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SOME EFFECTS OF PILE AREA EFFLUENT WATER ON YOUNG SILVER SALMON

A description of experiments carried out at the Fish Laboratory between December 6, 1946 and October 20, 1947.

By: PA Olson, Jr.

Date: February 17, 1948

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INTRODUCTION

The silver salmon, Oncorhynchus kisutch, is one of the five species of Pacific salmon which are found in the Columbia River. Although they are not as abundant in the upper Columbia River as the chinook, they are present in considerable numbers and are consequently exposed to the effluent water being discharged by the three pile areas. Because of their extensive use as a food fish and their great commercial value, second only to the chinook, it seemed advisable to determine what effect the Pile Area effluent water might have on the developing eggs and young of silver salmon. Conditions which existed in the river were duplicated as nearly as possible so that the effects of various concentrations of the Pile Area effluent water upon the eggs and young fish could be studied. These stages are of particular importance since they occur in the gravel beds and thus are not capable of swimming away from adverse conditions, as older fish may do.

In the following pages a detailed description is given of the second series of experiments which were undertaken by the Fish Laboratory. The first series of experiments were conducted on chinook salmon and steelhead trout. A detailed report describing this first series was prepared by R. F. Foster in Document Number 7-4759, "SOME EFFECTS OF PILE AREA EFFLUENT WATER ON YOUNG CHINOOK SALMON AND STEELHEAD TROUT".

SUMMARY

During the greater part of 1947 the Fish Laboratory made an extensive study on the effect of area effluent water on silver salmon eggs, fry and fingerlings. The water mixtures in which the fish were held during the egg and fry stage were as follows:

- Undiluted area effluent water partially cooled
- Undiluted area effluent water refrigerated to river water temperature
- One part area effluent to 5 parts of river water
- One part area effluent to 10 parts of river water
- One part area effluent to 25 parts of river water
- One part area effluent to 50 parts of river water
- One part area effluent to 100 parts of river water
- One part area effluent to 250 parts of river water
- Straight river water for control

During the early part of the fingerling stage water direct from the outlet side of the 107 Retention Basin was substituted for the undiluted area effluent water which contains water from other parts of the plant. Pre-pile process water which was passed through a charcoal filter to remove residual Chlorine was substituted for the one part effluent to 250 parts of river water.

The eggs were susceptible to the presence of area effluent water and its accompanying higher temperatures. Those held in the partially cooled area effluent water, 1:5, and 1:10 dilutions had egg mortalities significantly higher than those held in straight river water. However, where increased temperature was not a factor, the eggs appeared quite resistant to the area effluent water. There was no significant difference between the egg mortalities in the refrigerated area effluent water and the river water control lots. Nor did dilutions

of the area effluent water of 1:25 or greater significantly increase the mortality of the silver salmon eggs.

The young silver salmon appeared to be more susceptible to area effluent water during the fry stage than at any other time. There was a lack of proper development and a one hundred percent mortality during this stage among the fry held in the partially cooled area effluent water and in the refrigerated area effluent water. Fry mortalities significantly higher than those in the control lots could be demonstrated statistically in the 1:5, 1:10, 1:25 and 1:50 dilutions of area effluent water. In higher dilutions no significant increases in mortality were detectable.

The mortality of the fingerling size fish was high in the lots exposed to either refrigerated or unrefrigerated 107 Retention Basin water and in the pre-pile process water. The 1:5 and 1:10 lots also had mortality rates far above those of the river controls. In dilutions of 1:25 or greater, the effluent water did not significantly increase the mortality of the fingerling size silver salmon.

Growth and development of the silver salmon were retarded in undiluted area effluent water, 107 Retention Basin water, pre-pile process water and in the 1:5, 1:10, and 1:25 dilutions. In dilutions of 1:50 or greater, the effluent water did not retard the growth of the silver salmon.

EXPERIENCE AND CONDITIONS

The Eggs

The eggs used in this experiment were obtained from a stock entering Green River, a tributary to Puget Sound, and intercepted by the State of Washington, Department of Fisheries at Soos Creek. The progeny of silver salmon from Green River could be expected to react to the various concentrations of the area effluent water in the same manner as progeny from Columbia River silver salmon. The eggs were readily obtainable at the Soos Creek Hatchery, and in addition expected rates of survival and growth were known for this stock.

On the morning of December 6, 1946, the eggs were removed from the fish fertilized and immediately transported by car to the Fish Laboratory in the 100-F Area. The 63,360 eggs obtained were then distributed approximately equally among forty trays, there being two trays in each trough. These shallow trays were wedged near the surface in the upper part of each trough and baffles were installed to insure water circulation through the eggs. A lot number was assigned to each tray of eggs which corresponded to the trough number, and in addition contained the suffix "A", denoting the upper, or "B" the lower tray of the pair.

Since some loss was experienced from transporting the eggs, as could reasonably be expected, all obviously dead or injured eggs were removed from the trays during the evening of December 6 and on the morning of December 7. The total number removed was recorded, but this loss was not included in subsequent mortality data. The initial loss or "pick-off" was less than 5 per cent.

The eggs were subjected to the following water conditions:

Trough No.	Water Type	Rate of Flow
1 & 2	100 % area effluent water, partially cooled (Averaged 4.3 C. warmer than river water)	3 g.p.m.
3 & 4	100% area effluent water, refrigerated to river water temperature	3 g.p.m.
5 & 6	1:5 effluent to river water (Averaged 3.2°C. warmer than river water)	5 g.p.m.
7 & 8	1:10 effluent to river water (Averaged 1.7°C. warmer than river water)	5 g.p.m.
9 & 10	1:25 effluent to river water (Averaged .7°C. warmer than river water)	5 g.p.m.
11 & 12	1:50 effluent to river water	5 g.p.m.
13 & 14	1:100 effluent to river water	5 g.p.m.
15 & 16	1:250 effluent to river water	5 g.p.m.
17 & 18	100% river water	5 g.p.m.
19 & 20	100% river water	3 g.p.m.

Throughout this experiment the desired water conditions were maintained with reasonable strictness. The water flows were checked and adjusted if necessary twice each shift. Only on rare occasions and then for brief periods of time was it necessary to alter them because of equipment failure. During times of Pile shutdowns for metal replacement when large quantities of "Calol" were in the effluent water, river water was temporarily substituted for the effluent to avoid the toxic effect of "Calol".

During the first part of the incubation period the eggs were developing through stages which were very delicate and easily injured. They were, therefore, handled as infrequently and as gently as possible during this time. Dead eggs were removed, however, since their continued presence in the trays might spoil entire groups due to fungus and decay. Silt from the river water and ferric sulphate sludge from the effluent water accumulated on the eggs and occasionally had to be siphoned off or cleared away with a feather to prevent the eggs from smothering.

By the last week in December for the lots in warmer water (those in partially cooled area effluent and the 1:5 dilution), and by the first week in January for the other lots, the eggs had developed to what is known as the "eyed" stage. At this time development had proceeded far enough so that the pigmented eyes of the embryo were clearly visible through the translucent shell, and the eggs could withstand considerable handling without injury.

Due to the difference in water temperatures for the various lots hatching occurred over a considerable time interval, roughly two months. Figure I shows the temperatures of various water conditions which existed at the Fish Laboratory during this experiment. The eggs which were incubated in the warmest water, that is troughs 1, 2, 5, 6, 7, and 8 were the first to hatch. Those incubated in river and refrigerated effluent water were the last to hatch.

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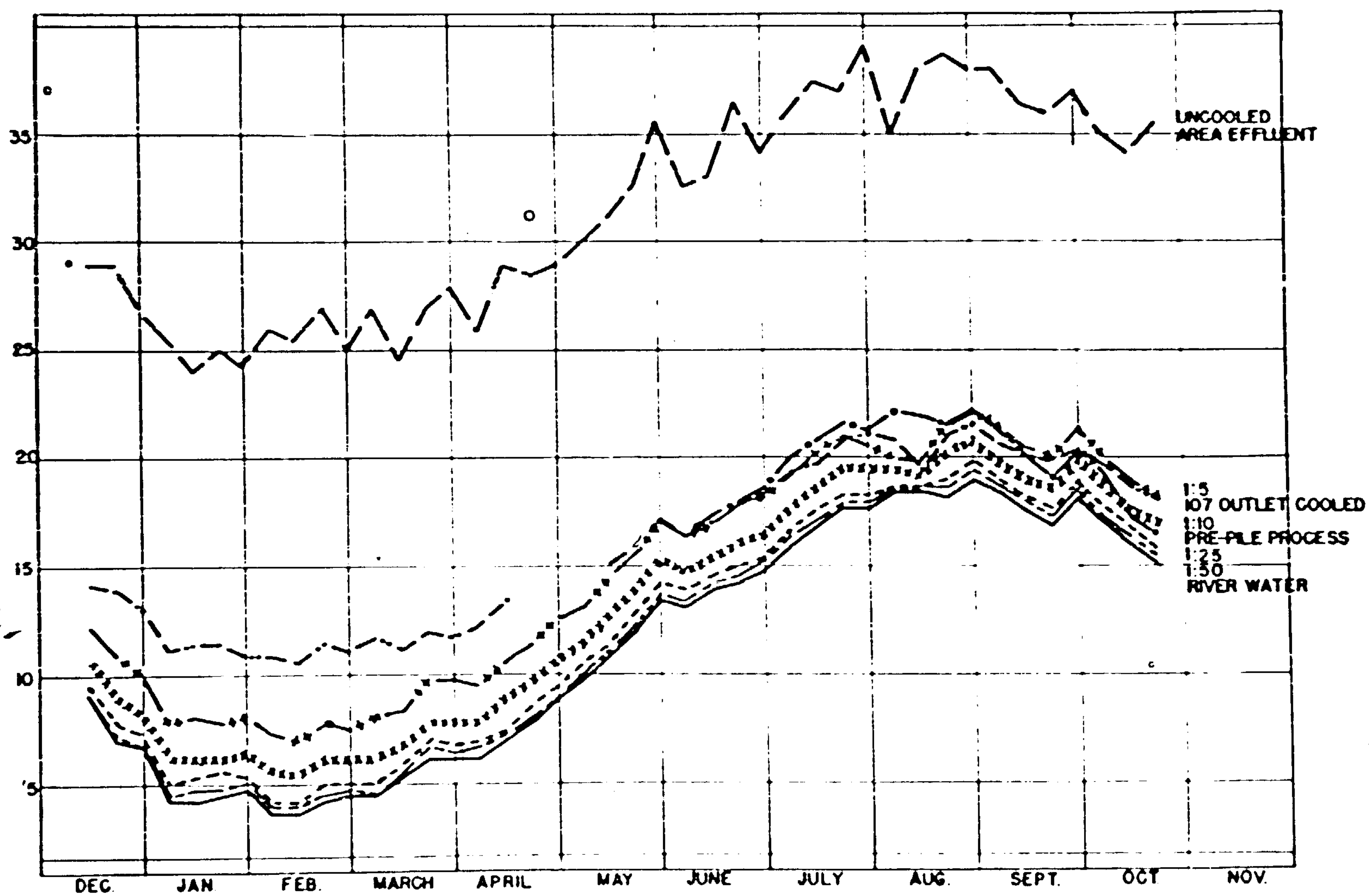
FIGURE T

WATER TEMPERATURES IN THE FISH LABORATORY DURING 1947



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All salmon eggs which were obviously dead or not developing were removed from the trays and a daily record of this pick-off was kept. The date on which an egg was removed did not necessarily correspond to the time at which it died or stopped developing since many eggs which are wholly infertile or scarcely developed are not distinguishable for several weeks. Therefore, nearly all of the eggs which were removed were cleared in salt solution and fixed with acetic acid so that any embryo formation might be observed. The eggs examined were arbitrarily classified into the following six stages:

A. Those which were infertile or showed no evidence of embryo formation.

B. Those which were fertile but had developed only as far as blastoderm formation.

C. Those in which a definite embryo was formed but had survived only to the formation of the chorda or primitive streak.

D. Those in which development had advanced to the formation of somites, fin buds, and optic vesicles but where the total length of the embryo was less than half the circumference of the egg.

E. Those in which the length of the well formed embryo exceeded half the circumference of the egg.

F. Those which died in hatching.

Table I is a summary of the mortality data, made by pooling egg lots which were incubated in like water conditions and presents the results as percentages. Figure 1 is a graphic representation of Table I and here a log scale has been used above the one per cent level in order to more clearly define the curves. A statistical procedure consisting of a t- test based on an arry of lot mortality percentages was used to determine whether or not significant differences were present. (1) Mortalities were significantly higher than those of the river water control group in the unrefrigerated area effluent, and in the 1:5 and 1:10 dilutions These significantly higher total mortalities have been underlined in Table I.

Eggs exposed to the undiluted and unrefrigerated effluent water suffered over an eighty per cent mortality. A major part of this effect was, however, due to the warm temperature of the effluent water since in the same effluent refrigerated to river water temperature the mortality was not greater than the river water controls. The greater effect of temperature over other factors is also shown by the fact that the 1:10 and 1:5 dilutions, in which the water temperatures were progressively higher than that of the river water, had mortalities which were in the same manner progressively greater than that of the refrigerated effluent group. Aside from the direct effect, increased temperature seems also to accentuate other adverse conditions such as toxic effects of chemicals.

On examining the mortalities which were significantly higher that the river controls it is seen that the adverse effects appear gradually, in most cases allowing considerable early development of the eggs. This condition is especially noticeable in the unrefrigerated effluent where by far the greatest mortality occurs after the embryo is well developed (Stages D through F).

(1) Values were considered to be significantly different if their chance of occurring in random sampling was less than five per cent.

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TABLE I

PERCENTAGE MORTALITIES OF SILVER SALMON EGGS
INCUBATED IN VARIOUS CONCENTRATIONS OF AREA EFFLUENT WATER

Type of Water	Effluent Water	Refrigerated Effluent Water	1:5	1:10	1:25	1:50	1:100	1:250	River Water
Lot Nos.	1A, 1B 2A, 2B	3A, 3B 4A, 4B	5A, 5B 6A, 6B	7A, 7B 8A, 8B	9A, 9B 10A, 10B	11A, 11B 12A, 12B	13A, 13B 14A, 14B	15A, 15B 16A, 16B	17A&B, 18A&B 19A&B, 20A&B
Stage A	1.92	1.04	1.34	1.48	1.53	1.40	1.40	1.36	1.19
Stage B	3.34	2.23	1.79	1.86	[illegible]	1.67	1.95	1.32	1.88
Stage C	2.25	0.80	0.51	0.54	[illegible]	0.46	0.24	0.36	0.32
Stage D	27.12	0.97	3.30	3.49	1.74	2.12	2.37	1.72	1.92
Stage E	28.27	0.72	3.32	[illegible]	[illegible]	.77	0.95	0.74	[illegible]
Stage F	[illegible]	[illegible]	1.43	.25	0.22	.22	0.18	0.15	[illegible]
Misc.	0.23		0.21	[illegible]					
Total	[illegible]	5.93	11.90	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

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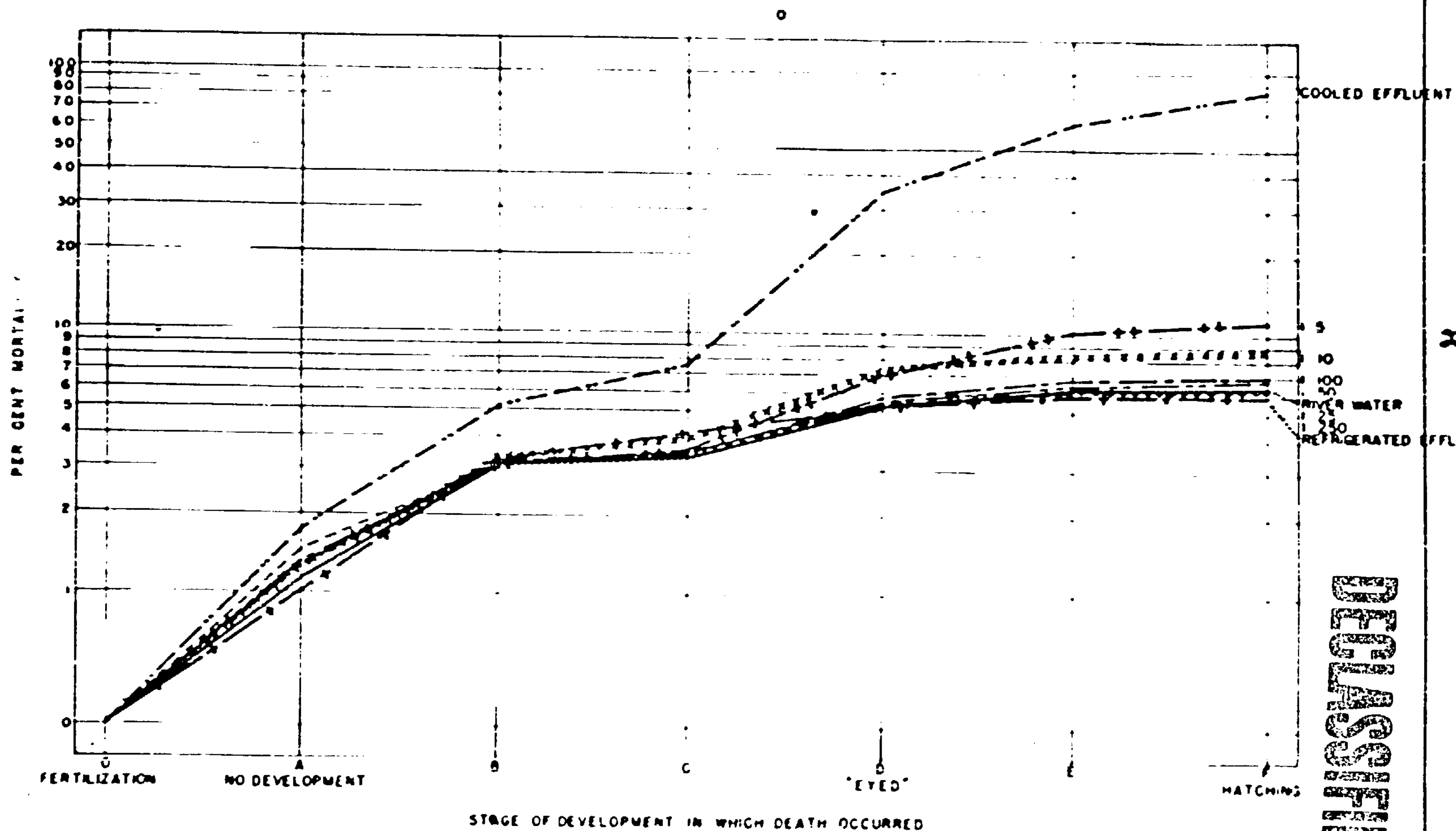
FIGURE I

MORTALITIES OF SILVER SALMON EGGS
INCUBATED IN VARIOUS CONCENTRATIONS OF EFFLUENT WATER



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The fish embryo while developing in the egg appears to be quite resistant to adverse chemical and possibly physical factors when the temperature is kept near an optimum range. This fact is brought out in the case of the eggs exposed to the refrigerated effluent water. During incubation of the eggs mortality was no greater than occurred in the river water controls; after hatching, however, the fry suffered a 100 per cent mortality.

The Fry

When first hatched, the young salmon or fry are nourished by a yolk sac which is incorporated into the ventral body wall. In water temperatures of 6° to 9° C., this yolk is used up in about six weeks or two months, and at the end of this time the young fish are ready to start feeding. In each trough the fry which hatched from the upper tray (A) and the lower tray (B) were combined into a single lot with a number corresponding to that of the trough.

Daily records of the numbers of fry dying in each trough have been condensed into weekly intervals. The mortalities in lots subjected to like water conditions were pooled into groups and Table II presents the combined mortalities together with their cumulative percentages. The data of Table II are shown graphically in Figure 2, where a log scale has been used above the one per cent level in order to more clearly define the curves in the lower percentages.

Table II and Figure 2 indicate the considerable period of time over which hatching took place since mortality in the fry stage naturally necessitated that the eggs be hatched and fry present. For example, almost all of the fry in the undiluted effluent water had died before the fish in the colder lots had started to hatch or consequently show mortality in the fry stage.

The fry in the undiluted effluent water suffered a considerable mortality immediately after hatching, a consistently high mortality for several weeks and then, during the last two weeks in February, a sharp rise in the rate of mortality again. Shortly after hatching the fish in this lot appeared weak and exhibited abnormal swimming actions, none reached the feeding stage and all were dead by the middle of March.

In troughs 3 and 4 where the effluent water was refrigerated, the cooler temperature delayed development. Upon hatching the fry appeared healthy and active and seemed to give no indication of their imminent fate. During the first month their rate of mortality was no greater than that of the river controls although they were not as active. Starting at about the sixth week after hatching there was a sharp rise in the rate of mortality followed by two weeks more of continued high mortality, then again by a sharp rise in mortality. The last fry of this lot died during the first week of June. The development of the fry in the refrigerated effluent water was considerably slower than in straight river water of the same temperature. When the fish in the control lots had completely absorbed their yolks and were starting to feed, those in the refrigerated effluent water of troughs 3 and 4 still retained a large amount of yolk and were smaller in size. The last fry in this lot died without completely absorbing their yolk sacs 7 weeks after the control lots had absorbed their yolks and were feeding.

The fry in the 1:5 dilution experienced a mortality of almost 50 per cent. As a group they appeared weak and exhibited abnormal swimming actions. They again

TABLE II

MORTALITIES OF SILVER SALMON FRY HELD IN
VARIOUS CONCENTRATIONS OF AREA EFFLUENT WATER

Type of Water	Effluent Water		Refrigerated Effluent Water		1:5		1:10		1:25		1:50		1:100		1:250		River Water	
Lot. Nos.	1 & 2		3 & 4		5&6		7&8		9&10		11&12		13&14		15&16		17,18,19,20	
No. of Fish	891		5600		5301		5531		5771		5653		5652		5619		11318	
Date	Mort.	Cum.%	Mort.	Cum.%	Mort.	Cum.%	Mort.	Cum.%	Mort.	Cum.%	Mort.	Cum.%	Mort.	Cum.%	Mort.	Cum.%	Mort.	Cum.%
- 1/11/57	1	.11																
1/12 - 1/18	203	22.90																
1/19 - 1/25	115	35.80			7	.13												
1/26 - 2/1	39	40.18			150	2.96												
2/2 - 2/8	24	42.87			19	3.22	1	.02										
2/9 - 2/15	66	50.28			13	3.57	0	.02										
2/16 - 2/22	259	79.35			436	11.79	88	1.61										
2/23 - 3/1	149	96.07	1	.02	89	13.47	39	2.31	47	.81								
3/2 - 3/8	22	98.54	3	.07	70	14.79	11	2.51	5	.90			3	.05	1	.02	2	.02
3/9 - 3/15	13	100	35	.70	89	16.47	17	2.82	4	.97	33	.58	39	.74	40	.73	68	.62
3/16 - 3/22	All		10	.88	141	19.13	20	3.18	3	1.02	9	.74	5	.83	8	.87	23	.82
3/23 - 3/29	Dead		14	1.12	195	22.62	37	3.85	3	1.07	1	.76	3	.88	3	.93	5	.87
3/30 - 4/5			14	1.38	365	29.50	87	5.42	7	1.20	1	.78	0	.88	3	.98	4	.90
4/6 - 4/12			256	5.95	450	37.99	79	6.85	18	1.51	11	.97	4	.96	2	1.01	4	.94
4/13 - 4/19			773	19.75	341	44.43	83	8.35	41	2.22	27	1.45	16	1.24	21	1.39	20	1.11
4/20 - 4/25			401	26.91	193	48.07	83	9.85	13	2.44	22	1.84	9	1.40	13	1.62	11	1.21
4/26 - 5/2			512	36.04														
5/3 - 5/9			1163	56.80														
5/10 - 5/16			1481	83.25														
5/17 - 5/23			733	96.34														
5/24 - 5/30			168	99.34														
5/31 - 6/6			37	100														

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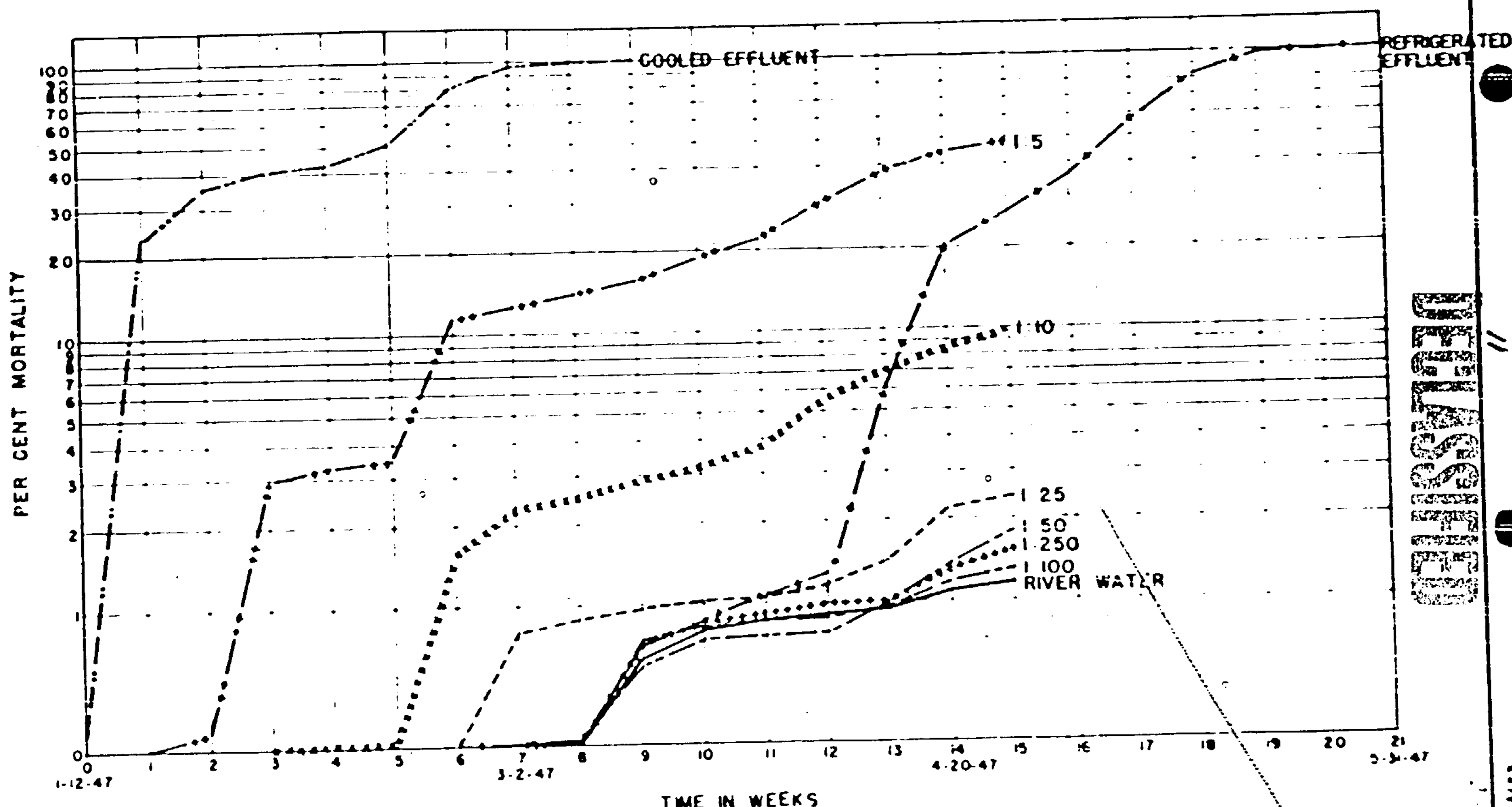
FIGURE 2

MORTALITIES OF SILVER SALMON FRY
INCUBATED IN VARIOUS CONCENTRATIONS OF EFFLUENT WATER



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showed surges of mortality followed by periods of good survival. By the middle of March they had absorbed their yolk sacs and feeding was started. Their size at the end of the yolk sac stage was appreciably smaller than that of the controls.

The fry in the first six troughs followed a very characteristic pattern. They appeared weak and instead of swimming actively large numbers would lie on the bottom, the only movement they would show would be weak gill action. When disturbed they would exhibit abnormal swimming actions. Many of the individuals that died showed a so called "white spot disease" characterized by precipitated particles in the yolk and often a white coloration along the posterior dorsal and ventral portions of the body. This condition, however, is thought to be caused by adverse environmental conditions rather than disease organisms.

In the 1:10 dilution the rate of mortality during the fry stage was appreciably higher than in the weaker dilutions. This resulted in the death of almost ten per cent of these fish. Some of the dying fish showed "white spot disease". By the last of March they had absorbed the yolk sac and had started to feed. Their size at the end of the yolk sac stage was appreciably smaller than that of the controls.

The 1:25 and 1:50 dilution levels seemed to significantly increase the mortality during the fry stage. The 1:100 and 1:250 dilution levels did not significantly increase the mortality during the fry stage. The general condition, appearance, activity and size of the young fish in dilutions of less than 1:10 appeared similar to that of the river water controls. By the middle of April these fish had absorbed the yolk sac and had started feeding.

The mortality of the silver salmon in the fry stage was characterized by the appearance of peaks or surges rather than a steady rate. One peak appeared shortly after hatching in all lots. In all cases there was a small percentage of weak or crippled fish which were able to hatch but which were not able to survive the fry stage. This period is one of physiological change since while in the egg the fish is protected by the shell membrane, but upon hatching it becomes an active, free swimming form and consequently encounters new conditions. During the last two weeks in February there was a sharp rise in the mortality of fish held in straight effluent water, and in the 1:5 and 1:10 dilutions. At this time the river water was very silty and dirty and large quantities of "ferrifloc" were being used and consequently appearing in the effluent water. It is conjectured that the increased numbers of solid particles, due to both "ferrifloc" and to silt in the river water, increased the abrasive action on the gills affecting respiration and possibly made the fish more susceptible to adverse chemical and physical conditions. Another definite peak in mortality for all lots appeared during the first twenty days in April. One possible reason for this was that all lots, with the exception of the refrigerated effluent water, had completed the absorption of their yolk sac during this period and had begun to feed. This is another critical period for the fish since it no longer has a reserve of yolk material to sustain it, but must begin to feed on its own. It is a period of marked physiological change.

Fingerlings

The distinction between the fry and fingerling stages is rather arbitrary, but is here characterized by an active feeding response by the fish. At this time it was also necessary and convenient to reduce the number of fish in each trough to approximately five hundred. New stocks were placed in troughs 1, 2, 3, and 4 since practically all of the fry in these troughs had died. These lots were designated as 1A, 2A, 3A and 4A. The new stocks were taken from surplus river water control fish. Between July 8 and July 10 all of the fish in lots 1A, 2A, 3A and 4A were accidentally killed by chlorine entering the supply in sanitary water used for pump priming. After this accident, new lots from river water control surplus stocks were again established in troughs 1 through 4 and were designated as 1B, 2B, 3B and 4B. Due to the increase in fish size it was advisable at this time to reduce the size of the lots in most of the other troughs to approximately two hundred. The surplus fish were liberated into the Columbia River. Since the numbers of fish in the 1:5 and 1:10 lots had been considerably reduced by heavy mortality, these lots were not reduced at this time. To make trough space available for another experiment lots 5 and 6 (1:5) were combined and placed in trough 7 and lots 7 and 8 (1:10) were combined and placed in trough 8.

During the fingerling stage there were two major changes in the Water Conditions. On May 8, new facilities made it possible to substitute straight 107 Retention Basin water from the outlet side for the undiluted area effluent water in troughs 1, 2, 3, and 4. The undiluted area effluent water consisted of a combination of pile effluent from the Retention Basin (Bldg. 107) mixed with all other area effluents. This mixed area effluent water was still used in the dilutions, i.e. 1:5, 1:10 etc. The 107 Retention Basin water was cooled by river water in a heat exchanger prior to going through the usual series of cooling coils in the laboratory. Thus the temperature conditions in troughs 1 through 4 were not altered materially by this change in water.

New equipment changes also made available a supply of pre-pile process water, which contained all of the added chemicals with none of the pile effects. This supply originated in the 190 Bldg., was brought to the Fish Laboratory via a 2 inch main and was connected to troughs 15 and 16. In this water the residual chlorine was of sufficient strength to kill young salmon in a matter of a few hours. This necessitated the removal of the chlorine, which was accomplished by installing an activated carbon filter in this water supply. Apparently this residual chlorine in the process water is largely driven off when going through the operating pile and subsequently by being held in the Retention Basin. The 1:250 dilution lot was discontinued in order that the pre-pile process water could be used. This was done on June 2. The temperature of the pre-pile water averaged about 3°C. warmer than the river water due to heat accumulated in transit.

The mortality data for the fingerlings was handled in precisely the same manner as that of the fry. The results were pooled into the group means shown in Table III. The cumulative percentages of Table III have been plotted in Figure 3, which also utilizes a log scale above the one per cent mortality level.

Two replacement groups of fish were subjected to the 107 Basin water and although these fingerlings had not previously been subjected to effluent of any kind their mortalities soon rose above that of the controls and continued high until their accidental deaths in the first case and the terminating of the experiment in the latter. The warmer water lots in troughs 1 and 2 were

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TABLE III

MORTALITIES OF SILVER SALMON FINGERLINGS HELD IN VARIOUS CONCENTRATIONS OF EFFLUENT WATER

Type of Water	107 Basin Outlet Water		Refrigerated 107 Basin Outlet Water		1:5		1:10		1:25		1:50		1:100		1:250		Pre-Pile Process Water		River Water	
Lot Nos.	1A&2A		3A&4A		5&6		7&8		9&10		11&12		13&14		15&16		15 & 16		17,18,19,20	
No. of Fish	941		990		978		974		996		966		994		926		918		1975	
Date	Mort.	Cum.%	Mort.	Cum.%	Mort.	Cum.%	Mort.	Cum.%	Mort.	Cum.%	Mort.	Cum.%	Mort.	Cum.%	Mort.	Cum.%	Mort.	Cum.%	Mort.	Cum.%
4/26-5/2	1	.11	9	.91	52	5.32	14	1.44	5	.50	5	.52	9	.91	3	.32			4	.20
5/3 - 5/9	9	1.06	4	1.31	47	10.12	6	2.05	2	.70	3	.83	4	1.31	3	.65			11	.76
5/10 - 5/16	3	1.38	1	1.41	64	16.67	9	2.98	2	.90	2	1.04	0	1.31	3	.97			4	.96
5/17 - 5/23	64	8.13	14	2.83	154	32.41	10	4.00	0	.90	1	1.14	0	1.31	1	1.08			0	.96
5/24 - 5/30	262	36.03	41	6.97	153	48.57	20	6.06	0	.90	1	1.24	2	1.51	0	1.08			2	1.06
5/31 - 6/6	204	57.70	180	25.15	125	61.35	64	12.63	0	.90	0	1.24	0	1.51			2	.22	0	1.06
6/7 - 6/13	25	60.36	254	50.81	50	66.46	27	15.40	0	.90	0	1.24	0	1.51			0	.22	0	1.06
6/14 - 6/20	8	61.21	78	58.69	67	73.31	47	20.23	0	.90	0	1.24	0	1.51			14	1.74	1	1.11
6/21 - 6/27	10	62.27	8	59.49	53	78.73	34	23.72	1	1.00	0	1.24	0	1.51			23	4.25	0	1.11
6/28 - 7/4	13	63.66	4	59.90	21	80.88	17	25.46	1	1.10	3	1.55	2	1.71			28	7.30	2	1.22
7/5 - 7/10	4	64.08	3	60.20	13	82.21	17	27.21	0	1.10	0	1.55	1	1.81			18	9.26	0	1.22
Lot Nos.	1B & 2B		3B & 4B																	
No. of Fish	377		395		162		381		401		393		401				402		780	
7/11 - 7/17	1	.27	0	0	22	84.63	6	28.35	0	1.10	0	1.55	0	1.81			19	13.55	0	1.22
7/18 - 7/24	3	1.06	0	0	14	86.16	2	28.74	3	1.84	0	1.55	0	1.81			23	18.74	0	1.22
7/25 - 7/31	49	14.06	9	2.28	2	86.38	4	29.50	1	2.09	0	1.55	0	1.81			37	27.09	0	1.22
8/1 - 8/7	51	27.59	11	5.06	11	87.59	3	30.08	1	2.34	0	1.55	0	1.81			22	32.05	0	1.22
8/8 - 8/14	76	47.75	22	10.63	5	88.14	2	30.46	0	2.34	0	1.55	0	1.81			26	37.92	1	1.35
8/15 - 8/21	16	51.99	4	11.65	0	88.14	2	30.84	0	2.34	0	1.55	1	2.06			21	42.67	1	1.48
8/22 - 8/28	1	52.25	1	11.90	4	88.58	2	31.22	0	2.34	0	1.55	0	2.06			9	44.70	0	1.49
8/29 - 9/4	16	56.50	6	13.42	10	89.68	7	32.56	0	2.34	1	1.80	0	2.06			11	47.18	0	1.48
9/5 - 9/11	22	62.33	22	18.99	4	90.12	1	32.75	1	2.58	0	1.80	0	2.06			26	53.05	1	1.60
9/12 - 9/18	18	67.11	20	24.05	6	90.78	2	33.14	0	2.58	0	1.80	0	2.06			11	55.54	0	1.60
9/19 - 9/25	10	69.76	24	30.13	2	90.99	3	33.70	0	2.58	0	1.80	0	2.06			20	60.05	0	1.60
9/26 - 10/2	21	75.33	18	34.68	5	91.54	2	34.09	2	3.08	0	1.80	1	2.30			20	64.57	0	1.60
10/3 - 10/9	24	81.70	16	38.73	4	91.98	1	34.28	3	3.81	0	1.80	0	2.30			13	67.50	0	1.60
10/10 - 10/16	5	83.02	21	44.05	1	92.09	1	34.47	0	3.81	0	1.80	0	2.30			17	71.34	0	1.60
10/17 - 10/20	2	83.55	3	44.81	0	92.09	0	34.47	0	3.81	0	1.80	0	2.30			6	72.69	0	1.60

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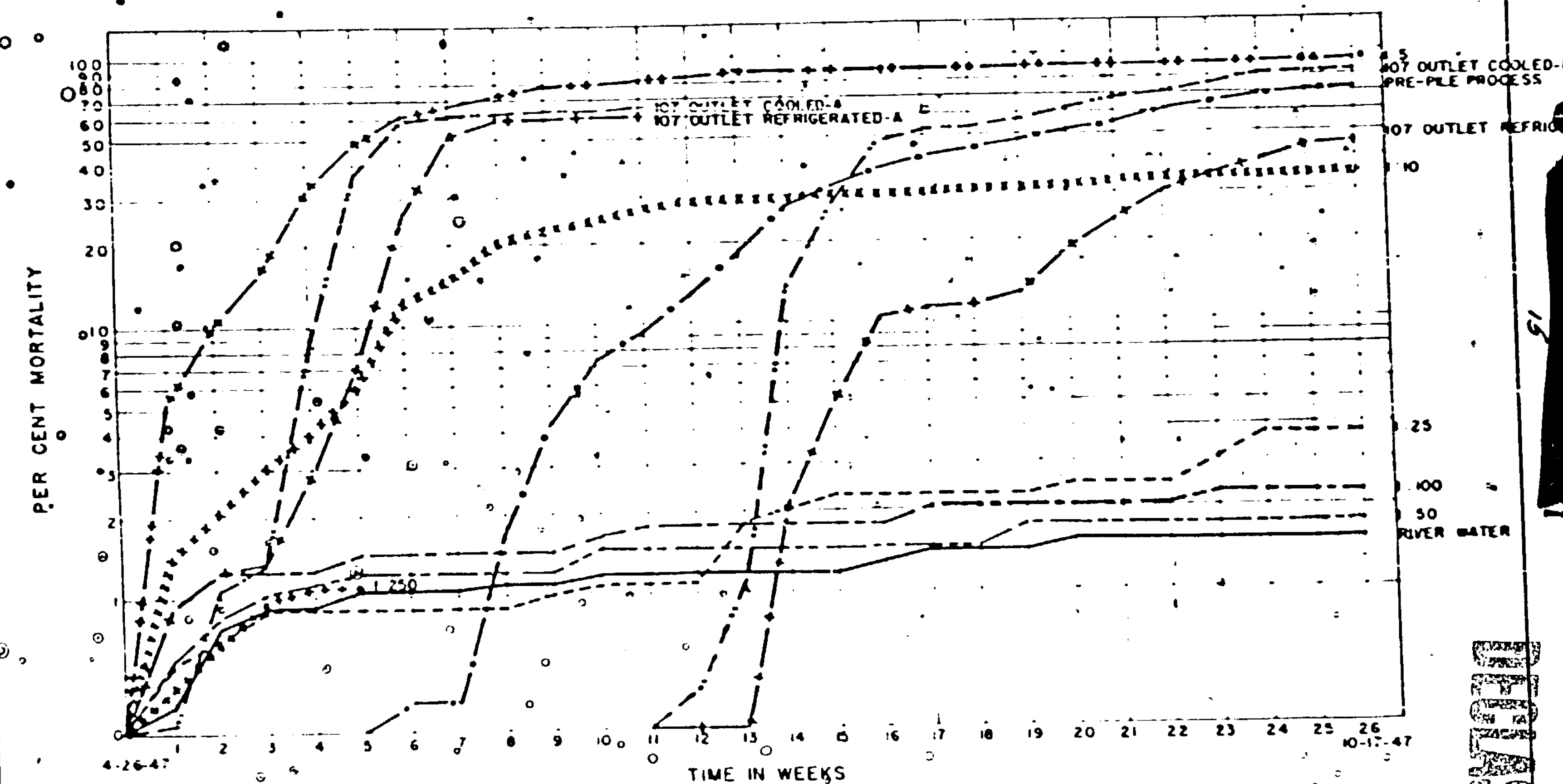
FIGURE 3

MORTALITIES OF SILVER SALMON FINGERLINGS HELD IN VARIOUS CONCENTRATIONS OF EFFLUENT WATER



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affected more quickly than the refrigerated ones in troughs 3 and 4 and suffered heavier rates of mortality.

The death rate in the 1:5 dilution at first glance appears to exceed that of the 107 Basin water. This paradox resulted because the fish in the 1:5 dilution had been exposed since the egg stage and a high mortality rate was already occurring in these fish at the time the fingerling data were started. The death rate in the 1:10 is well above that of the river controls. In both the 1:5 and 1:10 lots the fish which died were usually the weakest, most emaciated individuals. It appears that the effluent water has a gradual and continual toxic or weakening effect. During the last four months of the experiment the rates of mortality in these two lots decreased. One apparent reason for this lessening of mortality was that the stronger and hardier fish survived while the weaker ones had previously been killed.

The fish in the 107 Basin water and in the 1:5 and 1:10 dilutions again showed quite definite peaks of mortality during the fingerling stage. There was a rise in the rate of mortality of fish in the 107 Basin water between August 4 and August 15 when the pile was not operating. Subsequent developments indicate that during such periods enough chlorine remains in the cold basin water to adversely affect the fish.

The fish exposed to the pre-pile process water showed consistently high rates of mortality indicating that the chemicals in the effluent water are a major cause of high mortality rates among fish held concentrations of plant effluent.

In dilutions of 1:25 or greater, the effluent water did not significantly increase the mortality of the fingerling silver salmon.

Growth in Length and Weight

The growth in length and growth in weight followed identical trends, and so will be considered together. Length measurements were made every four weeks, and the fish were weighed in groups every two weeks. Table IV shows the average length of the salmon in each water type on each sampling date. Table V presents similar data for the weights. Figures 4 and 5 depict the growth of the fish in length and weight, respectively.

Size measurements were first made on March 20, on the 1:5 dilution lot which had just absorbed the yolk sac. At this time this was the only lot far enough advanced to be handled. The improper utilization of the yolk by the fry in the refrigerated effluent, 1:5 and the 1:10 lots is clearly shown in both the Length and Weight charts by the smaller sizes of these fish as compared with the other lots. The weights of fish in the refrigerated effluent on May 29 were greater than those of the fish in either the 1:5 or 1:10 dilution lots. However so few fish remained alive in the refrigerated effluent on this date that the sample was inadequate. The last of the fish in this lot died shortly afterwards.

Retardation of growth during the fingerling stage in the 1:5 and 1:10 dilution lots is clearly shown. In every case an effort was made to sample the population in a random manner. However, due to the extreme variation in size

TABLE IV

STANDARD LENGTHS IN MILLIMETERS OF SILVER SALMON HELD
IN VARIOUS CONCENTRATIONS OF EFFLUENT WATER

Type of Water	107 Basin Outlet Water		Refrigerated 107 Basin Outlet Water			1:5	1:10	1:25	1:50	1:100	1:250	Pre-Pile Process Water	River Water
Lot Nos.	1&2A	1&2B	3&4	3A&4A	3B&4B	5&6	7&8	9&10	11&12	13&14	15&16	15 & 16	17,18,19,20
March 20						28.6							
April 3							29.7						
April 17			27.8			28.4	30.5	33.1	32.6	32.6	32.2		31.6
May 15	36.4		29.0	36.0		30.2	32.8	37.9	38.0	37.2	36.0		36.8
June 12	45.4			39.6		31.4	33.2	44.2	46.0	45.2		44.2	44.6
July 10	51.4			49.5		35.8	39.0	51.8	54.6	53.8		51.5	52.1
August 7		55.6			57.5	44.4	44.8	57.4	61.9	60.0		56.6	60.9
Sept. 4-5		60.3			60.6	46.5	51.1	63.1	66.4	65.6		58.2	65.2
Oct. 2		64.5			68.0	51.2	53.9	69.8	73.2	73.4		63.8	72.9

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FIGURE 4

GROWTH IN LENGTH OF SILVER SALMON FINGERLINGS HELD IN VARIOUS CONCENTRATIONS OF EFFLUENT WATER

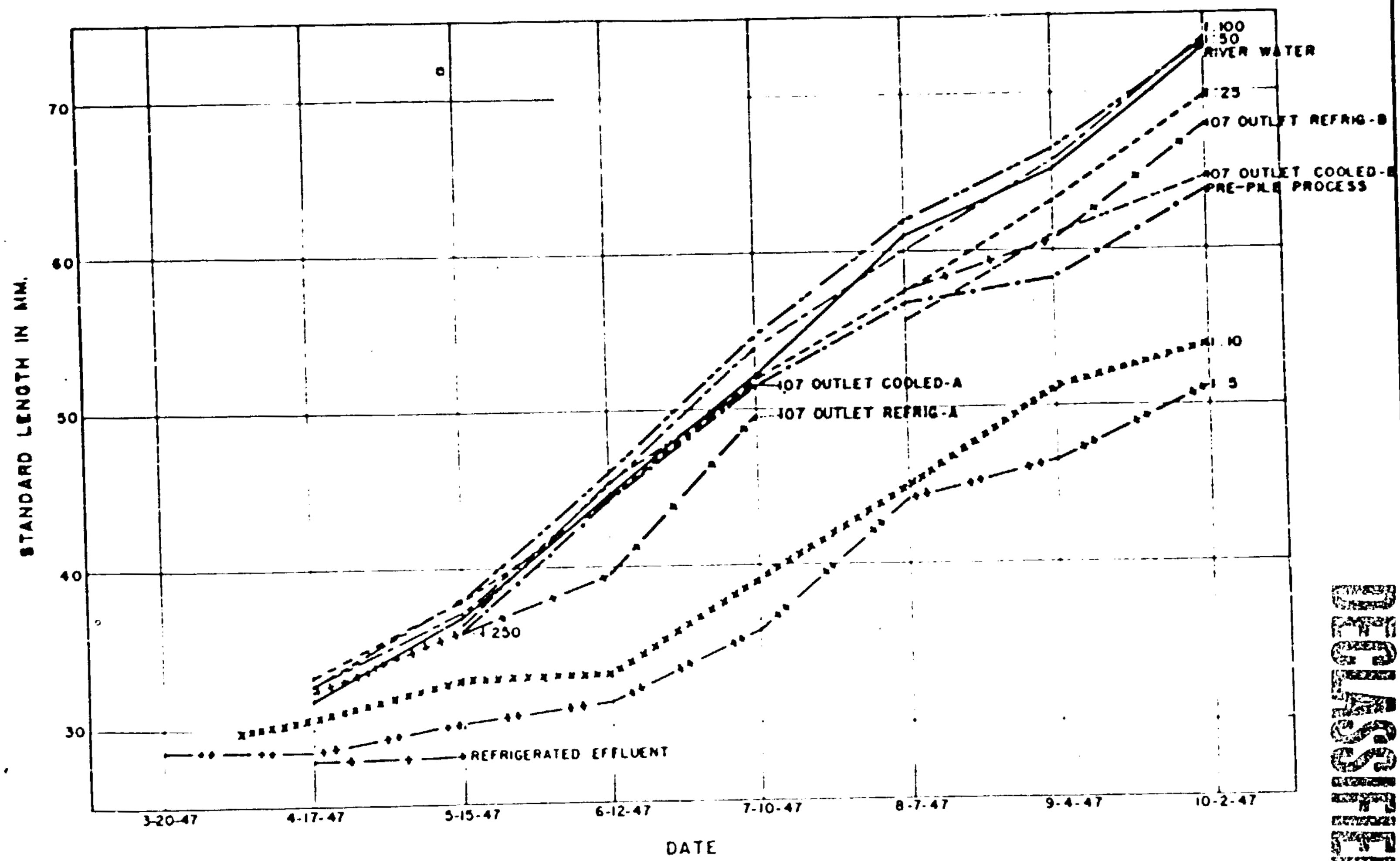

TABLE 7

AVERAGE WEIGHT IN GRAMS OF SILVER SALMON
HELD IN VARIOUS CONCENTRATIONS OF EFFLUENT WATER

[redacted]

Type of Water	107 Basin Outlet Water		Refrigerated 107 Basin Outlet Water			1:5	1:10	1:25	1:50	1:100	1:250	Pre-Pile Process Water	River Water
Lot Nos.	1A-2A	1B-2B	3-4	3A-4A	3B-4B	5-6	7-8	9-10	11-12	13-14	15-16	15 & 16	17,18,19,20
3/20/47						.32							
4/3						.29	.36						
4/17			.34			.28	.36	.52	.52	.50	.49		.42
5/1	.60		.32	.60		.31	.38	.64	.76	.65	.53		.60
5/15	.58		.30	.70		.32	.43	.81	.38	.84	.73		.80
5/29	1.02		.54	.74		.34	.45	1.09	1.24	1.18	.98		1.12
6/12	1.61			1.06		.48	.56	1.42	1.64	1.55		1.40	1.50
6/27	2.08			1.54		.68	.96	1.78	2.24	2.20		1.99	2.05
7/10	2.68			2.18		1.35	1.19	2.51	2.96	2.87		2.63	2.72
7/24		2.57			2.88	1.16	1.40	2.90	3.42	3.28		2.73	3.17
8/7		2.92			3.25	1.38	1.69	3.29	3.96	3.90		3.15	3.80
8/21		3.56			3.72	1.60	2.07	3.84	4.59	4.48		3.39	4.34
9/4		3.60			3.73	1.73	2.43	4.31	4.98	5.10		3.45	4.52
9/18		3.84			4.38	1.97	2.98	4.64	5.52	5.56		3.65	5.36
10/2		4.20			4.72	2.29	2.93	5.32	6.24	6.12		3.94	5.90
10/16		4.76			5.49	2.90	3.23	6.02	6.82	7.03		4.52	6.50

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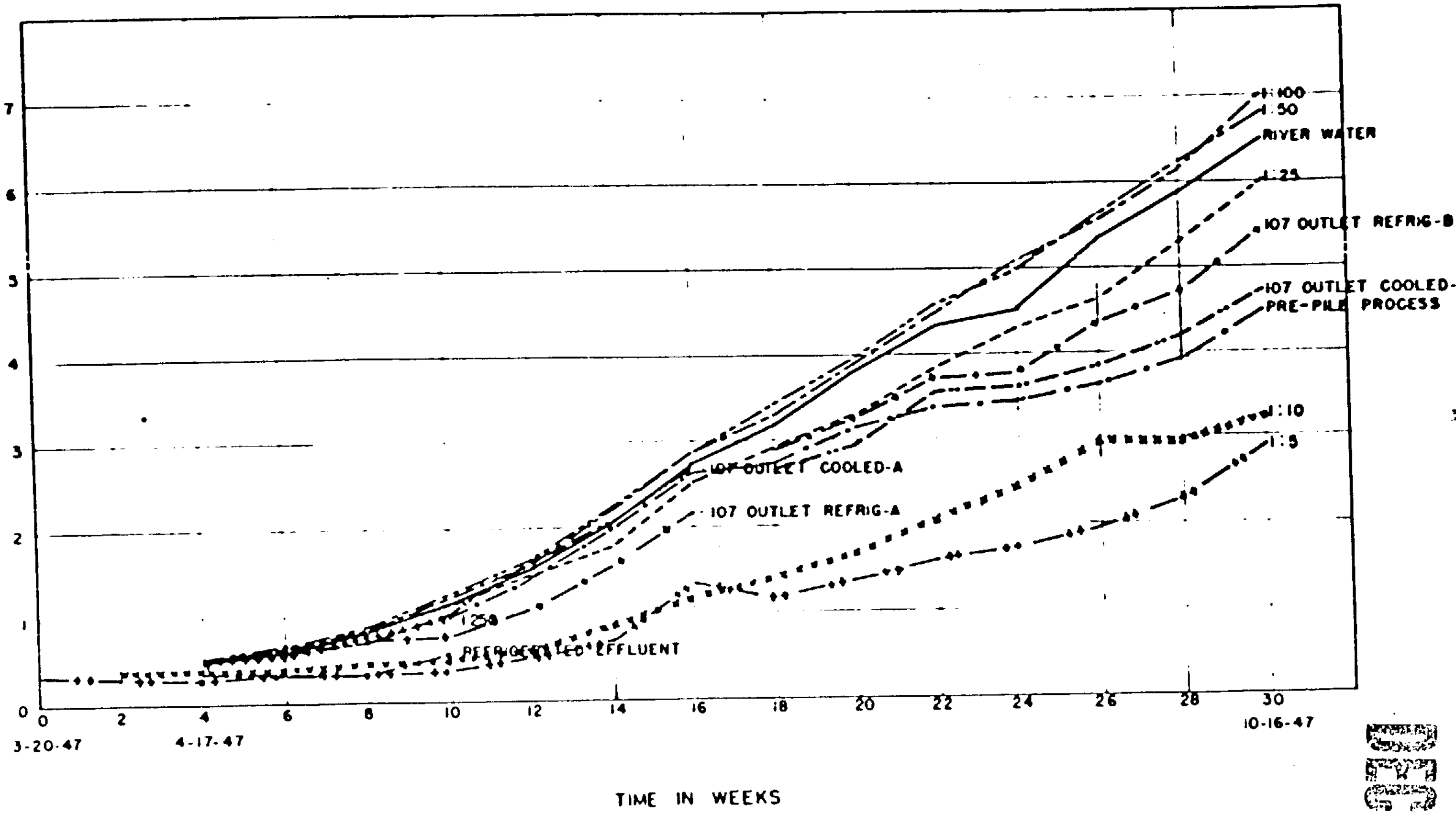
FIGURE 5

GROWTH IN WEIGHT OF SILVER SALMON FINGERLINGS HELD IN VARIOUS CONCENTRATIONS OF EFFLUENT WATER



among the individuals in both the 1:5 and 1:10 lots sampling irregularities did appear. Since there is roughly a cubic relationship between the weights and lengths, the weight figures accentuate these irregularities more than the lengths. On July 10 the weights of the fish in the 1:5 dilution were greater than those of the fish in the 1:10 dilution. Since the mortality of the 1:5 lot was very heavy, all of the remaining fish of the group were used in the weight determinations after June 12; whereas in the 1:10 lot, where the fish were more numerous, only a part of the fish were weighed. Since the fish which had died were mostly the smaller weaker ones, there remained in the 1:10 dilution a disproportionately larger percentage of smaller fish and this lowered the average fish size to below that of the 1:5 lot, in which only the larger, stronger fish had survived. Between September and October there was an apparent leveling off or slight decrease in growth among the fish held in the 1:10 dilution. This also was probably due to a sampling error resulting from the great variation in size of the fish.

The fingerlings placed in troughs 1 through 4 to replace the lots which had died showed slower rates of growth than the river controls. It should be remembered that the reason for the initial large size of the fish in lots 1A, 2A, 3A, 4A and later in lots 1B, 2B, 3B and 4B is that they were originally river water controls with normal rates of growth.

During May the fish in the 1:250 dilution were held in a single trough for a period of time. This crowding factor resulted in a slower rate of growth. During the first of June pre-pile process water was substituted for the 1:250 dilution. The fish in this water had sharply retarded rates of growth as is clearly shown by both the Length and Weight curves.

In the 1:25 dilution the fish show a rate of growth which was significantly slower than that of the river controls or of the fish held in greater dilutions. In dilutions of 1:50 or greater, the effluent water did not retard the growth of the fingerling silver salmon. Actually the size of the control fish appears slightly less than that of fish in weak dilutions of the effluent water, an effect which might be caused by the slight temperature differences which were in proportion to the amount of effluent added.

The nature of the weight data, which gave only average values without indicating the variation in size between individuals in each lot, make it impossible to test for significant differences between lots by ordinary methods. However, the significance of size differences between the various groups was adequately shown by the length data where each group was compared to the control by the t- test.

By October 1947, the young silver salmon were approaching a size at which they would normally migrate to the ocean; further, the results were showing a consistent trend and probably but little additional information could be obtained. Since repairs and alterations to troughs and piping equipment were required before a new series of experiments could be started, removal of the fish was necessary. On October 20, 1947, 2393 of the surviving fingerlings were liberated into the Columbia River adjacent to the 100-F Area, terminating this study.