APPENDIX B

EXPERIMENTS ON TOLERANCE OF YOUNG TROUT AND SALMON FOR SUSPENDED SEDIMENT IN WATER

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The experiments which are described in the following account were undertaken to obtain definite information as to the direct effect of large amounts of soil sediment in water upon the fish inhabiting such water. The Department of Geology and Mineral Industries of the state of Oregon arranged with me for experimental studies on this question. I have been ably assisted in carrying on the studies by Mr. Harry Beckwith of Reed College.

The experiments covered two periods: One of three weeks, the other of four weeks. In the first period the fish tested were cutthroat fingerlings; in the second, young chinook salmon. The fish were kept in troughs, similar to those used in fish hatcheries, in which a depth of five inches of water was maintained. The water was kept flowing by circulation through a centrifugal pump, and aeration was secured by ejection of the water into the troughs in a heavy spray. The pumps used were small, limiting the flow of water to a rate of about one-half mile an hour. The slow streamlike movement of the water along the troughs was sufficient to keep a much heavier load of fine sediment in suspension than is ordinarily found even in muddy streams, but was not rapid enough to keep in suspension all the sediment which was put into the troughs, or to maintain a turbidity of more than 750 parts per million for 24 hours.

The material used for the sediment consisted of soil and alluvial material taken from ten spots around the Esterly mine, near O'Brien, Josephine county, Oregon, which were representative of the alluvial soils of that region. The samples were thoroughly mixed; when material was needed for the tests, the dirt was mixed with water and the portion which settled quickly was rejected. When the remaining fine sediment was placed in the fish troughs it was found that a considerable portion settled out at a regular rate during the first six hours after it was put in, but that after that period the amount of suspended silt remained nearly constant. As the sediment which settled in the troughs was stirred and strained daily, and occasionally fresh soil was added, the water of the experimental trough carried a heavy load of sediment for a few hours of each day and a lighter but constant load for the remainder of the day.

After several preliminary experiments in which apparatus and methods were tested, the first trial run was begun. Two troughs were arranged parallel to each other in a dimly lighted, unheated building. The water with which the troughs were filled came from a spring-fed stream on the Reed College campus, in which trout are living and breeding. One trough contained the sediment-laden water, the other clear water. Aside from the processes needed to keep the sediment in suspension, both troughs and the fish placed in them were treated in the same manner.

December 11, 1937, 90 cutthroat trout fingerlings, 2 to 2½ inches in length, were secured from the federal hatchery at Clackamas, Oregon. Fifty of these were placed in the sediment-containing trough, 40 in the clear-water trough. The experiment continued until December 30. At the time of the daily stirring (at which time fresh sediment was occasionally added) the load of sediment varied from 2,300 to 3,500 parts per million by weight. This was enough to make the water a dark brown color, and so opaque that a hand held an inch under the surface was invisible. The load of sediment fell rapidly during the first hour, and then more slowly, until after the sixth hour an almost constant load was carried for the remainder of a 24-hour period. This constant load varied from day to day from 360 ppm to 600 ppm, being 500 or more ppm on all but six of the 19 days during which the test lasted.

The fish were fed with the same food used in the hatchery from which they came. Those in the clear water usually did not feed until the operator had backed away from the trough. In the muddy water the fish were not seen to feed for the first two days, but after that they rose to the surface and fed actively as soon as particles of food began to fall on the surface of the water. The trout in the clear water remained nervous throughout the experimental period, while those in the muddy water became bold enough to peck at the operator's hand when it was placed in the water. Because of

the necessity of scraping the bottom of the trough, stirring up the silt, and adding fresh soil, fish in the sediment trough were disturbed much more than those in the clear water.

When the test was ended on December 30, it was found that a much larger proportion of the fish in the sediment-containing trough had survived (56%) than in the clear-water trough (10%). There was no noticeable difference in the color of the surviving fish in the two troughs, and the fish which had lived in the muddy water were as large as the survivors from the clear-water trough.

On January 12, 1938, a second experiment was begun in which 150 chinook salmon fingerlings, 1¾ to 2 inches long, were divided equally between the two troughs. This time the sediment was placed in the trough which had contained clear water in the previous experiment, and the other trough was used for clear water. Care was taken to reduce all movements near the troughs to those absolutely necessary to conduct the test. During the period of this test, which lasted 28 days, until February 9, the load of sediment was greater than in the first test. The maximum load at the time of stirring was from 3,100 to 6,500 ppm on most days. The constant load after the sixth hour was from 300 to 480 ppm from January 12 to January 25; and from 650 to 750 ppm from January 26 to February 9, except on two days when the load fell to 380 and 410 ppm.

The salmon fingerlings in the clear water at first showed the same nervousness as the trout, but after a week those which survived were not easily disturbed and fed avidly. The young salmon were not seen to feed in the muddy water quite so quickly as the young trout, and when they were seen they took food more deliberately than the trout. After the fish became accustomed to the new conditions of their lives and to the movements of the operator, those in both troughs fed satisfactorily.

Most of the salmon fingerlings in the muddy water were considerably lighter in color than the controls at the close of the test, though a few had not changed color. The fish of the muddy water were also irregular in growth, some having grown as much as the controls, while some were noticeably smaller.

At the close of the 28-day experimental period, 88% of the fish kept in the muddy water were alive, while 36% of the controls lived. Most of the controls which died did so during the first three days of the test; after which time there is no significant difference in the death rate of the two lots of fish.

On examining the day-by-day record one is struck by the heavy mortality which occurred on the third day of both experiments among the fish kept in the clear-water trough. This was not due to special conditions in one of the troughs, because the troughs were reversed for the two experiments. It could not be determined whether the fish kept in clear water were more active than those in the muddy water trough because the latter were invisible most of the time. The fact that more of the fish in clear water jumped over the ends of their trough indicates that they were more nervous. It was evident also that the fish in clear water were more disturbed by movements of the observers, changes of light intensity, etc., than the other fish.

In the second experiment the electric lights in the dimly illuminated aquarium room were not turned on, so that disturbance was avoided; but it was necessary to scrape the bottoms of the troughs, adjust screens and strainers, and perform other necessary actions daily. All these disturbed the fish in clear water much more than those in the muddy water. When excited, the fish frequently darted against the sides of their trough with considerable force. On several occasions startled fish were seen to strike the side of the trough with sufficient speed to stun themselves. It seems possible that the high mortality of the fish in clear water during the first week of both experiments was due to the injuries they inflicted upon themselves when excited. After a few days the fish became accustomed to their living conditions and to the movements of the operator in and around their trough, and then were excited much less easily.

After the first week the mortality among the young trout of the first experiment was almost the same in both troughs; 13 in the muddy water, 11 in the clear water. As the cutthroat trout fed well and grew normally in the muddy water, the conditions there do not seem to have been unfavorable for these fish.

After the first week of the second experiment, with young salmon for subjects, 9 died in the muddy water trough and 2 in the clear water. But after the heavy loss discussed above only 29 remained alive in clear water and 74 in muddy water, so that the difference in mortality is relatively about the same.

The results of the experiments indicate that young trout and salmon are not directly injured by

living for considerable periods of time in water which carries so much soil sediment that it is made extremely muddy and opaque. They also indicate that cutthroat trout and salmon fingerlings can feed and grow apparently well in very muddy water.

The sediment load of the water in these experiments was continuously much greater than it is in the ordinary muddy stream. Water taken from the Willamette River at flood stage after three days of heavy winter rains, and when the river water appeared to be extremely turbid, contained only 42 ppm of sediments.

While the results of these experiments throw some light on the problems which were under consideration, it seems desirable that more extensive tests should be undertaken, in order to secure a larger accumulation of data, and to investigate factors which could not be studied in the limited time or with the apparatus available for these experiments.

EXPERIMENT I

Cutthroat Fingerlings

Date	Water Temperature	Sediment Stirred	Sample Taken	Parts per Million	Tank 1 with Sediment		Tank 2 with Clear Water	
					Dead	Living	Dead	Living
Dec.	*F.*							
11	62.6	5:00 pm	6:00 pm	840	0	50	0	40
12	62.6	9:00 am	10:00 am	760	0	50	0	40
13	62.6	9:00 am	9:30 am	1190	1	49	12	28
			4:00 pm	520	0	49	0	28
14	62.6	.....	.....	.....	2	47	3	25
15	62.6	9:00 am	9:30 am	1140	0	47	0	25
			4:00 pm	690	3	44	8	17
16	62.6	9:00 am	9:30 am	1130	0	44	0	17
			4:00 pm	390	3	41	2	15
17		No	record		0	41	0	15
18	62.6	9:00 am	9:30 am	990	0	41	0	15
			4:00 pm	480	5	36	* 5	10
19	62.6	9:00 am	9:30 am	1040	1	35	1	9
20	62.6	9:00 am	9:30 am	990	0	35	0	9
			4:00 pm	500	0	35	† 1	8
21	60.8	9:00 am	9:30 am	750	1	34	0	8
22	60.8	9:00 am	4:00 pm	560	‡ 4	30	0	8
23	58.0	.....	.....	.....	0	30	0	8
24	57.2	.....	.....	.....	1	29	1	7
25	58.0	.....	.....	.....	1	28	0	7
26	58.0	.....	.....	.....	0	28	2	5
27	58.0	.....	.....	.....	0	28	0	5
28	58.0	.....	.....	.....	0	28	1	4
29	58.0	.....	.....	.....	0	28	0	4
30	58.0	.....	.....	.....	0	28	0	4
				Totals	22	28	36	4

Circumstances made weighing impossible from December 28 to December 30; conditions of the troughs were kept the same as they had been.

* Two of these jumped over the end screen and were carried through the pump.

† Killed by the pump.

‡ One killed by the pump.

EXPERIMENT II

Chinook Salmon Fingerlings

Date	Water Temperature	Sediment Stirred	Sample Taken	Parts per Million	Tank 1 with Sediment		Tank 2 with Clear Water	
					Dead	Living	Dead	Living
Jan.	*F.*							
12	58.0	†	.....	.....	0	75	0	75
13	58.0	.....	.....	.....	0	75	1	74
14	58.0	.....	.....	.....	0	75	* 40	34
15	58.0	.....	.....	.....	1	74	5	29
16	58.0	.....	.....	.....	0	74	0	29
17	58.0	9:00 am	9:30 am	820	0	74	0	29
18	58.0	9:00 am	9:30 am	950	0	74	0	29
19	58.0	.....	.....	.....	0	74	0	29
20	58.0	9:00 am	9:30 am	960	0	74	0	29
21	58.0	9:00 am	9:30 am	1100	0	74	0	29
22	58.0	9:00 am	9:30 am	1350	0	74	0	29
23	58.0	3:00 pm	3:30 pm	1240	0	74	0	29
24	58.0	3:00 pm	3:30 pm	1600	1	73	1	28
25	57.2	.....	.....	.....	1	72	0	28
26	57.2	3:00 pm	3:30 pm	2130	1	71	0	28
27	55.4	11:30 am	4:00 pm	930	0	71	0	28
28	55.4	9:00 am	9:30 am	2050	0	71	0	28
29	55.4	9:00 am	9:30 am	1670	0	71	0	28
30	53.6	9:00 am	9:30 am	1520	0	71	0	28
31	53.6	9:00 am	9:30 am	2120	0	71	0	28
Feb.								
1	53.6	11:30 am	4:00 pm	850	2	69	0	28
2	53.6	9:00 am	9:30 am	1480	0	69	0	28
3	53.6	9:00 am	9:30 am	1060	1	68	0	28
4	55.4	.....	.....	.....	0	68	0	28
5	60.8	6:00 am	6:30 am	2317	3	65	0	28
			12:30 pm	841	0	65	0	28
			8:00 pm	770	0	65	0	28
6	60.8	.....	.....	.....	0	65	1	27
7	60.8	6:00 am	6:30 am	2150	0	65	0	27
			12:30 pm	780	0	65	0	27
			8:00 pm	760	0	65	0	27
8	60.8	.....	.....	.....	0	65	0	27
9	60.8	4:00 pm	4:01 pm	5960	0	65	0	27
				Totals	10	65	48	27

From January 12 to 16 silt was added to the sediment trough daily in order to build up the load of suspended matter to a maximum. The load of suspended material was somewhat greater than during the first experiment.

* Four of these jumped over the screen at the outlet and were killed in the pump; six leaped over the side at the inlet end, which was not covered by mosquito netting as was the rest of the trough.

† Fish put in trough.

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