechanical effect of a gravel matrix on survival under conditions of adequate intragravel dissolved oxygen and velocity.

The gravel composition of the control mixture was determined from samples taken from redds where survival was known to be high. To that mixture, fine materials were added in 10 percent increments. A total of eight concentrations of fine materials (0-70 percent) was tested. A trough arrangement provided for six replications of each percentage of fines (Figure 12). Mean coho survival ranged from 6 percent to 87 percent. The relationship of the proportion of fines to survival was inverse (Figure 13).

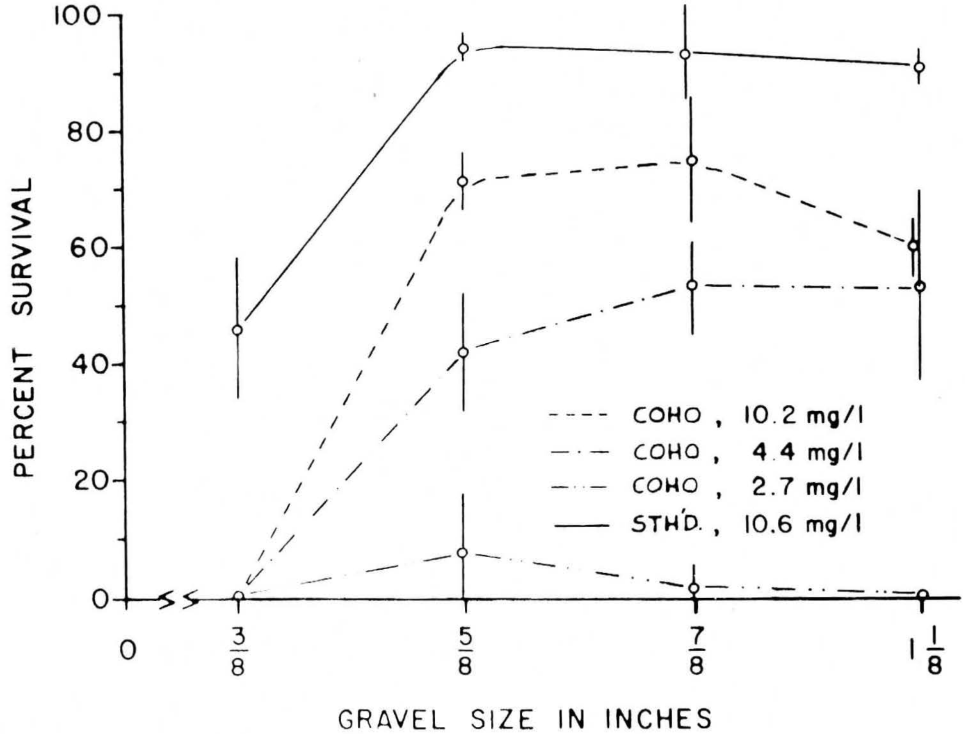

Figure 9. Influence of gravel size on survival-to-emergence of coho and steelhead fry at various dissolved oxygen concentrations in gravel-filled troughs.

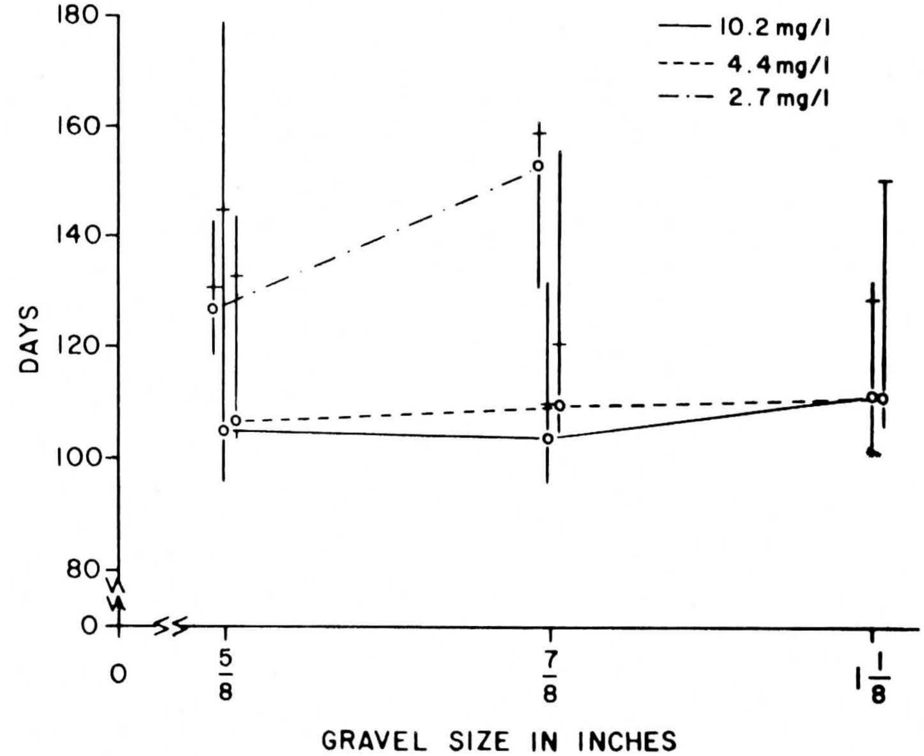

Figure 10. Influence of gravel size on number of days to emergence for coho fry in gravel-filled troughs.

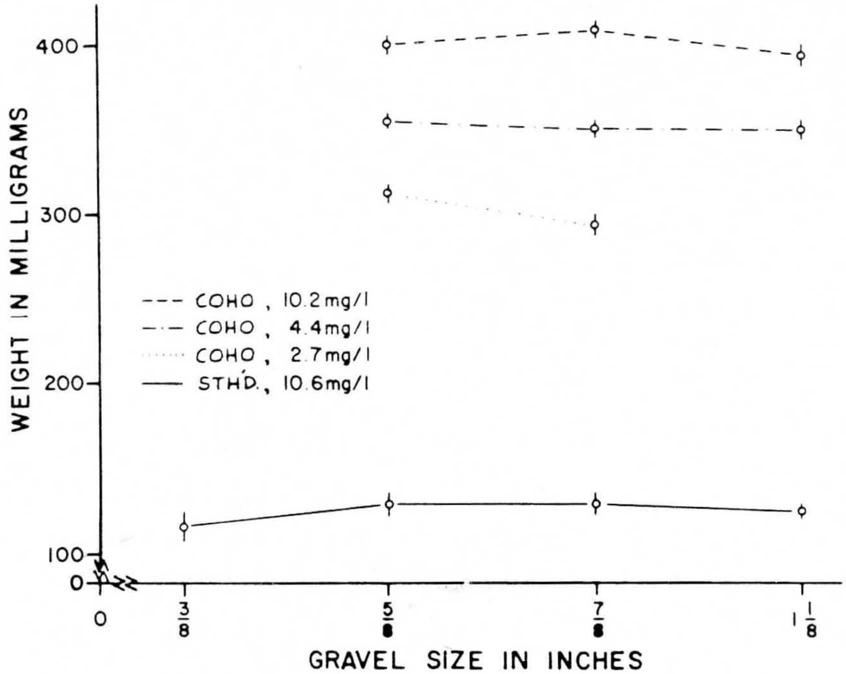

Figure 11. Influence of gravel size on wet weight (mg) of coho and steelhead fry preserved in Bouin's fluid following emergence from gravel-filled troughs

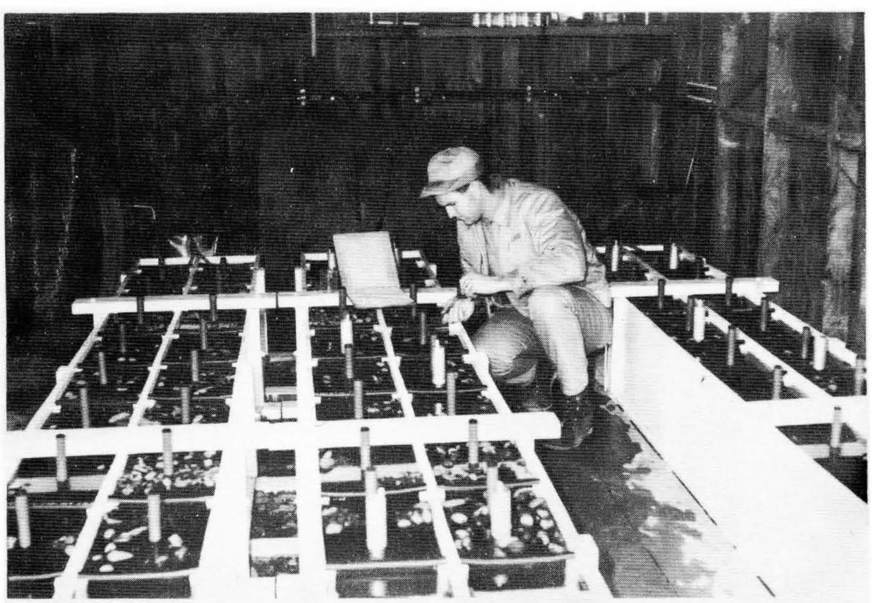

Figure 12. An experiment testing the effect of various percentages of fine materials (1-3 mm in diameter) on the survival-to-emergence of coho salmon and steelhead fry.

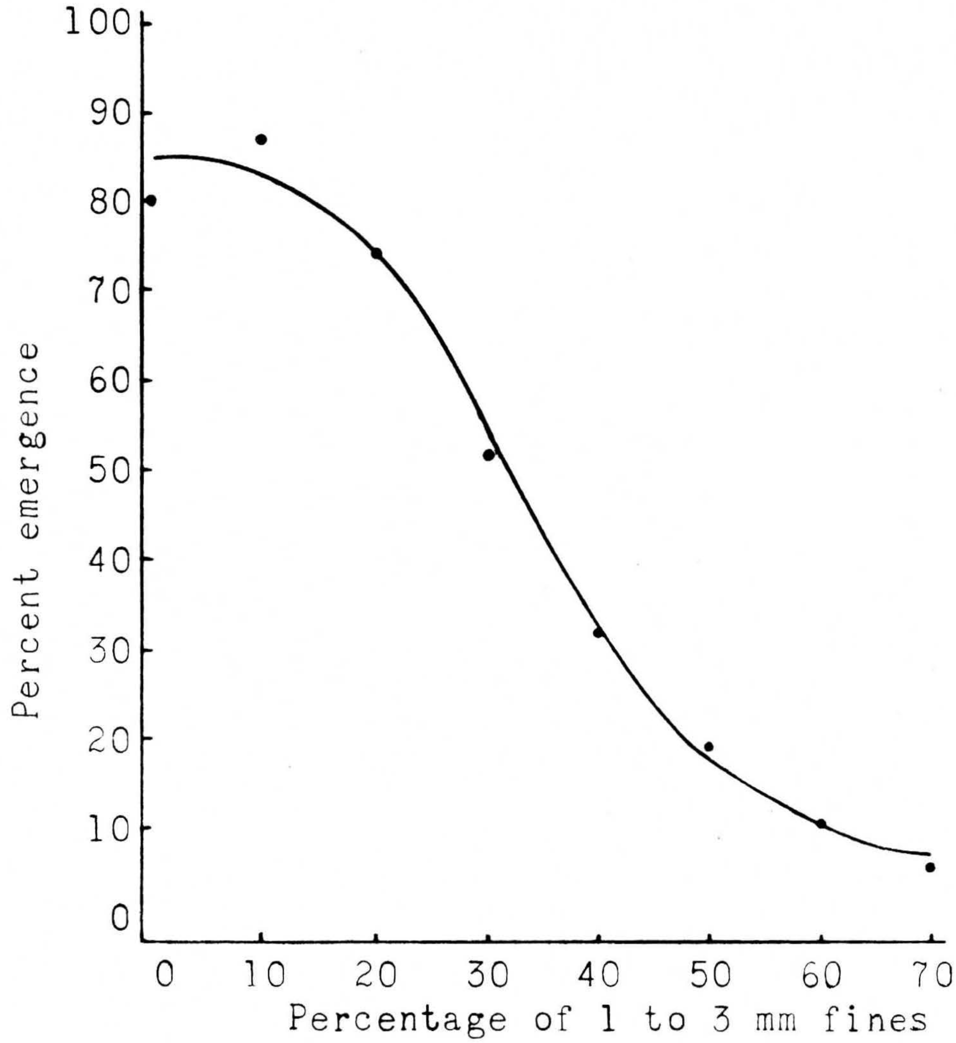

Figure 13. Survival-to-emergence of coho salmon fry in seven concentrations of 1 to 3 mm fines.

The permeability of stream beds was monitored systematically in the pre-logging calibration period. No direct relationship with the survival of salmonids has been shown in the experiments conducted as a part of this study.

B. Biological

Since 1964, the nylon fry trap has been used to obtain direct estimates of survival from 49 coho salmon redds in the three study streams at Drift Creek. Gravel samples are taken from each trapped redd site and analyzed for size composition. Survival can then be compared with gravel size and the proportion of "fines" present. Table 5 summarizes mean survival estimates from 1964 through 1966. The percentage of gravel less than 3.3 mm in diameter is negatively correlated ($r=-0.69$) with fry survival in natural redds. Thus, the composition of the gravel matrix holding salmon embryos is a vital link to good survival and the successful emergence of fry.

Table 5

Mean survival-to-emergence (percent) of coho fry as estimated with fry traps

Year	Deer Creek	Flynn Creek	Needle Branch	All streams
1964	54	14	25	28
1965	27	20	22	23
1966	12	20	44	30
3 year mean	31	18	30	27

Standing crop estimates based on the Bailey modification of the Peterson Index have been made as a basis for post-logging comparisons. Table 6 summarizes representative values.

Table 6

Comparison of standing crop estimates in Needle Branch

Source and date	Species	Number ($/m^2$)	Weight (g/m^2)
Chapman (1965) (Nov. 1 ave. 1960-63)	Coho salmon	1.0	2.4
Lowry (1964) (Nov. 1, 1962)	Cutthroat trout	0.3	3.7
Phillips (Oct. 28-29, 1964)	Reticulate sculpin	3.5	3.1

The large proportion of stream biomass conprised of the reticulate sculpin (Cottus perplexus) suggested a possible significant interspecific relationship. Consequently, laboratory studies were undertaken to test the ability of the reticulate sculpin to prey on young salmonids.

Initial experiments were conducted in a wood and plexiglas trough (Figure 14) where observations could be made to determine the ability of two size groups of reticulate sculpins to penetrate various sizes of gravel. Table 7 summarizes the results of the experiment.

The ability of the reticulate sculpin to move in gravel varied inversely with the size of the fish and directly with the size of the gravel. Sculpins were capable of moving through 2.9 cm gravel with ease, especially individuals in the 3.0 to 4.0 cm size group.

Since sculpins can penetrate some sizes of gravel to depths where salmon eggs are normally deposited, experiments were conducted to determine the extent of predation.

Figure 14. Glass-sided trough used to determine the ability of the reticulate sculpin to penetrate various gravel sizes.

Table 7

Observed depth of movement (cm) of *Cottus perplexus*

in four gravel size groups

Mean diameter and range of gravel (cm)	Total length of sculpins (cm) 3.0 - 4.0	5.0 - 7.5
2.9 (2.5-3.2)	36	18
2.2 (1.9-2.5)	18	10
1.6 (1.3-1.9)	8	0
1.0 (0.6-1.3)	0	0

Results showed that the pre-emergence mortality of coho salmon was about 5 percent in the larger gravels by the larger size group of sculpins. No predation occurred in the smaller gravel sizes. Post-emergence mortality of coho (until fry were collected) was also about 5 percent.

Post-emergence mortality on steelhead embryos by the larger sculpins was about 10 percent. Pre-emergence mortality increased with increasing gravel size, reaching a maximum of about 25 percent in the gravel. The higher incidence of sculpin predation of the steelhead alevins is believed caused by the smaller size of steelhead which were more easily ingested than coho.

Another potential predator in the gravel environment is the large stonefly nymph, *Acroneuria pacifica*. This insect is abundant in the study streams at the time salmonid alevins are developing.

Consequently, experiments were designed to determine: (1) the ability of the stonefly to move through various gravel sizes and (2) whether stoneflies would attack salmonid eggs and alevins. Table 8 summarizes the depths in certain gravels in which the stonefly was observed in a glass-sided trough.

Table 8

Observed depth of movement (cm) of Acroneuria pacifica in four gravel size groups

	Gravel size groups (cm)			
Size of nymph	2.5 - 3.2	1.9 - 2.5	1.2 - 1.9	0.6 - 1.2
2.0 - 2.5 cm	36	15	8	15

The large stonefly was capable of killing steelhead eggs and alevins in the laboratory aquaria. During a 21-day experiment, 29 Acroneuria pacifica attacked and killed 10 steelhead eggs and 22 alevins. Similar attacks were observed on cutthroat in a later experiment. The extent of predation on salmonids by this insect in the stream is not known; however, these studies suggest it could be an important predator.

SOME IMMEDIATE EFFECTS OF LOGGING

Cutting began on two of the study drainages in April, 1966. Again, we are comparing the clearcutting of an entire watershed, Needle Branch, where timber is harvested to the stream edge, with smaller clearcuts on Deer Creek where about 25 percent of the watershed area is cut in three patches. Strips of streamside vegetation remained as buffer areas on Deer Creek. High-lead logging methods were used on both watersheds (Figures 15 and 16).

The immediate effects of logging were most notable in Needle Branch. An accumulation of slash and debris in the stream from April through September created a significant decrease in the dissolved oxygen content of the surface and intragravel waters. An intensified sampling program for dissolved oxygen was begun in May. Samples were taken

Figure 15. Needle Branch watershed during logging operations. The entire drainage was logged during 1966.

Figure 16. High-lead logging in the Deer Creek drainage. The stream flows through the buffer strip of alder at bottom of canyon.

twice a week at 500 ft. intervals over the 3,000 ft. of stream usually accessible to salmon. By late June the surface dissolved oxygen content had dropped below 2 mg/l at the 1,000 ft. station and the intragravel oxygen levels averaged less than 1 mg/l. More intensive sampling at 100 ft. intervals between 500 and 1,500 showed that surface dissolved oxygen levels of less than 3 mg/l and as low as 0.6 mg/l persisted for several weeks during the summer (Figure 17). This section represented approximately one-third of the original rearing area available to salmonids.

A bioassay using juvenile coho salmon placed in live boxes confirmed the fact that this portion of the stream would not support fish life. All of the small salmon tested were dead within 8 to 40 minutes while fish were able to survive in the stream short distances above and below the area of degradation. Mortality wad probably caused by low dissolved oxygen levels and not to toxic substances in the water. During the same period of time, the surface dissolved oxygen levels on Deer Creek remained between 9 and 10 mg/l.

Stream temperatures rose significantly in Needle Branch following the loss of streamside cover and the formation of dams by debris. A maximum summer stream temperature of 75°F was recorded in Needle Branch during logging. This represents a 14°F increase over the highest temperature ever recorded on the same stream during the seven year pre-logging calibration period. Although this increase in temperature would be partially responsible for the low surface dissolved oxygen values, the ponding and retention of the small flow of water by debris was the most significant factor.

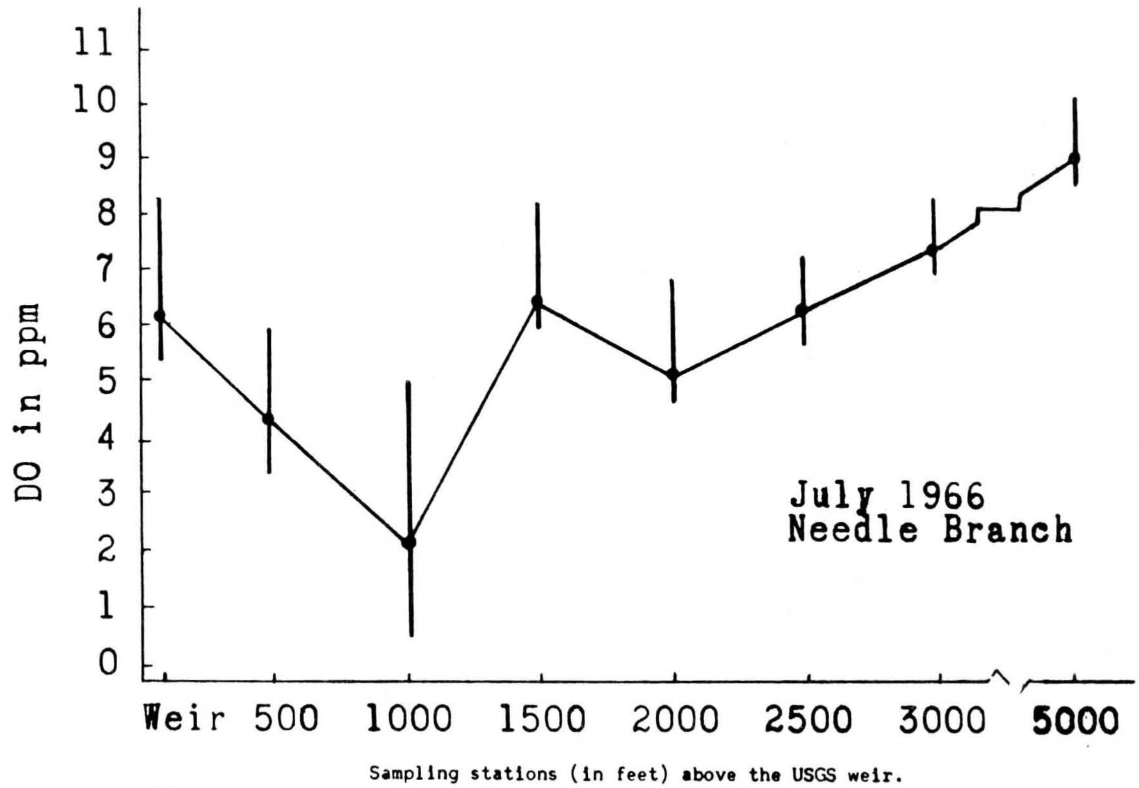

Figure 17. Needle Branch surface dissolved oxygen profile during logging -- July, 1966.

Following the completion of logging on the watershed in September, large debris was cleaned from the channel in that area accessible to anadromous fish at the request of the district fishery biologist of the Oregon Game Commission.

A common silvicultural practice on clearcut areas is to remove slash by burning. This is an aid to Douglas fir regeneration and was done on Needle Branch in early October. The watershed was completely burned in about three hours. The hottest portion of the burn occurred in the upper section of the watershed, an area of steep topography which represents about one-fourth of the total rearing space. A substantial kill of coho salmon and cutthroat trout took place. This mortality appeared to be caused by the high water temperatures in the canyon. The one thermometer in this area of the stream registered a maximum of 82°F. No mortality or significant temperature increase was recorded in the lower stream area where the topography is more gentle and the fire was less intense.

It should be emphasized here that the objective of this report is to outline the scope, methods and techniques of our study and to present some of the initial effects of logging that have occurred. It cannot be regarded as a full evaluation of the effects of logging on the fish populations of these watersheds although it does serve to point out some specific problem areas. An evaluation will be possible in the future as we progress into the post-logging calibration period. For example, a small population of young coho salmon did survive the extreme conditions of last summer and early fall on Needle Branch. An evaluation of the importance of the mortality on these coho will be possible following the completion of smolt migration next spring. We will also be able to determine if logging will have any effect on the upstream migration of adults this coming winter.

Our plans for the future include an expanded sampling effort in other watersheds. The present effort is confined to three small watersheds on one of the many major drainages along the Oregon coast and a considerable variation in the effects of logging on the Needle Branch watershed was noted. Therefore, by sampling a wider range of field conditions (i.e. stream sizes, gradients, and logging methods) we feel that we can eliminate the present single-area concept and make the entire study more representative.

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