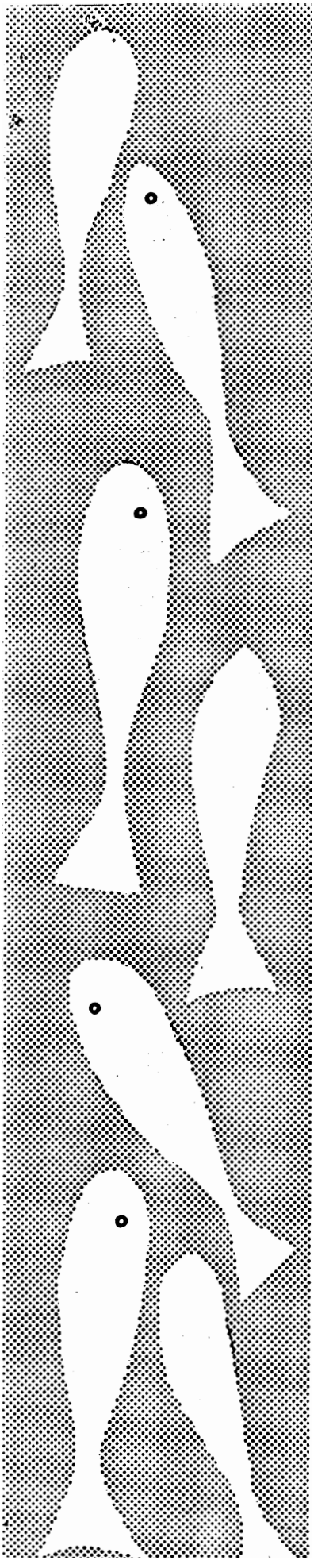

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COLUMBIA RIVER THERMAL EFFECTS STUDY

SURVIVAL OF JUVENILE COHO SALMON EXPOSED TO SUDDEN WATER TEMPERATURE INCREASES

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CONTENTS

INTRODUCTION

Two thermal electric plants were proposed for siting on the lower Columbia River coincidental with a national directive to establish water temperature standards for the same waters. The importance of the fishery and inconsistancies in suggested water temperature standards for the interstate waters of the Columbia prompted the Secretary of the Interior to direct a study that would result in the definition of water temperature criteria for salmonids.

Successful hatchery operations have increased the production of coho salmon in the Columbia River. Continuing success of this program is in part dependent upon optimum water temperatures in the lower river.

During 1968 and 1969, tests were conducted in the Bureau of Commercial Fisheries laboratory located near Prescott, Oregon (Snyder, Blahm, and McConnell, 1970) to define the effects of water temperature increases on the survival of juvenile coho salmon.

TEST FISH, EQUIPMENT AND PROCEDURE

Source of fish

Coho juveniles used for these tests were the progeny of adults which returned to the Kalama River, Washington. The adults were spawned and the young reared at the Kalama Falls Fish Hatchery of the Washington Department of Fisheries. The test fish referred to as "hatchery" were transported from the hatchery to the test facility in a tank truck--a trip that required from one to two hours, during which time oxygen was

metered into the water. The fish referred to as "river" were captured in the Columbia River, near the test facility with beach seines (McConnell and Snyder, 1970). The "river" fish were identified as Kalama hatchery stock by marks that were placed on 10 percent of the fish prior to release into the Kalama River. The fish were captured in the Columbia River from 4 to 6 weeks after release. Only unmarked fish were used in the tests. It is possible that some of the unmarked coho originated from other than the Kalama River, but for purposes of these tests, we assumed that the majority were from the Kalama Hatchery. All test fish were held several days pre-test. During that time, fish adversely affected by handling or transporting were removed; mortality was less than 1.0%. Fish were held in 1.8 x 1.2 m redwood tanks through which water from the Columbia River was circulated at a rate providing at least one complete interchange each hour. Water temperature at the Kalama hatchery was within 0.5± C of the water in which the fish were held (10 C).

Test equipment

Physical test equipment was essentially the same as that described by Blahm and McConnell (1970a) and Snyder, Blahm, and McConnell (1970).

Test procedure

Procedures of the thermal tolerance tests were patterned after those recommended by Fry (1946) and used by various experimenters, e.g., Brett (1952); Blahm and McConnell (1970b). These procedures have remained basically consistent since their inception. Samples of 20 fish were transferred to pre-adjusted test temperatures and survival times of individual fish were recorded. Observation was constant at the higher test temperatures and less frequent at the lower temperatures, but never less than 8 to 10 observations per day.

THERMAL EFFECTS TESTS

1968 tests

Exploratory tests were conducted in 1968 using "hatchery" and "river" fish. The test temperatures spanned a range which would encompass: (1) the water quality standards in existance at the time, e.g., 68 F (20 C), (2) the temperatures above ambient that could be expected at the discharge of a 1,000 Mw thermal power plant operating with "once through" condenser cooling and (3) the temperature at which we could expect incipient lethal level[1/] for coho juveniles. The duration of exposure to the various test temperatures was 4 hours; this was to assess the effect of conditions that could prevail in a tide-flow reversal. Clark and Snyder (1969) pointed out that the river flow stops, reverses, stops, then returns to downstream flow; this cycle can last 4 to 5 hours at Prescott, Oregon.

Samples of 20 "hatchery" fish each were subjected to 12, 20, 23, 26, 28, and 34 C. Individual time of death was also recorded for the duration of post-test holding (72 hours) in water at acclimation temperature.

Five percent mortality was recorded at 26 C in 13 minutes; TD50[2/] and TD100 at 26 C were 22.5 and 52 minutes respectively (Table 1).

"River" fish were tested at the same temperature levels as the "hatchery" fish with the exception of 26 C. Five percent mortality occurred in 2 minutes at 28 C; the TD50 and TD100 at 28 C were 2.3 and 3.2 minutes respectively (Table 2).

1/ That level at which 50% of the sample can no longer survive for an indefinite period of time.

2/ TD50, TD100 = Time to death 50% and 100% of sample.

Table 1.--Time to death of juvenile coho salmon (Kalama Hatchery) subjected to various water temperatures for a 4-hour test period, May 1968

Water temperature °C	°F	Temperature increase (F)	Time to death by percent mortality 5%	50%	100%
				Minutes	
12 (control)	53	0	-	-	-
20	68	15	-	-	-
23	73	20	-	-	-
26	78	25	13.0	22.5	52.0
28	83	30	1.4	2.0	3.3
34	93	40	0.6	0.8	0.9

Table 2.--Time to death of juvenile coho salmon ("river" fish) subjected to various water temperatures for a 4-hour test period, May 1968

Water temperature °C	Water temperature °F	Temperature increase (F)	Time to death by percent mortality 5%	50%	100%
				Minutes	
12 (control)	53	0	-	-	-
20	68	15	-	-	-
23	73	20	-	-	-
28	83	30	2.0	2.3	3.2
34	93	40	0.5	0.7	1.0

Survival of "hatchery" and "river" fish at the 28 C and 34 C level was comparable. At 28 C no fish ("hatchery" or "river") survived longer than 3.3 minutes (Tables 1 and 2). The lethal level for coho salmon has been reported by Brett (1952) as 25.0 C. In tests reported above, no deaths were recorded below 26 C, but exposure time was considerably less than that in tests by Brett.

1969 tests

Tests in 1969 were of longer duration than those in 1968 and at somewhat different temperature levels. Test duration was 2 weeks. Temperature ranged from 10 to 29 C. "Hatchery" fish were tested during April and May at test temperatures of 10 (control), 17, 20, 21, 22, 23, 24, 25, 26 and 29 C. "River" fish were tested in June at similar temperatures except that the control was 14 C. Twenty fish per sample were transferred to pre-adjusted test temperatures; each mortality was recorded as it occurred.

For "hatchery" fish, a TD50 occurred in 17,319 minutes (approximately 12 days) at 22 C; the TD50 at 24 and 25 C occurred in 1,352 and 114 minutes respectively (Table 3). Coho acclimated to 10 C and tested by Brett (1952), reached 50% mortality in 340 minutes at 25 C and approximately 2,000 minutes at 24 C.

Among "river" fish, a 75% mortality was recorded in the control group (14 C) and 100% at 22 C (Table 4).

Table 3.--Time to death (at 5-percent mortality increments) of juvenile coho salmon from the Kalama Falls Hatchery which were subjected to elevated water temperatures for 2 weeks or until death.

Percent mortality	Time to death at test temperatures of-- °C									
	10*	17	20	21	22	23	24	25	26	29
	Minutes to death									
5	1/		20089	11442	127	4320	45	4	2.5	1.0
10					1359	12875	86	6	2.9	1.2
15					12879	13325	121	14	6.8	1.3
20					14319	14315	206	30	7.3	1.4
25					14619	14315	228	33	11.3	1.4
30					15759	14315	229	87	12.0	1.4
35					15759	14315	245	94	12.2	1.5
40					15759	14315	273	105	12.3	1.5
45					15759	14435	411	108	13.6	1.5
50					17319	14525	1352	114	16.1	1.5
55					17319	14615	1352	115	20.3	1.6
60					17319	15755	1352	125	20.4	1.7
65					18639	15755	1352	126	22.9	1.8
70					18639	17315	1352	128	23.4	1.8
75					18639	17315	1352	135	25.6	1.9
80					18669	17315	1352	138	26.5	1.9
85					20079	17315	1352	140	30.1	2.1
90					20079		1592	143	33.8	2.1
95					20079		2792	158	35.2	2.2
100								202	44.2	2.4

1/ Solid line indicates no mortality
Tested April and May 1969
20 fish per test
* Control

Table 4.--Time to death (at 5-percent mortality increments) of juvenile coho salmon from the Columbia River which were subjected to elevated water temperatures for 2 weeks or until death.

Percent mortalit	Time to death at test temperatures of-- °C									
	14*	17	20	21	22	23	24	25	26	29
	Minutes to death									
5	4250	3079	291	1375	11	27	30	5.0	3.7	.9
10	6110	4249	4252	1525	11	27	30	8.9	3.7	1.0
15	7310	5809	8572	1660	13	252	50	11.4	5.0	1.2
20	8720	7279	8572	3085	1378	1413	1416	15.7	5.3	1.7
25	11450	7279	8752	4675	2818	1563	1416	22.2	7.3	1.7
30	12890	7279	8752	7285	2818	2853	1416	27.1	10.1	1.9
35	12890	8569	8752	7285	2818	3123	1416	47.8	17.0	1.9
40	15770	8569	10012	8575	3088	3333	1746	80.7	49.8	2.0
45	15860	10009	10042	8575	3328	4293	2856	125.1	74.5	2.0
50	18740	10009	10192	8575	4528	4293	2856	178.7	75.8	2.2
55	18740	10429	11452	8575	4528	4563	2856	198.3	85.0	2.3
60	18740	10429	11452	10015	7288	5853	2856	275	85.8	2.6
65	20090	12889	11452	10015	7288	5853	3126	1380	96.3	2.8
70	20090	12979	11452	10015	7288	5853	3126		120.5	2.8
75	20090	14329	12892	11455	8578	5853	3126		122.1	2.9
80	1/	14329	14332	11605	8578	7323	3126		124.4	2.9
85		18649	14632	12895	8578	7323	3216		127.6	2.9
90			17302	15895	10018	7323	4296		139.0	4.1
95			17302	17305	11458	7323	4296		147.5	4.9
100					12898	7323	4296		166.9	5.9

1/ Solid line indicates no mortality
Tested June 1969
20 fish per test
Control

SURVIVAL AND ENVIRONMENTAL CONDITIONS

During the 1968 tests, gas bubble disease symptoms were not noted on test fish. In 1968 during April and May, N_2 the Columbia River was approximately 115% in the tailrace at Bonneville Dam. Gas equilibration does occur between Bonneville Dam and Astoria, Oregon. Nitrogen gas levels at Prescott, Oregon were estimated (for April and May 1968) at approximately 105%.[1/]

During May and June 1969, nitrogen measurements were made near Prescott, Oregon. The level ranged from 118% on May 7 to 126% on June 5, 1969.

No evidence of gas bubble symptoms were noted on the fish tested during April and early May 1969. Obvious gas bubble symptoms began to show in late May and early June 1969, and were noted on test fish and other species of salmonids captured in the river (McConnell and Snyder, 1969). Bubbles formed on the animals by the nitrogen gas create areas subject to secondary infection. Table 5 summarizes symptoms noted on "river" fish as they died. The high percentage of fungus infection is possibly an indirect effect of temperature increases and gas bubble disease. Although the ultimate lethal level for coho juveniles as established in the laboratory by Brett (1952) was 25 C, on site tests at Prescott, Oregon, indicate substantial mortality obviously can occur at water temperatures well below that level if the fish are stressed by other environmental conditions.

1/ Personal communication, Wesley J. Ebel, BCF, Seattle, Wash.

Table 5.--Incidence of disease symptoms (pre-test, test, and post test) noted on juvenile coho salmon captured in the Columbia River during May and June 1969

Temperature (C)		Test fish with gas bubble symptoms	
		Pre-test	During and post-test
		Percent	
Control	14	1/	60
	17	5	70
	20	5	55
	21	10	45
	22	5	55
	23	1/	35
	24	1/	10

1/ No obvious symptoms on fish.

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