NOAA Technical Report NMFS SSRF- 688

Effect of Gas Supersaturated Columbia River Water on the Survival of Juvenile Chinook and Coho Salmon

THEODORE H. BLAHM, ROBERT J. McCONNELL, and GEORGE R. SNYDER

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NATIONAL OCEANIC AND
ATMOSPHERIC ADMINISTRATION
Robert M White, Administrator

National Marine
Fisheries Service
Robert W Schoning, Director

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Effect of Gas Supersaturated Columbia River Water on the Survival of Juvenile Chinook and Coho Salmon

THEODORE H. BLAHM, ROBERT J. McCONNELL, and GEORGE R. SNYDER[1]

ABSTRACT

The deleterious effect of high concentrations of dissolved gas on valuable stocks of Columbia River salmon and trout has led pollution control agencies in the Pacific Northwest to consider establishing standards for the amount of dissolved gas in the water. Research has been done with salmonids to define the criteria upon which such standards should be based, but the majority of these studies were carried out in shallow tanks (less than 1 m deep) where supersaturated concentrations of gas had been artificially induced. This report discusses tests that were performed at a field laboratory on the Columbia River. Juvenile chinook, *Oncorhynchus tshawytscha*, and coho, *O. kisutch*, salmon were tested in deep and shallow tanks with river water reflecting the prevailing (and fluctuating) concentrations of dissolved gases. Results indicated that the water depth in a deep (3 m) test tank enhanced the survival of test fish compared to shallow tanks (< 1 m). These tests support the hypothesis that test conditions in tanks 1 m deep are not representative of all river conditions that directly relate to mortality of juvenile salmon and trout in the Columbia River.

INTRODUCTION

Early in 1972, Washington and Idaho set water quality standards for maximum permissible levels of dissolved elemental nitrogen at 110% of saturation for the Columbia and Snake rivers; Oregon adopted 105% as the maximum allowable. These preliminary standards were established without the benefit of adequate biological information concerning the effects on fish of dissolved nitrogen in combination with other dissolved gases, water temperature, exposure time, and swim depths. The Nitrogen Task Force (which consists of, and is open to, Federal and State fisheries and water quality agencies and to public and private power companies) of the Columbia River Fisheries Engineering Research Technical Advisory Committee recommended studies that would provide information on the gas supersaturation problem, its effects, and its possible control. Although final approval of State standards for saturation levels (which has not been done to date) is the responsibility of the Federal Environmental Protection Agency (EPA), many water-use agencies have an interest in the development of research programs that will provide data for use in the final EPA evaluation.

Concentration of gas in the Columbia River at Prescott, Oreg., and throughout the entire length of the river's estuary is dependent upon the amount of water being released over the spillways of the upriver dams. Ebel (1969) reported supersaturated concentrations at estuarine sampling stations during periods when spillrace flows were "high" at Bonneville Dam. High concentrations in the upper estuary are significant because valuable stocks of migrating Pacific salmon, *Oncorhynchus* sp., and steelhead trout, *Salmo gairdneri*, must pass through this area and supersaturated concentrations sometimes cause gas-bubble disease in salmon and trout.

The National Marine Fisheries Service (NMFS) and the U.S. Army Corps of Engineers initiated and completed a cooperative research study during 1972 which was designed to provide information on the gas supersaturation problem and its solution. The specific purpose of this research was to estimate the mortality of ocean-bound juvenile chinook, *O. tshawytscha*, and coho, *O. kisutch*, salmon exposed to combinations of nitrogen supersaturation and water temperature that prevail in the Columbia River during the spring freshet period when heavy spilling occurs at dams. The work reported herein was performed under contract number DAGW57-72-F0471, dated 4 April 1972, between the Corps of Engineers and NMFS. This report describes the results of that research study.

METHODS

Test Facility

The field station at which the tests were conducted has been described in detail by Snyder et al. (1971).

[1]Northwest Fisheries Center, National Marine Fisheries Service, NOAA, 2725 Montlake Blvd. E., Seattle, WA 98112.

The test facilities are housed on two 33.5 × 10.5 m covered barges which are moored in the estuary at Prescott, Oreg., on the Columbia River approximately 117 km (75 miles) downstream from Bonneville Dam (Fig. 1). To simulate water quality conditions of the Columbia River, water is pumped directly from the river through the control and test tanks.

Test Fish and Fish-Holding Procedures Prior to Experiment

Two species of test fish were used—coho and chinook salmon, all juveniles. The coho salmon were obtained from the Washington State Department of Fisheries hatchery on the upper Kalama River; the chinook salmon were obtained from Little White Salmon Hatchery, Bureau of Sport Fisheries and Wildlife, near Carson, Wash. When they were taken to the test facility, the coho salmon averaged 20 g in weight and 127 mm in length; the chinook salmon averaged 2.3 g in weight and 59 mm in length. The fish were transported to the facility (in a 1,500-liter hauling tank) in hatchery water maintained at the same temperature as in the hatchery (10°C); holding water temperature at the facility was 1°C lower than the hatchery water temperature. The fish were held in Columbia River water with a gas content of about 100% of saturation for approximately 10 days prior to the beginning of the test.

Because of mechanical failure, the test in the deep tank was started 10 days subsequent to the other tests.

Test Tanks and Fish-Holding Procedures During Experiment

Three 1.8-m (6-foot) diameter redwood tanks were used for fish holding—a deep test tank, a shallow test tank, and a control tank.

The deep test tank was supplied with water at a flow rate of 75 liters/min; total capacity of the tank was 6,400 liters. Water depth was maintained at 2.5 m (8 feet). It was stocked (at beginning of test) with 950 subyearling chinook and 500 yearling coho salmon.

Figure 1.—Location of study area and National Marine Fisheries Service facility on the Columbia River near Prescott, Oreg.

The shallow test tank was supplied with water at a flow rate of 75 liters/min; total capacity of the tank was 2,800 liters. Water depth was maintained at 1 m (3 feet). It was stocked (at beginning of test) with 505 subyearling chinook and 297 yearling coho salmon.

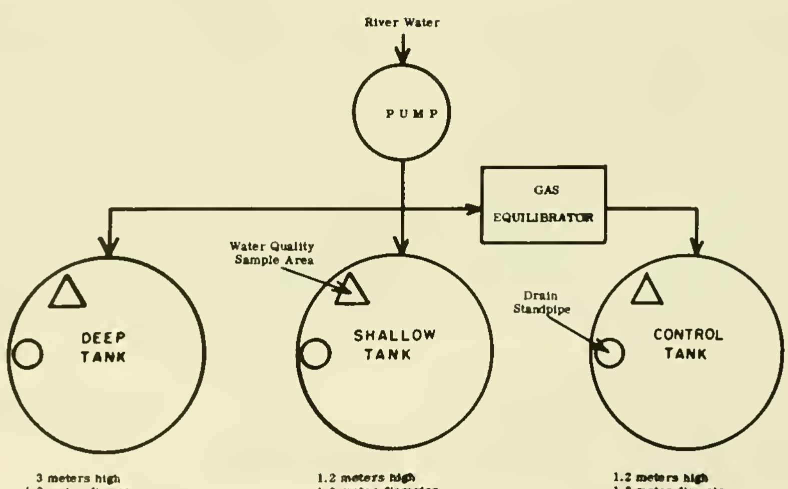
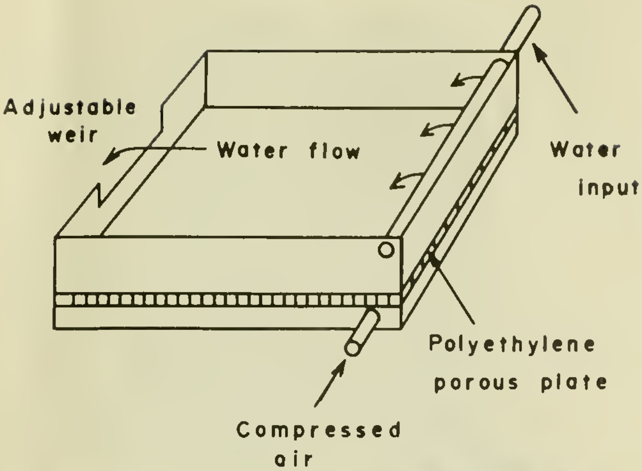


Figure 2.—Schematic diagram of holding tanks and water supply system.



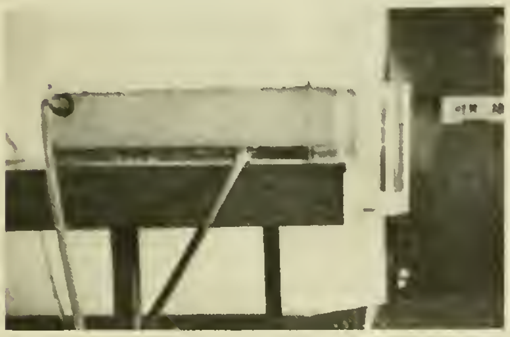


Figure 3.—View of gas equilibration device used to reduce concentration of gas in river water to about 100% of saturation. Water flowing to the tank from perforated pipe is passed over a 46- by 46-cm porous plate, 0.635 cm thick. Compressed air is forced up through the plate and into the flowing water. The quantity of water that can be effectively equilibrated is determined by depth of the water over the plate.

The control tank was supplied with water at a flow rate of approximately 26 liters/min. Total capacity of the tank was 2,800 liters. Water depth was maintained at 1 m. It was stocked with 450 subyearling chinook and 290 yearling coho salmon.

All tanks were supplied with Columbia River water by a single pump (Fig. 2). The water flow remained constant in each tank throughout the test.

Gas content of the water varied between the control and test tanks. Gas content of water fed to the control tank was lowered to about 100% of saturation by forcing air through a gas equilibration device—a porous plate over which the supply water flowed to the tank (Fig. 3). The water in the control tank was then supplied with supplemental oxygen to increase its oxygen content to about the same concentration as in the river. Oxygen replenishing was not required in the test tanks. Unaltered Columbia River water was used, and oxygen depletion due to biological demand was not a problem because of the high rate of water flow (75 liters/min) in the tanks.

The holding tanks were lined with partitioned nets that could be drawn to the water surface to check fish mortality. Daily mortality records were maintained throughout the test. Death criterion was cessation of opercular (gill) movement. Size of dead fish and incidence of gas-bubble disease symptoms were recorded. Examples of the external symptoms referred to in this report are shown in Figure 4, e.g., bubbles on the body, fins, lateral line, and in the mouth, in addition to protruding eyes. Besides daily observations, samples of 20 live fish were taken weekly from each tank and examined for external symptoms, after which the fish were returned to the holding tank.

Procedures to Determine Water Quality

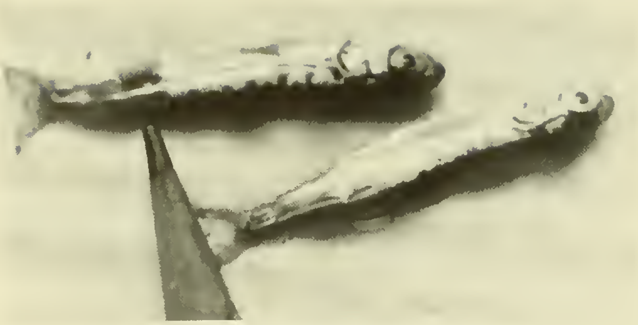
Water quality samples were taken daily from the Columbia River and intermittently from the control and test tanks. Figure 2 shows the sampling area within the tanks. All samples were taken at the surface and are reported as surface values. Following is an outline of data monitored, method of analysis, and units that the data are reported in.

1. Dissolved oxygen—Winkler method (Welsh 1948) and gas chromatograph—mg/liter.
2. Nitrogen gas—van Slyke and gas chromatograph (Swinnerton et al. 1962)—ml/liter.
3. Carbon dioxide—Titrimetric phenolphthalein method (American Public Health Association 1971)—ppm.
4. pH—Expanded scale pH meter—pH units.
5. Turbidity—Hach turbidimeter—Jackson Turbidity Units, JTU.
6. Conductivity meter—micromhos per centimeter, μmho/cm.
7. Water temperature—Daily continuous record from thermograph in Columbia River in addition to standard laboratory thermometer for river and test tanks—degrees centigrade, °C.

A summary of the number of days that an analysis was made for each type of water quality datum is given in Table 1. A review of similar data from tests in 1971 showed that daily samples would not be required from the tanks if samples were taken daily from the river. These same tests also showed that only one sample per day was needed to monitor the water conditions in the river and tanks. To demonstrate this point, particularly with regard to nitrogen concentrations, we collected samples every 4 h from the Columbia River and the deep test tank for the 24-h period ending 15 June 1972. The results are compiled in Table 2. Although the concentration of nitrogen in the test tank was consistantly lower than in the river, the average difference was only 1.3 percentage points (relative accuracy of the analysis technique is approximately 2%).

RELATION BETWEEN COLUMBIA RIVER WATER AND WATER IN TEST TANKS

The monitored physical and chemical water



A. On lateral line and body.

B. Protruding eyes.

C. On head and operculum.

D. In mouth.

Figure 4.—Examples of external symptoms of gas-bubble disease as noted throughout the experiment.

conditions that prevailed in the Columbia River during the test period were closely reflected in the test tanks. However, variations did occur in river water quality conditions and the control tank. A summary of the maximum average differences throughout the test in water quality data between the river and the holding tanks is given in Table 3; comprehensive data can be found in Appendix Tables 1 through 4.

In this report nitrogen gas saturation is discussed with more detail than other types of quality parameters because it was used as the index to which fish mortality was related.

Control tank.—In this tank the concentration of nitrogen gas was near 100% of saturation; however, on one occasion during the test period 109% of saturation was recorded. Of the 61 daily samples taken, 52 (85%) fell between 97 and 106% of saturation.

Table 1.—Number of daily water samples analyzed from the river and each holding tank during the test period.

Type of data	Number of daily samples analyzed			
	River	Deep tank	Shallow tank	Control tank
Nitrogen	82	48	46	61
Oxygen	82	52	50	69
Carbon dioxide	44	28	30	35
pH	69	54	55	61
Turbidity	58	49	50	49
Conductivity	63	55	53	56
Water temperature	82	54	55	70

Table 2.—Concentration (percentage saturation) of dissolved nitrogen gas in the Columbia River and deep test tank, from samples taken every 4 h during a 24-h period, 14-15 June 1972.

Time of day	Nitrogen concentration		Difference in concentration between river and tank
	River	Deep tank	
0800	125.6	124.9	-0.7
1200	125.6	125.3	-0.3
1600	127.5	126.4	-1.1
2000	126.8	124.2	-2.6
2400	125.8	125.0	-0.8
0400	127.2	126.8	-0.4
0800	127.7	124.4	-3.3
		Average difference	-1.3

Table 3.—Maximum and average difference from river values of water quality data monitored in each holding tank.

Type of data	Deep tank[1]		Shallow tank[1]		Control tank[2]	
	Maximum	Average	Maximum	Average	Maximum	Average
Nitrogen (% points)	4.4	1.4	4.0	[3]1.4	—	—
Oxygen (% points)	10.0	5.1	7.5	3.3	40.8	11.5
Carbon dioxide (ppm)	1.9	0.2	0.6	0.1	2.8	0.7
pH	0.3	0.1	0.3	0.1	0.7	0.2
Turbidity (JTU)	4.0	1.0	14.0	2.5	14.0	2.0
Conductivity (μmho/cm)	10.0	2.5	13.0	3.2	20.0	6.0
Water temperature (°C)	0.5	0.1	0.5	0.1	0.4	0.2

[1]Tank supplied with unaltered Columbia River water.

[2]Tank supplied with Columbia River water; nitrogen gas content of water had been reduced to about 100% of saturation.

[3]This is within the sampling and analysis error.

Oxygen concentrations were quite erratic, on a day to day basis, ranging from 65 to 132% of saturation. A combination of factors affected gas content of water in the control tank; the water flow had to be reduced to 26 liters/min to avoid exceeding the capacity of the gas equilibration device. Moreover, control of the air supply to the device required constant monitoring, which we were not able to do. Supplemental oxygen was added to the water in the control tank to increase its oxygen content to about the same level (after biological demand) as in the river. It is obvious that this was not accomplished. The addition of supplemental oxygen into the tank probably caused lower concentrations (below 100%) of saturation of nitrogen by "stripping." More efficient methods of manipulating gas content are required if very precise concentrations of gas are needed. Even though there is disparity in gas levels in the control tank, it did not seem to cause erratic behavior or unexplained mortality of test fish.

Slight variations between river and control tank water do occur in data other than oxygen and nitrogen (Appendix Tables 3 and 4), however, all remained in acceptable biological ranges throughout the test period.

Test tanks.—In the two test tanks which were to reflect the prevailing Columbia River conditions (as outlined previously), there were only slight variations between the river and the tanks in water quality data (Table 3 and Appendix Tables 1, 2, 4).

The concentrations of nitrogen gas in tanks 1 and 2 averaged 1.4 percentage points lower than in river water; this is within the 2% sampling and analysis error inherent in the gas analysis techniques.

MORTALITY AND INCIDENCE OF SYMPTOMS OF GAS-BUBBLE DISEASE

Mortality and Symptoms in Relation to Type of Tank

The total mortality and incidence of the gas-bubble disease symptoms that were recorded throughout the test varied from tank to tank.

Control tank.—Total mortality of chinook and coho salmon in the control tank was 2.2 and 4.1%, respectively, during the 72 days of the test period (3 April to 13 June). These mortalities are not more than would normally be expected from the effects of confining and holding a population of fish for 72 days. External symptoms of gas-bubble disease did not develop on the fish nor were symptoms found on any of the fish that died. Mortality data by date for tank 3 are compiled in Appendix Table 3.

Deep tank.—Mortalities of chinook and coho salmon in the deep tank were 8.7 and 4.2%, respectively, during the 72-day test period (13 April to 23 June). Mortality by date is shown in Figure 5 and Appendix Table 1. The first dead fish in this tank with external symptoms of gas-bubble disease was a chinook salmon that died on 8 June. On 10 June two coho salmon died, one of which showed symptoms. Prior to this, nine fish had died in this tank, none of which showed external symptoms.

Beginning on 26 May, nitrogen concentrations (at the surface) in the deep tank remained above 120% until the end of the test. It was during this time that external symptoms of gas-bubble disease first became evident on the fish in this tank (Table 4). Nitrogen concentrations at the surface of 120% and 130% correspond to 100% of saturation at 2.13-m (7-foot) and 3-m (10-foot) depths, respectively; they also correspond to 110% of saturation at 1-m (3-foot) and 2-m (6-foot) depths, respectively.

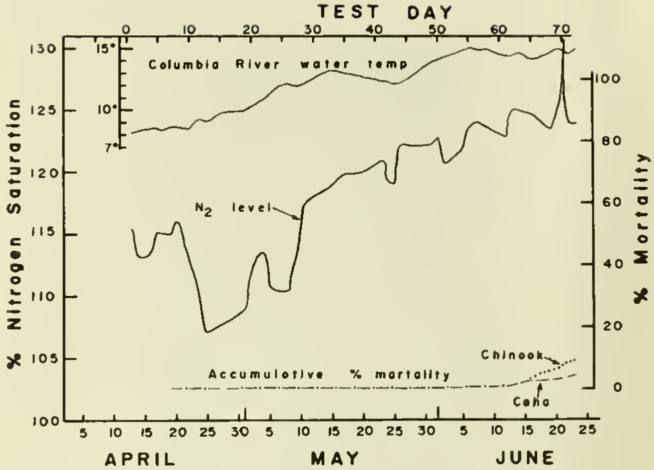


Figure 5.—Nitrogen concentrations and accumulative mortality of fish in deep test tank (river water, tank 2.5 m deep) during test.

Shallow tank.—Mortalities of chinook and coho salmon in the shallow test tank were 98.2 and 80.1% respectively. Mortality by date is shown in Figure 6 and Appendix Table 2. The first mortality in the chinook salmon group occurred 5 days after the test began on 3 April. In the coho salmon, the first mortality occurred on test day 8. Until that date, the concentrations of nitrogen gas in the river and the shallow tank had been below 113% of saturation. Fifty percent mortality was recorded by test day 50 for the chinook

Table 4.—Incidence (percentage) of symptoms of gas-bubble disease on samples (20 fish each) taken from the holding tanks on the dates indicated. Included for comparison is the accumulative mortality (percentage) from the shallow test tank.

	Deep tank[1]		Shallow tank[1]				Control tank[2]	
	Chinook	Coho	Chinook		Coho		Chinook	Coho
Date	with symptoms	with symptoms	Symptoms	Acc. mort.	Symptoms	Acc. mort.	with symptoms	with symptoms
April 3	—	—	0	0	0	0	0	0
6	—	—	7	0	53	0	0	0
7	—	—	0	0	70	0	0	0
10	—	—	25	0.6	60	0	0	0
12	—	—	40	4.5	90	0.3	0	0
19	0	0	30	10.9	90	0.3	0	0
26	0	0	20	20.6	30	0.7	0	0
May 3	0	0	0	24.3	0	1.0	0	0
10	0	0	0	26.0	0	2.4	0	0
18	0	0	45	44.0	70	4.7	0	0
24	0	0	45	55.0	90	6.7	0	0
31	0	0	65	78.0	100	23.5	0	0
June 7	40	20	65	92.8	100	44.8	0	0
14	45	40	—	—	—	—	—	—
21	65	55	—	—	—	—	—	—

[1]Tank supplied with unaltered Columbia River water.

[2]Tank supplied with Columbia River water; nitrogen gas content of water had been reduced to about 100% of saturation.

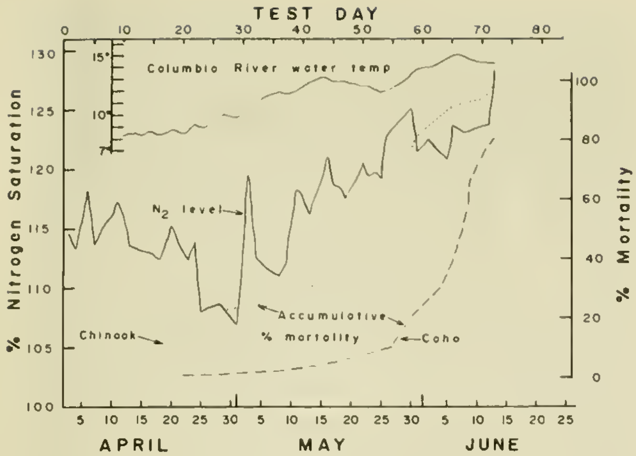


Figure 6.—Nitrogen concentrations and accumulative mortality of fish in shallow test tank (river water, tank 1 m deep) during test.

Table 5.—Number of dead fish and percentage with symptoms of gas-bubble disease in each holding tank.

Holding tank	Chinook: Total dead	Chinook: Dead fish with symptoms (%)	Coho: Total dead	Coho: Dead fish with symptoms (%)
1	84	80	20	50
2	493	79	238	96
3	11	0	46	0

salmon and day 67 for the coho salmon. In this tank, 79% of the chinook salmon and 96% of the coho salmon that died had definite external symptoms of gas-bubble disease (Table 5).

Weekly checks for gas-bubble disease (Table 4) showed that from 25 April through 2 May, symptoms completely disappeared on the test fish. It was during this period that nitrogen concentrations in the river at Prescott were decreased by the closure of spillway gates at the dams (the spill closure was planned to aid downstream migrating juvenile salmon and trout released from hatcheries).

Mortality and Symptoms in Relation to Species and Size of Fish

There were differences in rate of mortality and incidence of disease symptoms between the two species of test fish. The chinook salmon were the first to show external symptoms, although to a lesser degree of severity than the coho salmon. However, the chinook salmon were the first to begin dying—a trend which persisted throughout the test (Figs. 5, 6). For example, in the shallow tank, 50% accumulative mortality was recorded for chinook salmon on test day 50, whereas 50% accumulative mortality of coho salmon occurred on test day 67. The coho salmon showed a higher incidence of symptoms of gas-bubble disease but seemed to withstand the effects of the disease longer than did the chinook salmon.

A slight increase in length of fish was recorded throughout the test period (Fig. 7); the trend is more

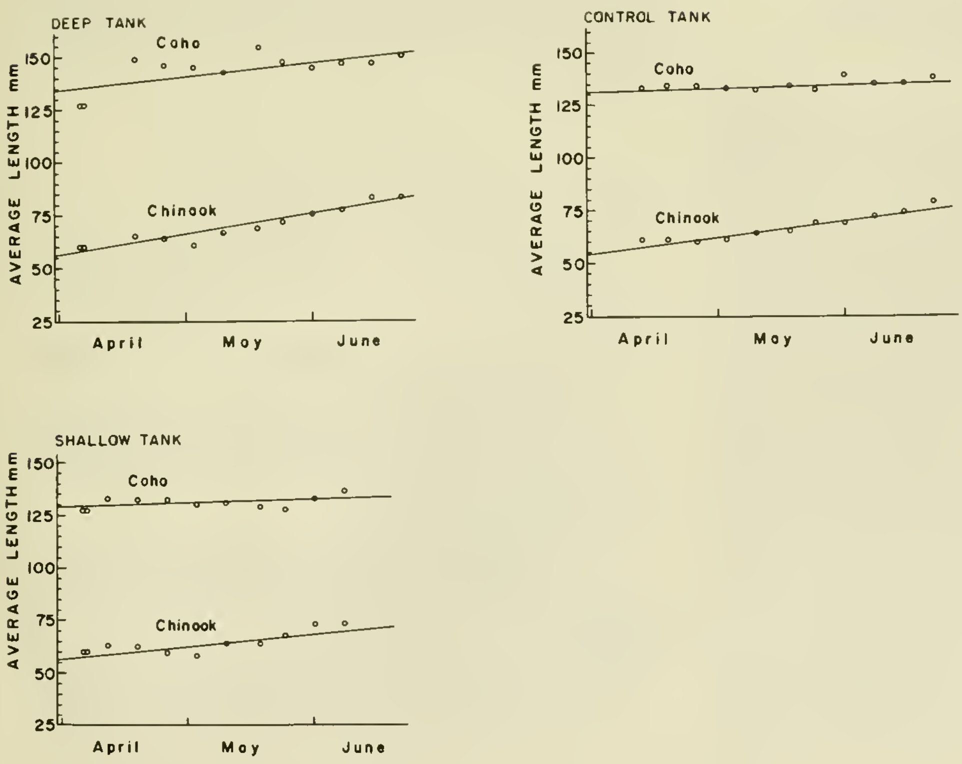


Figure 7.—Fitted regression lines for average body length of samples (20 fish each) of juvenile coho and chinook salmon during test.

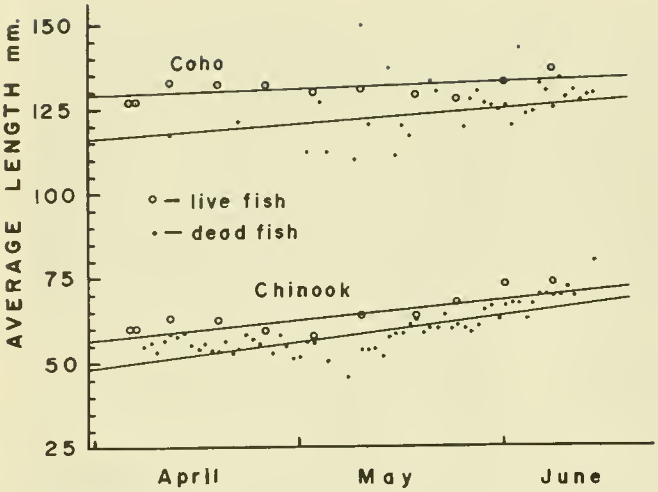


Figure 8.—Calculated regression lines of average body length of samples of live fish (20 fish each) as compared to average size of dead fish taken daily from shallow test tank during test.

pronounced in the chinook salmon populations. Each point on the graphs represents the average length of a sample of 20 fish that were examined for gas bubble symptoms during the test. The growth rate (length) is not as great as might be expected in hatchery reared populations. In the shallow tank, where the greatest mortality occurred, it appears as though the smaller fish, in each species, were the ones that succumbed (Fig. 8). These are observations of general trends that might be representative of these tests only.

EFFECT OF WATER DEPTH ON FISH SURVIVAL

Comparing the accumulative mortality in the deep (Fig. 5) and shallow tanks (Fig. 6), it is obvious that the added depth of water in the deep tank did enhance the survival of test fish. These data suggest that the extent of mortality that occurred in the shallow tank was possibly greater than that which would occur in the river under the existing circumstances; however, this condition is not representative inasmuch as the young fish in the river are not restricted to such shallow confinement. Neither should we assume that the relatively "low" mortality experienced in the deep tank represents all river conditions that relate to mortality; for example, the fish in our holding tanks were not subject to predation. Although, one can argue, predators may also have been affected by high concentrations of dissolved gas. If dissolved nitrogen (at Prescott) had been consistently above 130% of saturation, it is quite probable that additional mortality would have occurred in the deep tank. For example, Ebel (1971) showed that a group of juvenile chinook salmon (of hatchery origin) held in a cage for 7 days (in the Columbia River), in which the fish could range from surface to 4.5 m, had a mortality of 68%. Nitrogen concentrations during his test ranged from 127 to 132%. To make more meaningful extrapolations from test results, we need to know at what depths the majority of the fish in the river are found, both resident and migrating species. From work that has been done on vertical distribution of seaward migrants, most investigators (Mains and Smith 1964, Smith et al. 1968, Monan et al. 1969) agree that the largest percentage of juvenile salmon and trout can be found in the top 5 m of water; this tends to support the hypothesis that results of tests done in less than 1 m of water are not representative of the populations of juvenile salmon and trout in the river. There are other factors that may affect the depth patterns of fishes, e.g., spawning behavior, light intensity, water temperature, and turbidity. These items should be examined in the future. The test outlined in this report should by no means be considered conclusive, but results indicate that there should be more biological data made available to State and Federal regulatory agencies prior to establishment of permanent water quality standards relating to gas saturation in the Columbia River and its tributaries.

ACKNOWLEDGMENT

The National Marine Fisheries Service appreciates the close liaison and cooperative attitude that prevailed between NMFS and the Corps of Engineers during this study. Technical representative for the Corps of Engineers was Peter B. Boyer, Chief, Water Quality Section, North Pacific Division. The technical reviews, outlines, and suggestions of the Corps's representative and his associates materially aided the successful completion of our work as did the expertise of Lawrence Davis and Maurice Laird, both technicians with NMFS at the Prescott, Oreg., facility.

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Appendix Table I -- Daily mortality of fish and water quality in deep test tank (river water, tank 2.5 m deep) throughout test.

Date	Time of chemical sample (p.m.)	Temperature (°C)	pH	Turbidity (JTU)	Conductivity (μmho/cm)	CO_2 (mg/l)	O_2 (mg/l)	O_2 (percentage saturation)	N_2 (ml/l)	N_2 (percentage saturation)	Mortality data: Chinook: Mortality	Number dead with symptoms	Accumulative mortality	Remaining total	Accumulated mortality(%)	Coho: Mortality	Number dead with symptoms	Accumulative mortality	Remaining total	Accumulated mortality(%)
April																				
13	0910	8.2	7.35	25	100	.55	12.5	106.2	17.9	115.5	0	0	0	950	0	0	0	0	500	0
14	0930	8.4	7.30	25	100	.75	12.7	108.6	17.5	113.2	--	--	--	--	--	--	--	--	--	--
15	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
16	1030	8.5	7.30	--	105	.60	11.9	101.7	17.5	113.5	--	--	--	--	--	--	--	--	--	--
17	0840	8.5	7.25	17	106	.45	12.4	106.2	17.7	115.0	--	--	--	--	--	--	--	--	--	--
18	0905	8.3	7.40	16	110	.45	12.3	105.0	--	--	--	--	--	--	--	--	--	--	--	--
19	0830	8.5	7.55	18	115	--	12.4	106.2	17.7	115.0	--	--	--	--	--	--	--	--	--	--
20	0903	8.7	7.30	17	110	--	12.5	107.2	17.8	116.0	--	--	--	--	--	--	--	--	--	--
21	0905	8.6	7.35	17	111	--	12.4	106.3	--	--	--	--	--	--	--	--	--	--	--	--
22	1000	8.5	7.30	--	119	2.00	12.4	106.4	17.1	111.3	--	--	--	--	--	--	--	--	--	--
23	1010	8.9	7.35	--	111	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
24	1010	9.3	7.30	23	115	2.40	11.7	101.7	17.0	112.4	--	--	--	--	--	--	--	--	--	--
25	1055	9.0	7.40	16	119	--	11.7	101.0	16.3	107.1	--	--	--	--	--	--	--	--	--	--
26	1010	9.2	7.30	--	110	--	11.7	101.6	--	--	--	--	--	--	--	--	--	--	--	--
27	1030	9.6	7.40	8	110	3.50	11.8	103.5	16.2	107.7	--	--	--	--	--	--	--	--	--	--
28	0845	9.9	--	17	110	--	11.7	103.8	--	--	--	--	--	--	--	--	--	--	--	--
29	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
30	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
May																				
1	0914	9.9	7.50	10	110	2.10	11.5	101.9	16.3	108.8	1	0	1	949	.1	1	0	1	499	.2
2	0850	10.3	7.50	9	110	2.90	11.9	106.5	16.6	111.9	--	--	--	--	--	--	--	--	--	--
3	0813	10.5	7.70	13	112	1.20	11.9	106.8	16.7	113.3	--	--	--	--	--	--	--	--	--	--
4	0955	10.8	7.80	12	115	1.20	11.9	107.6	16.6	113.4	--	--	--	--	--	--	--	--	--	--

Appendix 1 --- Continued

	Water quality data										Mortality data									
											Chinook					Coho				
Date	Time of chemical sample (p.m.)	Temperature (°C)	pH	Turbidity(JTU)	Conductivity (µmho/cm)	CO_2 (mg/l)	O_2 (mg/l)	O_2 (percentage saturation)	N_2 (ml/l)	N_2 (percentage saturation)	Mortality	Number dead with symptoms	Accumulative mortality	Remaining total	Accumulated mortality(%)	Mortality	Number dead with symptoms	Accumulative mortality	Remaining total	Accumulated mortality(%)
May																				
5	1005	11.4	7.80	13	121	--	11.7	106.9	16.0	110.7	--	--	--	--	--	--	--	--	--	--
6	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
7	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
8	0927	12.0	7.70	11	122	1.50	10.9	100.9	15.8	110.4	--	--	--	--	--	--	--	--	--	--
9	0920	11.8	7.75	13	130	1.80	11.6	107.1	16.2	112.9	1	0	2	948	.2	--	--	--	--	--
10	0900	--	7.55	11	126	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
11	0940	12.2	7.40	9	125	1.40	11.6	108.0	16.8	118.2	--	--	--	--	--	--	--	--	--	--
12	0920	12.5	7.80	11	125	1.30	11.5	108.1	16.6	117.6	--	--	--	--	--	--	--	--	--	--
13	0730	12.8	7.75	--	130	1.10	11.8	111.6	16.7	118.6	--	--	--	--	--	--	--	--	--	--
14	0915	13.0	7.90	--	113	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
15	0940	13.1	7.90	9	130	1.10	11.8	112.4	16.5	118.3	--	--	--	--	--	--	--	--	--	--
16	0910	13.0	7.80	16	130	1.10	11.7	111.2	16.8	120.2	--	--	--	--	--	--	--	--	--	--
17	0915	12.9	7.75	14	130	1.20	11.2	106.2	16.8	119.1	--	--	--	--	--	--	--	--	--	--
18	0900	12.8	7.65	12	122	1.20	11.3	106.9	16.8	119.7	--	--	--	--	--	--	--	--	--	--
19	0908	12.8	7.60	11	110	1.20	11.3	106.9	16.8	119.7	--	--	--	--	--	--	--	--	--	--
20	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
21	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
22	0930	12.4	7.40	17	102	1.10	11.1	103.6	17.1	120.5	--	--	--	--	--	--	--	--	--	--
23	0850	12.4	7.45	18	102	1.10	11.1	103.6	17.1	120.8	--	--	--	--	--	--	--	--	--	--
24	0840	12.3	7.20	18	100	--	11.4	106.6	16.9	119.2	--	--	--	--	--	--	--	--	--	--
25	0940	12.0	7.40	11	98	--	11.5	106.9	17.0	119.1	--	--	--	--	--	--	--	--	--	--
26	1006	12.2	7.50	--	--	.70	11.6	108.3	17.4	122.1	--	--	--	--	--	--	--	--	--	--
27	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1	0	2	498	.5
28	--	--	--	--	--	--	--	--	--	--	1	0	3	947	.3	1	0	3	497	.6
29	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
30	0850	13.5	7.40	12	88	--	11.8	113.4	17.3	125.0	--	--	--	--	--	--	--	--	--	--
31	0840	13.8	7.40	12	97	--	12.2	118.0	16.8	122.2	--	--	--	--	--	--	--	--	--	--

Appendix 1 --- Continued

	Water Quality data										Mortality data									
											Chinook					Coho				
Date	Time of chemical sample (p.m.)	Temperature (°C)	pH	Turbidity (JTU)	Conductivity (µmho/cm)	CO_2 (mg/l)	O_2 (mg/l)	O_2 (percentage saturation)	N_2 (ml/l)	N_2 (percentage saturation)	Mortality	Number dead with symptoms	Accumulative mortality	Remaining total	Accumulated mortality(%)	Mortality	Number dead with symptoms	Accumulative mortality	Remaining total	Accumulated mortality (%)
June																				
1	0935	14.0	7.40	9	95	--	10.6	103.0	16.8	122.6	--	--	--	--	--	--	--	--	--	--
2	0845	14.2	7.40	11	90	--	10.7	104.4	16.5	120.6	--	--	--	--	--	--	--	--	--	--
3	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
4	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
5	0850	14.8	7.35	12	85	--	10.8	106.3	16.4	121.7	--	--	--	--	--	--	--	--	--	--
6	0910	15.0	7.30	13	85	.70	11.0	102.8	16.6	123.6	--	--	--	--	--	--	--	--	--	--
7	0900	--	7.30	12	80	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
8	1010	14.8	7.25	10	80	--	10.9	107.4	16.7	123.9	1	1	4	946	.4	1	0	5	495	1.0
9	0925	14.8	7.25	17	80	--	10.8	107.2	17.5	130.2	--	--	--	--	--	--	--	--	--	--
10	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	2	1	7	493	1.4
11	--	--	--	--	--	--	--	--	--	--	4	4	8	942	.8	--	--	--	--	--
12	0940	14.4	7.25	30	80	--	10.5	102.4	16.7	122.9	1	0	9	941	.9	--	--	--	--	--
13	0910	14.4	7.20	30	78	.80	10.7	105.2	17.0	125.1	6	4	15	935	1.6	2	0	9	491	1.8
14	0820	14.6	--	24	80	--	11.2	110.2	16.9	124.9	6	5	21	929	2.2	2	1	11	489	2.2
15	0845	14.4	7.25	20	83	--	10.7	104.9	16.9	124.4	6	4	27	923	2.8	--	--	--	--	--
16	0850	14.1	7.30	19	80	--	11.3	109.6	17.1	124.8	7	6	34	916	3.4	1	0	12	483	2.4
17	--	--	--	--	--	--	--	--	--	--	9	9	43	907	4.5	--	--	--	--	--
18	--	--	--	--	--	--	--	--	--	--	6	6	49	901	5.1	2	2	14	486	2.8
19	0840	14.5	7.30	21	78	.80	11.6	113.9	16.8	123.5	5	5	54	896	5.7	1	0	15	485	3.0
20	0910	14.8	7.30	20	85	--	11.5	113.8	16.8	124.5	5	4	59	891	6.2	2	2	17	483	3.4
21	0910	14.8	7.55	20	85	--	10.8	106.8	17.1	126.9	11	9	70	880	7.4	2	2	19	481	3.8
22	0915	14.6	7.50	15	90	--	10.7	105.3	16.8	124.0	9	8	79	871	8.3	--	--	--	--	--
23	0845	14.8	7.45	20	88	--	10.7	105.8	16.7	123.9	4	2	83	867	8.7	2	2	21	479	4.2

Appendix Table II--Daily mortality of fish and water quality in shallow test tank (river water, tank 1 m deep) throughout test.

	Water quality data										Mortality data									
											Chinook					Coho				
Date	Time of chemical sample (p.m.)	Temperature (°C)	pH	Turbidity (JTU)	Conductivity (μmho/cm)	CO_2 (mg/l)	O_2 (mg/l)	O_2 (percentage saturation)	N_2 (ml/l)	N_2 (percentage saturation)	Mortality	Number dead with symptoms	Accumulative mortality	Remaining total	Accumulated mortality(%)	Mortality	Number dead with symptoms	Accumulative mortality	Remaining total	Accumulated mortality(%)
April																				
3	0902	7.7	7.20	24	--	.65	13.1	109.9	18.4	117.4	0	0	0	505	0	0	0	0	297	0
4	0900	7.8	7.20	24	--	.65	12.4	104.5	17.7	113.2	--	--	--	--	--	--	--	--	--	--
5	0900	7.9	7.25	19	--	.75	12.9	108.3	18.0	115.6	--	--	--	--	--	--	--	--	--	--
6	0913	8.1	7.35	18	--	.70	12.5	105.5	18.4	118.2	--	--	--	--	--	--	--	--	--	--
7	0920	7.9	7.40	24	120	.55	12.5	105.1	17.7	113.6	--	--	--	--	--	--	--	--	--	--
8	1016	8.1	--	--	110	--	--	--	--	--	2	2	2	503	.4	--	--	--	--	--
9	0945	8.4	--	--	110	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
10	0914	8.4	7.25	24	108	--	12.6	107.3	17.9	116.0	1	1	3	502	.6	--	--	--	--	--
11	0935	8.4	7.40	24	--	--	12.9	110.4	18.1	117.1	5	5	8	497	1.6	--	--	--	--	--
12	0935	8.1	7.35	25	101	--	12.6	106.8	17.6	113.3	15	13	23	482	4.5	1	1	1	296	.3
13	0925	8.4	7.45	25	100	.55	12.3	105.0	17.9	116.0	6	6	29	476	5.7	--	--	--	--	--
14	0950	8.4	7.40	25	100	.80	12.6	107.7	17.5	113.5	4	4	33	472	6.5	--	--	--	--	--
15	--	--	--	--	--	--	--	--	--	--	3	3	36	469	7.1	--	--	--	--	--
16	1035	8.5	7.30	--	105	--	--	--	--	--	3	3	39	466	7.7	--	--	--	--	--
17	0855	8.5	7.35	17	109	.55	12.5	106.6	17.4	112.9	4	2	43	462	8.5	--	--	--	--	--
18	0920	8.3	7.45	17	110	.45	12.5	106.5	17.4	112.3	6	3	49	456	9.7	--	--	--	--	--
19	0835	8.5	7.55	18	118	--	12.3	104.9	17.5	113.7	6	2	55	450	10.9	--	--	--	--	--
20	0911	8.7	7.45	17	111	--	12.4	106.7	17.7	115.2	6	2	61	444	12.1	--	--	--	--	--
21	0920	8.6	7.45	17	113	--	12.4	106.3	--	--	7	3	68	437	13.4	--	--	--	--	--
22	1008	8.5	7.20	--	119	--	--	--	--	--	6	6	74	431	14.6	1	0	2	295	.7
23	1010	8.9	7.45	--	110	2.00	11.9	102.9	17.1	112.3	6	5	80	425	15.8	--	--	--	--	--
24	1022	9.2	7.35	16	115	2.70	11.9	103.7	17.2	113.8	13	6	93	412	18.4	--	--	--	--	--

Appendix II -- Continued

	Water quality data										Mortality data									
											Chinook					Coho				
Date	Time of chemical sample (p.m.)	Temperature (°C)	pH	Turbidity (JTU)	Conductivity (µmho/cm)	CO_2 (mg/l)	O_2 (mg/l)	O_2 (percentage saturation)	N_2 (ml/l)	N_2 (percentage saturation)	Mortality	Number dead with symptoms	Accumulative mortality	Remaining total	Accumulated mortality (%)	Mortality	Number dead with symptoms	Accumulative mortality	Remaining total	Accumulated mortality (%)
April																				
25	1105	9.0	--	16	119	--	12.0	103.7	16.4	107.8	11	2	104	410	20.6	--	--	--	--	--
26	1020	9.2	7.45	--	112	--	11.6	101.1	--	--	--	--	--	--	--	--	--	--	--	--
27	1040	9.6	7.55	16	110	--	11.8	104.0	--	--	4	0	108	397	21.4	--	--	--	--	--
28	0855	9.9	7.90	12	110	2.43	12.0	106.0	16.2	108.6	2	1	110	395	21.8	--	--	--	--	--
29	--	--	--	--	--	--	--	--	--	--	2	0	112	393	22.2	--	--	--	--	--
30	--	--	--	--	--	--	--	--	--	--	2	0	114	391	22.5	--	--	--	--	--
May																				
1	0916	9.8	7.45	11	112	--	11.9	104.9	16.0	106.9	3	1	117	388	23.2	--	--	--	--	--
2	0900	10.3	7.75	13	111	1.90	11.9	106.5	16.6	111.9	4	1	121	384	24.0	1	1	3	294	1.0
3	0747	10.5	7.70	12	115	1.20	12.7	114.0	17.6	119.4	2	0	123	382	24.3	--	--	--	--	--
4	1000	10.8	7.85	17	115	1.40	12.2	109.9	16.5	112.7	--	--	--	--	--	1	0	4	293	1.3
5	1007	11.4	7.85	12	121	--	11.8	107.8	--	--	2	0	125	380	24.7	1	0	5	292	1.7
6	--	--	--	--	--	--	--	--	--	--	1	0	126	379	25.0	--	--	--	--	--
7	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
8	0939	12.0	7.80	17	125	1.40	11.5	106.7	15.8	110.8	4	1	130	375	25.7	--	--	--	--	--
9	0930	11.8	7.90	15	130	1.80	11.6	107.7	16.1	112.0	--	--	--	--	--	1	0	6	291	2.0
10	0930	--	7.70	15	132	--	--	--	--	--	1	0	131	374	26.0	1	0	7	290	2.4
11	0950	12.2	7.35	18	125	1.55	11.9	111.5	16.8	118.2	1	0	132	373	26.1	3	0	10	287	3.4
12	0930	12.5	7.95	13	128	1.10	11.7	110.0	16.6	117.6	2	0	134	371	26.5	--	--	--	--	--
13	0740	12.8	8.00	--	130	1.10	11.9	112.6	16.3	116.1	4	1	138	367	27.3	--	--	--	--	--
14	0920	13.0	8.10	--	113	--	--	--	--	--	6	1	144	361	28.5	1	1	11	286	3.7
15	0950	13.2	7.90	16	130	1.10	11.8	112.6	16.6	118.9	17	14	161	344	31.8	1	1	12	285	4.0
16	0930	13.0	7.90	17	130	1.10	12.0	114.1	16.9	120.9	22	16	183	322	36.2	1	1	13	284	4.4
17	0925	12.9	7.85	17	130	1.20	11.6	104.8	16.9	120.6	27	24	210	295	41.6	1	1	14	283	4.7
18	0910	12.8	7.70	18	120	1.20	11.4	107.8	16.9	120.4	12	8	222	283	44.0	--	--	--	--	--
19	0915	12.8	7.60	22	110	1.30	10.8	102.3	16.5	117.5	10	10	232	273	46.0	--	--	--	--	--

Appendix II -- Continued

	Water quality data										Mortality data									
											Chinook					Coho				
Date	Time of chemical sample (p.m.)	Temperature	pH	Turbidity(JTU)	Conductivity (µmho/cm)	CO_2 (mg/1)	O_2 (mg/1)	O_2 (percentage saturation)	N_2 (ml/1)	N_2 (percentage saturation)	Mortality	Number dead with symptoms	Accumulative mortality	Remaining total	Accumulated mortality(%)	Mortality	Number dead with symptoms	Accumulative mortality	Remaining total	Accumulated mortality(%)
May																				
20	--	--	--	--	--	--	--	--	--	--	11	11	243	262	48.1	2	2	16	281	5.4
21	--	--	--	--	--	--	--	--	--	--	6	6	249	256	49.3	3	3	19	278	6.4
22	0940	12.4	7.35	18	110	1.10	11.2	105.0	17.1	120.5	14	10	263	242	52.1	1	1	20	277	6.7
23	0900	12.4	7.40	18	102	.90	11.3	105.9	16.9	119.4	10	6	273	232	54.0	--	--	--	--	--
24	0850	12.2	7.35	18	100	--	11.0	102.7	17.0	119.6	5	4	278	227	55.0	--	--	--	--	--
25	0950	12.0	7.40	13	95	--	12.0	111.6	17.0	119.1	4	4	282	223	55.8	2	2	22	275	7.4
26	0955	12.2	7.50	14	92	.80	12.0	112.0	17.5	122.8	7	6	289	216	57.2	4	4	26	271	8.7
27	--	--	--	--	--	--	--	--	--	--	16	15	305	200	60.4	4	3	30	267	10.1
28	--	--	--	--	--	--	--	--	--	--	23	20	328	177	64.9	6	6	36	261	12.1
29	--	--	--	--	--	--	--	--	--	--	24	24	352	153	69.7	11	11	47	250	15.8
30	0900	13.5	7.45	11	92	--	11.9	114.1	17.3	125.0	18	18	370	135	73.3	12	12	59	238	19.8
31	0853	13.8	7.40	11	97	1.50	11.7	113.2	16.7	121.5	24	22	394	111	78.0	11	11	70	227	23.5
June																				
1	0945	14.0	7.40	14	95	--	11.4	111.2	16.7	121.9	7	6	401	104	79.4	6	6	76	221	25.6
2	0855	14.2	7.45	12	90	--	11.4	111.2	16.7	122.4	10	10	411	94	81.4	1	1	77	220	25.9
3	--	--	--	--	--	--	--	--	--	--	2	2	413	92	81.8	5	5	82	215	27.6
4	--	--	--	--	--	--	--	--	--	--	8	8	421	84	83.4	8	8	90	207	30.3
5	0900	14.8	7.40	11	85	--	11.1	109.4	16.3	120.9	14	13	435	70	86.1	3	3	93	204	31.3
6	0920	15.0	7.35	13	85	.70	11.5	107.0	16.6	123.6	25	25	460	45	91.1	24	24	117	180	39.4
7	0905	--	7.35	12	82	--	--	--	--	--	9	9	469	36	92.8	16	16	133	164	44.8
8	1020	14.8	7.30	11	80	--	10.9	107.8	16.6	123.1	9	7	478	27	94.6	26	26	159	138	53.5
9	0930	--	7.30	16	80	--	--	--	--	--	11	10	489	16	96.8	38	38	197	100	66.3
10	--	--	--	--	--	--	--	--	--	--	5	5	494	11	97.8	13	13	210	87	70.7
11	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	10	10	220	77	74.0
12	0950	14.4	7.30	30	80	--	10.7	104.9	16.8	123.6	--	--	--	--	--	10	10	230	67	77.4
13	0917	14.4	7.25	30	78	--	11.2	110.1	17.4	128.3	2	2	496	9	98.2	8	8	238	59	80.1

Appendix Table III--Daily mortality of fish and water quality in control tank (nitrogen gas about 100% of saturation, tank 1 m deep).

Water quality data											Mortality data									
											Chinook					Coho				
Date	Time of chemical sample (p.m.)	Temperature (°C)	pH	Turbidity (JTU)	Conductivity (μmho/cm)	CO_2 (mg/l)	O_2 (mg/l)	O_2 (percentage saturation)	N_2 (ml/l)	N_2 (percentage saturation)	Mortality	Number dead with symptoms	Accumulative mortality	Remaining total	Accumulated mortality (%)	Mortality	Number dead with symptoms	Accumulative mortality	Remaining total	Accumulated mortality (%)
April																				
3	0840	7.7	7.10	24	--	.60	13.9	116.3	15.7	100.4	0	0	0	450	0	0	0	0	290	0
4	0900	8.0	7.20	24	--	.60	13.3	112.0	15.7	99.9	--	--	--	--	--	--	--	--	--	--
5	0855	8.1	7.20	19	--	.65	13.2	111.4	16.0	103.0	--	--	--	--	--	--	--	--	--	--
6	0910	8.3	7.25	18	--	.65	12.6	107.2	16.0	103.6	--	--	--	--	--	--	--	--	--	--
7	0910	8.0	7.35	24	120	.60	12.4	109.5	16.2	104.1	--	--	--	--	--	--	--	--	--	--
8	1012	8.3	--	--	110	--	12.7	108.1	--	--	--	--	--	--	--	--	--	--	--	--
9	0955	8.5	--	--	110	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
10	0903	8.4	7.10	24	110	.70	12.8	109.0	15.7	101.7	--	--	--	--	--	--	--	--	--	--
11	0930	8.5	7.30	24	--	--	12.8	109.0	15.9	103.3	--	--	--	--	--	--	--	--	--	--
12	0930	8.4	7.25	--	102	--	12.6	107.9	15.2	98.5	--	--	--	--	--	--	--	--	--	--
13	0920	8.4	7.40	25	100	.55	12.8	109.5	15.8	102.4	--	--	--	--	--	--	--	--	--	--
14	0935	8.6	7.35	25	100	1.00	12.4	106.3	16.1	104.5	--	--	--	--	--	--	--	--	--	--
15	0920	8.6	--	--	100	.60	12.2	104.3	15.7	102.2	--	--	--	--	--	--	--	--	--	--
16	1030	--	7.20	--	105	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
17	0845	8.6	7.35	17	110	--	13.1	112.3	15.6	101.4	--	--	--	--	--	--	--	--	--	--
18	0910	8.4	7.40	17	110	--	11.7	99.6	16.2	105.1	--	--	--	--	--	--	--	--	--	--
19	0833	8.6	7.55	18	118	.45	11.3	96.9	16.3	106.3	--	--	--	--	--	--	--	--	--	--
20	0908	8.8	7.35	17	110	--	12.5	107.8	15.6	101.8	--	--	--	--	--	--	--	--	--	--
21	0910	8.8	7.40	17	113	--	13.7	118.1	--	--	--	--	--	--	--	--	--	--	--	--
22	1008	8.6	7.18	--	119	2.10	12.8	109.7	15.2	99.0	--	--	--	--	--	--	--	--	--	--
23	1010	9.1	7.40	--	112	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
24	1018	9.3	7.30	16	115	3.00	15.0	127.8	13.9	91.8	--	--	--	--	--	--	--	--	--	--

Appendix III --- Continued

	Water quality data										Mortality data									
											Chinook					Coho				
Date	Time of chemical sample (p.m.)	Temperature (°C)	pH	Turbidity(JTU)	Conductivity (µmho/cm)	CO_2 (mg/l)	O_2 (mg/l)	O_2 (percentage saturation)	N_2 (ml/l)	N_2 (percentage saturation)	Mortality	Number dead with symptoms	Accumulative mortality	Remaining total	Accumulated mortality(%)	Mortality	Number dead with symptoms	Accumulative mortality	Remaining total	Accumulated mortality(%)
April																				
25	1100	9.1	7.20	16	120	--	10.9	94.3	15.5	101.5	--	--	--	--	--	--	--	--	--	--
26	0930	9.2	7.35	--	112	--	10.9	95.1	15.6	102.9	--	--	--	--	--	--	--	--	--	--
27	1035	9.8	7.45	16	110	--	11.3	99.4	--	--	--	--	--	--	--	--	--	--	--	--
28	0850	9.9	7.40	14	112	2.95	15.0	132.3	13.8	92.5	--	--	--	--	--	--	--	--	--	--
29	0930	10.0	7.45	--	--	--	10.6	94.4	15.4	103.7	--	--	--	--	--	--	--	--	--	--
30	0940	--	--	--	--	--	11.1	97.8	--	--	--	--	--	--	--	--	--	--	--	--
May																				
1	0912	9.9	--	11	112	3.20	13.6	120.2	14.8	99.0	1	0	1	449	.2	--	--	--	--	--
2	0855	10.5	7.75	12	111	2.00	11.7	104.1	14.9	101.2	3	0	4	446	.9	--	--	--	--	--
3	0810	10.7	7.50	12	116	2.60	9.7	88.4	15.2	103.9	1	0	5	445	1.1	--	--	--	--	--
4	1000	11.1	7.50	12	115	1.90	11.2	101.6	14.8	102.0	1	0	6	444	1.3	--	--	--	--	--
5	1006	11.5	7.40	13	130	1.73	12.0	110.7	14.8	100.3	--	--	--	--	--	--	--	--	--	--
6	1146	11.7	7.50	--	--	--	8.8	81.3	14.7	102.4	1	0	7	443	1.5	--	--	--	--	--
7	0950	11.9	7.35	--	--	--	8.2	75.5	--	--	--	--	--	--	--	--	--	--	--	--
8	0935	12.2	7.45	18	130	3.10	12.0	112.4	14.0	98.3	--	--	--	--	--	--	--	--	--	--
9	0925	12.0	7.35	15	140	--	12.1	112.8	13.9	97.2	--	--	--	--	--	--	--	--	--	--
10	0925	12.0	7.40	11	128	--	10.0	92.5	14.6	102.3	--	--	--	--	--	--	--	--	--	--
11	0945	12.2	6.80	14	123	2.90	8.8	82.2	15.0	105.4	2	0	9	441	2.0	1	0	1	289	.3
12	0925	12.7	7.35	12	128	1.90	8.0	75.5	14.8	105.2	--	--	--	--	--	--	--	--	--	--
13	0735	13.1	7.45	--	131	1.60	11.6	110.4	12.5	96.8	--	--	--	--	--	--	--	--	--	--
14	0920	13.2	7.70	--	112	--	10.8	102.6	13.9	100.4	--	--	--	--	--	--	--	--	--	--
15	0945	13.3	7.35	13	141	2.30	9.6	92.2	14.2	102.2	1	0	10	440	2.2	--	--	--	--	--
16	0917	13.2	7.45	17	132	2.60	9.3	88.7	14.5	104.2	--	--	--	--	--	--	--	--	--	--
17	0920	13.0	7.20	17	148	4.00	7.3	69.3	14.7	105.2	--	--	--	--	--	--	--	--	--	--
18	0905	13.0	7.30	13	125	1.90	6.9	65.3	14.7	105.1	--	--	--	--	--	1	0	2	288	.7
19	0905	13.0	7.20	22	113	3.30	8.6	82.0	14.1	100.8	--	--	--	--	--	--	--	--	--	--

Appendix III --- Continued

Date	Time of chemical sample (p.m.)	Temperature (°C)	pH	Turbidity (JTU)	Conductivity (µmho/cm)	CO_2 (mg/l)	O_2 (mg/l)	O_2 (percentage saturation)	N_2 (ml/l)	N_2 (percentage saturation)	Chinook: Mortality	Chinook: Number dead with symptoms	Chinook: Accumulative mortality	Chinook: Remaining total	Chinook: Accumulated mortality (%)	Coho: Mortality	Coho: Number dead with symptoms	Coho: Accumulated mortality	Coho: Remaining total	Coho: Accumulated mortality (%)
	Water quality data										Mortality data									
May																				
20	0610	13.3	7.25	--	124	1.73	7.8	74.0	14.7	105.4	--	--	--	--	--	--	--	--	--	--
21	0940	13.0	7.25	--	100	--	10.6	100.7	--	--	--	--	--	--	--	--	--	--	--	--
22	0935	12.6	7.20	16	110	1.50	13.1	122.9	13.5	95.7	--	--	--	--	--	--	--	--	--	--
23	0855	12.5	7.10	15	115	1.30	12.2	114.7	13.2	93.5	--	--	--	--	--	1	0	3	287	1.0
24	0843	12.4	7.05	17	100	--	13.6	127.5	14.8	104.6	--	--	--	--	--	--	--	--	--	--
25	0945	12.2	7.15	12	100	--	11.8	110.2	13.8	97.1	--	--	--	--	--	--	--	--	--	--
26	0925	12.4	7.20	12	97	1.00	11.8	110.6	13.5	95.1	--	--	--	--	--	--	--	--	--	--
27	0910	12.7	--	--	--	--	10.3	97.3	14.3	101.8	--	--	--	--	--	--	--	--	--	--
28	0825	13.0	--	--	--	--	12.2	120.2	13.9	99.3	--	--	--	--	--	1	0	4	286	1.4
29	1010	13.4	--	--	--	--	10.6	101.6	14.1	101.9	--	--	--	--	--	--	--	--	--	--
30	0855	13.6	7.20	11	92	1.30	11.7	112.7	13.8	99.9	--	--	--	--	--	--	--	--	--	--
31	0845	14.0	7.15	11	105	2.60	12.6	122.4	12.8	93.4	--	--	--	--	--	--	--	--	--	--
June																				
1	0940	14.2	7.15	11	98	--	10.0	97.5	13.7	100.4	--	--	--	--	--	--	--	--	--	--
2	0850	14.3	7.15	12	95	--	10.8	105.7	13.4	98.5	--	--	--	--	--	--	--	--	--	--
3	0632	14.8	--	--	--	--	12.7	125.6	--	--	--	--	--	--	--	--	--	--	--	--
4	0905	14.6	--	--	--	--	10.8	105.9	--	--	--	--	--	--	--	--	--	--	--	--
5	0855	14.9	7.10	10	90	--	12.4	122.4	12.6	93.7	--	--	--	--	--	--	--	--	--	--
6	0915	15.1	7.10	11	87	2.30	6.7	66.4	14.3	106.7	--	--	--	--	--	1	0	5	285	1.7
7	0900	15.0	7.10	10	85	--	7.3	72.3	13.9	103.5	--	--	--	--	--	--	--	--	--	--
8	1015	15.0	7.05	11	82	--	10.4	103.3	13.9	99.8	--	--	--	--	--	--	--	--	--	--
9	0930	15.0	7.10	17	80	--	11.6	114.8	13.4	100.0	--	--	--	--	--	--	--	--	--	--
10	0705	14.7	--	--	--	--	12.7	125.0	13.5	100.2	--	--	--	--	--	1	0	6	284	2.1
11	0915	14.6	6.90	--	--	--	11.9	116.8	13.7	100.9	--	--	--	--	--	1	0	7	283	2.4
12	0945	14.5	7.10	30	82	--	9.4	91.8	14.3	105.5	--	--	--	--	--	3	0	10	280	3.4
13	0913	14.6	7.10	30	80	1.60	9.5	93.2	14.0	103.8	--	--	--	--	--	2	0	12	278	4.1

Appendix Table IV. --Water quality data monitored in Columbia River throughout test.

Date	Time of chemical sample (a.m.)	Temperature (°C)	pH	Turbidity(JTU)	Conductivity (µmho/cm)	CO_2 (mg/l)	O_2 (mg/l)	O_2 (percentage saturation)	N_2 (ml/l)	N_2 (percentage saturation)
April										
3	0845	7.7	6.95	23	--	.60	12.8	106.9	18.4	117.6
4	0900	7.9	7.20	23	--	.70	12.8	107.6	18.1	115.9
5	0845	8.1	7.00	17	--	.55	13.0	110.2	17.9	115.1
6	0855	8.1	7.10	17	--	.70	13.0	110.0	18.6	119.8
7	0900	8.1	7.10	22	120	.60	12.6	106.2	17.8	114.4
8	1000	8.2	--	--	110	.90	12.5	106.4	17.6	113.7
9	1005	8.4	--	--	110	.75	12.7	107.7	17.5	113.6
10	0900	8.6	7.20	24	105	.60	12.5	107.4	18.1	117.6
11	0915	8.4	7.15	24	--	--	13.0	110.6	18.1	117.3
12	0920	8.2	7.10	25	100	--	12.8	109.2	17.6	113.6
13	0905	8.1	7.10	25	99	.60	12.2	103.6	17.7	114.0
14	0920	8.4	7.20	25	100	.85	12.5	106.7	17.5	113.1
15	0910	8.5	7.10	--	100	.55	12.3	105.0	17.6	114.4
16	1025	8.5	7.10	--	105	.50	12.5	107.1	17.4	113.3
17	0840	8.5	7.15	17	105	--	12.8	109.7	17.6	114.4
18	0900	8.6	7.20	16	110	.45	12.6	107.7	17.4	113.4
19	0825	8.6	7.45	16	105	.45	12.6	107.7	17.4	113.4
20	0855	8.8	7.10	16	110	2.10	12.3	106.3	17.7	115.7
21	0900	8.6	7.15	17	110	--	12.3	105.5	17.2	111.8
22	0950	8.8	7.40	--	113	2.10	12.5	107.6	17.3	112.9
23	1005	9.1	7.45	--	119	2.00	12.3	106.5	16.8	110.2
24	0925	9.2	7.20	23	115	--	11.9	103.3	16.9	111.5

Appendix IV --- Continued

Date	Time of chemical sample (a.m.)	Temperature (°C)	pH	Turbidity(JTU)	Conductivity (µmho/cm)	CO_2 (mg/l)	O_2 (mg/l)	O_2 (percentage saturation)	N_2 (ml/l)	N_2 (percentage saturation)
April										
25	0830	9.0	7.10	16	115	--	12.1	104.8	16.2	106.7
26	0905	9.3	7.15	--	110	--	12.1	105.4	15.9	105.4
27	0850	9.6	7.20	8	105	1.55	12.0	105.4	16.3	108.3
28	0840	9.8	--	15	105	1.65	12.2	107.8	16.4	110.0
29	0945	9.9	7.65	--	--	--	12.0	105.6	15.7	106.2
30	1020	9.6	7.70	--	--	--	12.1	106.2	16.4	109.2
May										
1	0910	9.9	7.45	10	105	1.65	12.1	106.9	16.4	109.8
2	0845	10.6	7.55	9	110	1.65	12.3	110.6	16.6	113.0
3	0755	10.5	7.60	13	111	1.20	12.7	114.0	17.0	115.4
4	0950	11.0	7.75	11	110	1.30	12.6	114.4	16.7	114.5
5	0945	11.9	7.80	13	118	1.30	12.1	111.9	16.8	117.3
6	1140	11.5	7.70	--	--	1.20	12.1	111.2	16.4	113.6
7	1005	11.8	--	--	--	--	11.7	108.2	16.2	112.8
8	0920	11.9	7.70	9	118	1.10	11.7	108.3	16.2	113.2
9	0910	11.7	7.85	12	125	1.20	11.9	109.7	16.0	111.8
10	0930	11.6	7.75	12	126	--	12.2	112.6	16.5	114.7
11	1010	12.2	7.50	10	122	1.20	12.1	117.6	16.9	119.1
12	0945	12.9	7.80	9	125	1.20	12.3	116.3	16.6	118.4
13	0800	12.8	8.05	--	125	1.20	12.7	119.8	16.8	119.4
14	0910	13.0	--	--	--	--	12.1	114.6	16.8	120.1
15	1040	13.1	7.95	6	125	1.00	12.4	117.7	16.6	119.0
16	0937	13.0	7.70	16	128	1.20	12.4	117.9	16.9	120.9
17	0940	12.8	7.75	10	128	1.20	11.8	112.1	17.0	121.2
18	0930	12.8	7.70	14	120	1.20	11.6	109.7	16.8	119.5
19	0925	12.9	7.55	8	100	1.20	11.6	109.8	16.8	119.9

Appendix IV -- Continued

Date	Time of chemical sample (a.m.)	Temperature (°C)	pH	Turbidity(JTU)	Conductivity (µmho/cm)	CO_2 (mg/l)	O_2 (mg/l)	O_2 (percentage saturation)	N_2 (ml/l)	N_2 (percentage saturation)
May										
20	0600	12.8	7.65	--	120	1.20	11.8	111.8	17.2	122.1
21	0930	12.6	7.15	--	120	--	11.6	109.0	17.1	121.8
22	0955	12.3	7.40	17	100	1.20	11.5	107.6	17.0	119.9
23	0925	12.2	7.40	16	100	.85	11.6	108.3	17.1	120.3
24	0905	12.2	7.30	18	98	--	12.0	112.0	17.2	121.4
25	1005	12.1	7.30	9	94	--	12.3	114.5	17.4	122.1
26	0945	12.2	7.20	14	89	.70	12.1	112.6	17.4	122.4
27	0920	12.4	--	--	--	--	12.1	113.2	17.2	121.6
28	0840	12.6	--	--	--	--	12.1	113.5	17.5	124.1
29	1005	13.1	--	--	--	--	11.8	112.8	17.0	122.1
30	0950	13.6	7.35	11	85	.80	12.5	120.4	17.3	125.3
31	0927	13.8	7.40	11	93	1.40	12.3	119.0	17.0	124.0
June										
1	1000	13.9	7.45	9	93	--	11.6	113.0	16.9	123.1
2	0905	14.2	7.40	9	85	--	11.6	113.1	16.7	122.1
3	0630	14.5	--	--	--	--	11.6	114.3	16.9	124.9
4	0910	14.4	--	--	--	--	11.5	112.5	16.8	123.5
5	0915	14.6	7.35	10	85	--	11.6	114.3	16.7	123.4
6	0935	15.0	7.30	11	83	.70	11.7	116.2	16.8	125.1
7	0910	14.8	7.25	12	80	--	11.5	113.5	16.7	123.8
8	1030	14.8	7.20	9	80	--	11.4	113.1	16.7	123.9
9	0920	14.8	7.30	17	78	--	11.5	113.0	17.1	127.1
10	0700	14.5	--	--	--	--	11.5	112.7	16.9	124.7
11	0920	14.4	7.15	--	--	--	11.1	109.1	16.8	123.8
12	1000	14.4	7.20	30	78	--	11.2	109.8	17.1	125.8
13	0930	14.5	7.15	30	78	.80	11.4	112.0	17.7	130.5

Appendix IV --- Continued

Date	Time of chemical sample (a.m.)	Temperature (°C)	pH	Turbidity(JTU)	Conductivity (μmho/cm)	CO_2 (mg/1)	O_2 (mg/1)	O_2 (percentage saturation)	N_2 (ml/1)	N_2 (percentage saturation)
June										
14	0800	14.6	7.20	24	80	--	11.5	113.1	17.0	125.6
15	0800	14.4	7.20	20	80	--	11.5	112.7	17.4	127.7
16	0900	14.1	7.30	19	80	--	11.6	113.0	17.4	127.0
17	0905	14.1	--	--	--	--	11.6	112.8	17.2	126.1
18	0940	14.4	--	--	--	--	11.5	113.1	17.1	125.7
19	0850	14.5	7.30	19	78	.80	11.8	115.9	16.8	123.9
20	0900	14.8	7.35	17	80	--	11.8	116.8	17.3	128.3
21	0855	14.8	7.40	17	82	--	11.3	111.8	17.5	129.8
22	0905	14.5	7.78	15	89	--	11.5	113.1	17.0	125.1
23	0900	14.8	7.35	17	85	--	11.3	111.8	17.0	126.1

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