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Report to Corps of Engineers Gas Supersaturation Research Prescott Facility 1974

by

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REPORT TO CORPS OF ENGINEERS

GAS SUPERSATURATION RESEARCH

PRESCOTT FACILITY - 1974

CONTRACT NUMBER: DACW57-74-F-0414

BY

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TABLE OF CONTENTS

	Page
List of figures and tables	i
Introduction	1
Gas saturation levels at Prescott, Oregon 1974	1
Gas equilibration characteristics in the Columbia River between The Dalles Dam and Astoria, Oregon	4
Methods	4
Mixing and equilibration between Bonneville and Prescott - April 1974	4
Mixing and equilibration between The Dalles and Astoria - June 1974	7
Bioassay of prevailing Columbia River nitrogen and temperature conditions	10
Bioassay tanks	10
Test fish and study duration	11
Water quality	11
Mortality in the bioassay tanks	13
Vertical distribution of fish by using depth sounding gear	16
Literature cited	20
Appendix A -- Parameters monitored in Columbia River throughout test period	21
Appendix B -- Tabulation of mortality and parameters monitored in shallow control tank (gas equilibrated - 1 m water depth) throughout test period	23
Appendix C -- Tabulation of mortality and parameters monitored in shallow test tank (river conditions - 1 m water depth) throughout test period	25
Appendix D -- Tabulation of mortality and parameters monitored in deep test tank (river conditions - 2.5 m water depth) throughout test period	27
Appendix E -- Tabulation of mortality and parameters monitored in shallow control tank (gas equilibrated - 1 m water depth) throughout test period	29
Appendix F -- Tabulation of mortality and parameters monitored in shallow test tank (river conditions - 1 m water depth) throughout test period	31

TABLE OF CONTENTS (continued)

Page

Appendix G -- Tabulation of mortality and parameters monitored in deep test tank (river conditions - 2.5 m water depth) throughout test period..... 33

LIST OF TABLES AND FIGURES

Figure 1 -- Lower Columbia River and locale (inset) of Prescott Field Facility..... 2

Figure 2 -- Ten day average N_2 gas level at Prescott, Oregon, January thru August, 1972, 1973 and 1974..... 3

Figure 3 -- River miles on the Columbia River at which water samples were taken during a study to define the gas equilibration characteristics in the river between The Dalles Dam and Astoria, Oregon..... 5

Table 1 -- Percent N_2 saturation of water samples taken between Bonneville Dam and Prescott, Oregon..... 6

Table 2 -- Percent N_2 saturation of water samples taken between The Dalles and Astoria, Oregon..... 8

Table 3 -- Tank size, species and number of fish used in each bioassay tank..... 12

Figure 4 -- Levels of various water quality parameters as they occurred in the Columbia River 1974, and a shallow test tank, during a bioassay test to determine the effect of prevailing Columbia River gas saturation on the survival of juvenile salmonids..... 14

Figure 5 -- Accumulative percent mortality from deep (2.5 m) and shallow (1 m) tanks during bioassay of naturally prevailing gas saturation in the Columbia River at Prescott, Oregon during spring of 1974..... 15

Figure 6 -- Ten transducer sonic array and recorder..... 18

Figure 7 -- Numbers of fish detected (at .3 m intervals) by sonic gear during 75 hours of operation at Columbia River beaches near Prescott, Oregon..... 19

INTRODUCTION

In 1974 the Corps of Engineers partially funded gas supersaturation studies that were conducted by the National Marine Fisheries Service (NMFS). The base of operation for these studies was the Environmental Field Facility at Prescott, Oregon. (Snyder, et al. 1971) (figure 1)

The 1974 study proposal outlined the following objectives:

1. to determine the gas saturation of the Columbia River at Prescott, Oregon during periods of major upstream and downstream migrations of salmonid fishes.
2. to define the gas equilibration characteristics in the Columbia River from The Dalles Dam to Prescott, Oregon.
3. to determine the survival of juvenile salmonids (steelhead, cutthroat and chinook) exposed to combinations of naturally occurring environmental parameters prevailing in the Columbia River during the normal migration period.

This report outlines the efforts made, and resulting information obtained, for each of the study objectives. Included are preliminary results of exploratory tests using depth sounding gear to determine vertical distribution of fish.

GAS SATURATION LEVELS AT PRESCOTT, OREGON 1974

Since January (1974) 393 water samples were analyzed for gas content. The highest nitrogen level recorded in the river near Prescott, Oregon (1974) was 137% near mid-channel on June 25, while the 10 day average was 127.8% (figure 2). The N_2 levels recorded during 1973 were considerably

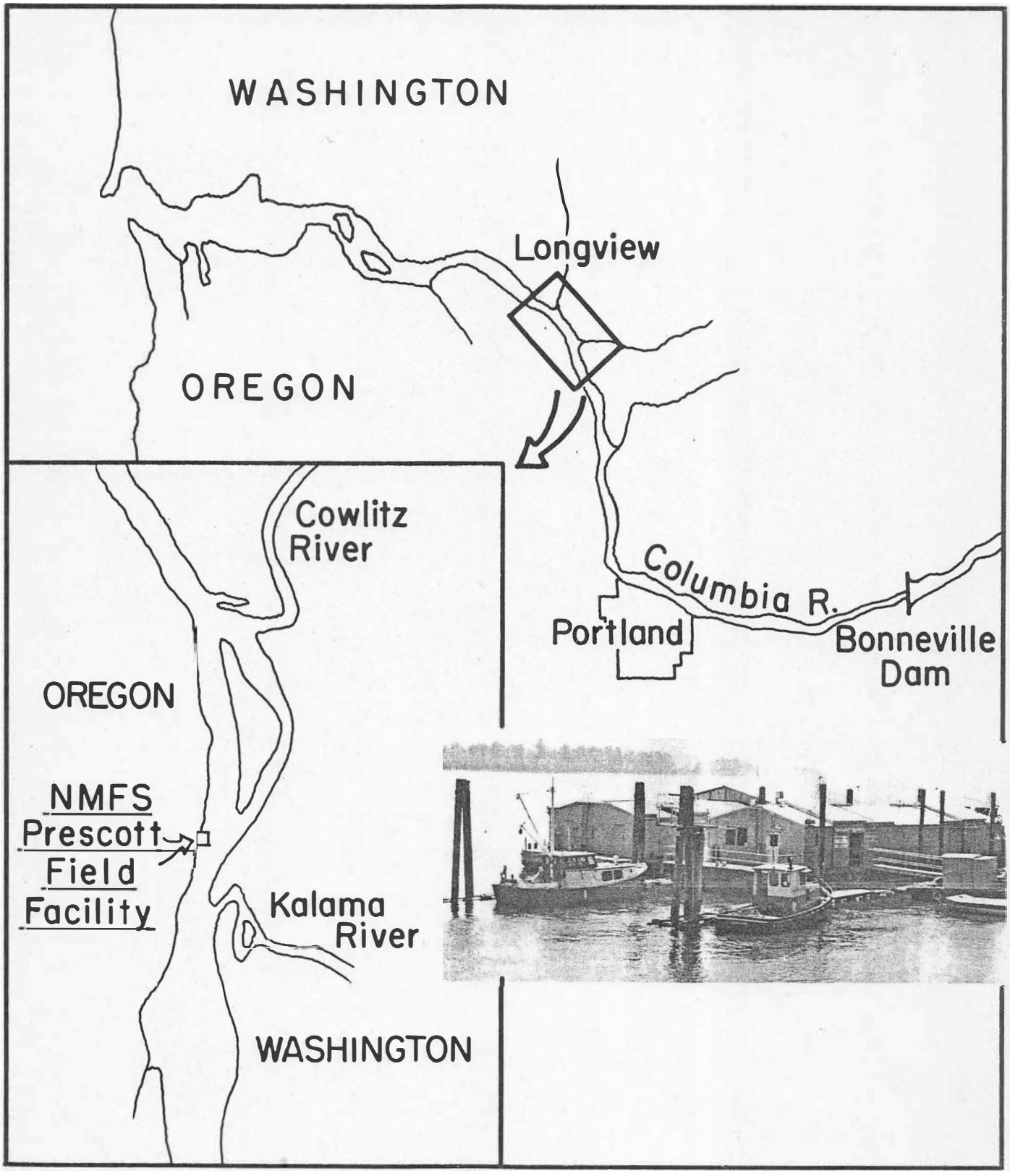
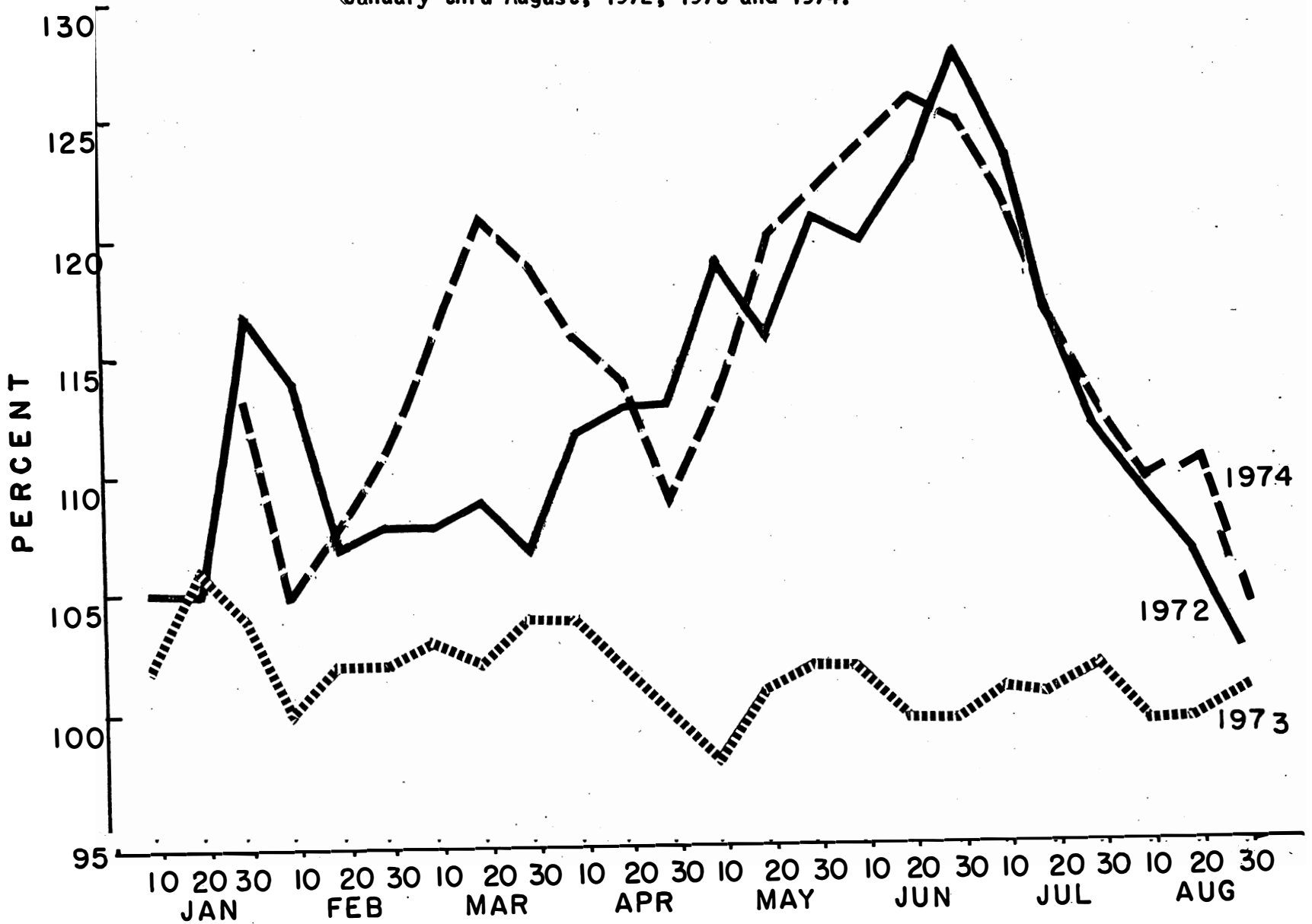


Figure 1 -- Lower Columbia River and locale (inset) of Prescott Field Facility.

Figure 2 -- Ten day average N_2 gas level at Prescott, Oregon, January thru August, 1972, 1973 and 1974.



less than those reported for previous years. The 1972 and 1974 levels are comparable (figure 2) and both were associated with, 1 in 40 year water flows.

The data collected from this sampling program was tabulated and sent periodically to the Corps of Engineers, North Pacific Division. The data is stored in the Corps of Engineers' ADP system and therefore, is not included in this report.

GAS EQUILIBRATION CHARACTERISTICS IN THE COLUMBIA RIVER BETWEEN THE DALLES DAM AND ASTORIA, OREGON

Surveys were conducted during 1974 to determine the mixing characteristics and rate of gas equilibration in the Columbia River between The Dalles Dam and Astoria, Oregon. One survey was done between Bonneville Dam and Prescott on April 9 and 10 and another between The Dalles Dam and Astoria during June 11 to 14, 1974.

Methods

A boat was used to follow a lighted bouy which was floating with the water mass. Transectional and/or single water samples were taken at least every 10-12 river miles[1/] (figure 3) and returned to Prescott for analysis. Time delay on the samples, between collection and analysis, was never more than 12 hours.

Mixing and Equilibration Between Bonneville and Prescott - April 1974

Table 1 is a summary of the results of the survey. The "float" time between Bonneville and Prescott was approximately 26 hours. The average

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[1/] River mile (RM), rather than river kilometer, is used in this report because most current references do not include the metric equivalent.

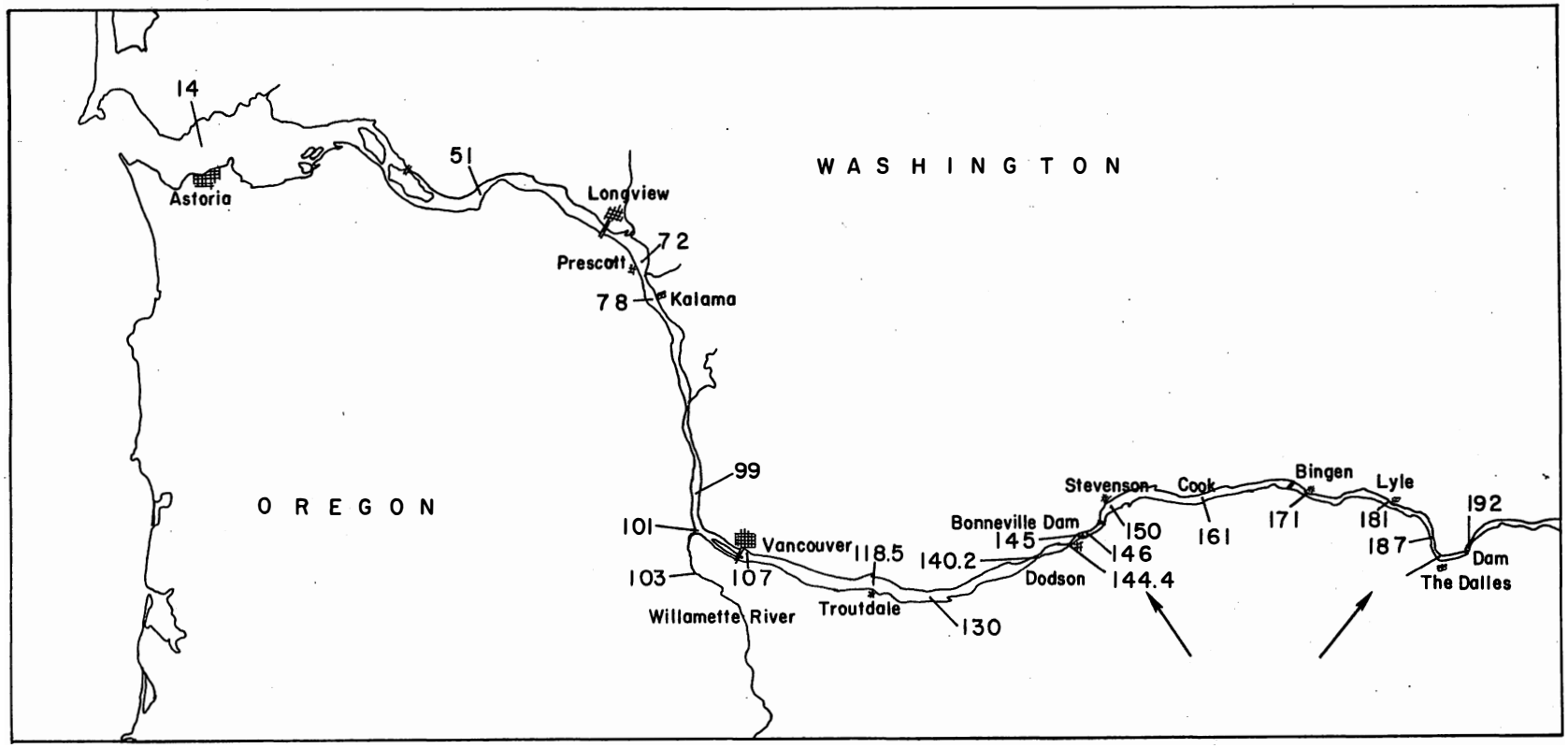


Figure 3 -- River miles on the Columbia River at which water samples were taken during a study to define the gas equilibration characteristics in the river between The Dalles Dam and Astoria, Oregon.

Table 1 -- Percent N_2 saturation of water samples taken between Bonneville Dam and Prescott, Oregon; the survey was done on April 9-10, 1974. The average water flow past Bonneville Dam during this period was 286 KCFS.

Sample Site	River Mile	Location in River	Time of Sample	Temp.	N_2 ml/l	N_2 %
April 9						
Bonneville Forebay	146.0	Center	07:35	8.0	17.9	114.9
Bonneville Power House	145.0	Center	08:10	7.8	17.95	114.7
Bonneville Spillway	145.0	Ore.	08:20	7.9	19.2	123.0
		Center		7.8	19.9	127.1
		Wash.	08:25	7.9	20.2	129.5
Tanner Creek	144.4	Ore.	08:35	7.8	17.95	115.0
		Center		7.8	19.1	122.1
		Wash.		8.0	19.8	127.1
Dodson	140.2	Ore.	09:05	7.8	18.1	115.7
		Center		7.8	18.3	117.0
		Wash.		8.0	19.3	124.0
Rooster Rock	130.0	Ore.	11:15	8.0	18.4	118.2
		Center		7.9	18.8	120.5
		Wash.		7.9	18.85	120.8
Troutdale	118.5	Center	17:00	8.1	18.4	118.5
Vancouver	107.0	Ore.	19:40	8.0	18.4	118.2
		Center		8.1	18.4	118.5
		Wash.		8.0	18.4	118.2
Above Willamette River	101.0	Center	21:50	8.1	17.7	114.0
Morgan Turn	99.0	Ore.	23:05	8.2	17.5	112.9
		Center		7.9	18.1	116.0
		Wash.		7.9	18.3	117.3
April 10						
Sauvie	88.0	Ore.	02:35	7.9	18.1	116.0
Kalama	78.5	Center	06:20	8.0	18.0	115.6
Prescott	72.0	Ore.	09:00	8.4	17.3	112.2
		Center		8.0	17.9	115.0
		Wash.		7.6	17.7	112.7

outflow from Bonneville Dam was 286 KCFS during this period. Bonneville forebay and power house samples each showed 115% N_2 saturation at the beginning of the survey. The N_2 saturation in the spillrace (3 transect samples) ranged from 123 to 130%. Table 1 shows side to side mixing (within error of analysis) at Rooster Rock (RM 130), approximately 15 miles down river from Bonneville Dam. Below Vancouver the N_2 values were apparently influenced (decreased) by the inflow from the Willamette River. The N_2 level decreased approximately 10% between Bonneville and Prescott.

Mixing and Equilibration Between The Dalles and Astoria - June 1974

This sampling effort was begun on June 11 at The Dalles (RM 192) and completed on June 14 at Astoria, Oregon (RM 14). No significant equilibration occurred in the 46 mile reservoir between The Dalles and Bonneville Dams (table 2). Spillway discharge at The Dalles was held constant at 239 KCFS for a seven hour period prior to the start of the survey; total outflow during this period was 379 KCFS. At these flow conditions the water mass appears to be mixed (side to side on the surface) within 2.5 miles of The Dalles Dam. The average total flow at The Dalles on June 10-11 was 386 KCFS while the average spill was 170 KCFS. In reference to nitrogen level the surface water seems to be mixed (side to side) immediately below the dam and remains so to the Bonneville forebay.

After a 22 hour time lapse the survey was continued from Bonneville to Astoria on June 12. The Bonneville forebay and power house samples were approximately the same, 119 and 120% N_2 respectively (table 2); while the three transect spillrace samples ranged from 135 to 142% N_2. Side to side mixing had apparently occurred at Rooster Rock (RM 130). As with the April survey there was an approximate 10% decrease in N_2 level between

Table 2 -- Percent N_2 saturation of water samples taken between The Dalles and Astoria, Oregon. The survey was done on June 11-14, 1974. The average water flow past both The Dalles and Bonneville Dams was approximately 400 KCFS.

Sample Site	River Mile	Location in River	Time of Sample	Temp.	N_2 ml/l	N_2 %
June 11						
The Dalles	192.0	Wash.	06:50	13.5	17.6	127.2
Docks	189.0	Ore.	06:55	13.4	17.6	126.9
		Center		13.4	17.8	128.3
		Wash.	07:00	13.4	17.7	127.6
Crates Point	187.0	Ore.	07:10	13.4	17.7	127.6
		Center		13.4	17.6	126.9
		Wash.	07:15	13.4	17.7	127.6
Lyle 160' marker "56"	181.0	Ore.	07:35	13.5	17.0	122.8
		Center		13.4	17.5	126.2
		Wash.	07:45	13.4	17.0	122.6
Bingen	171.0	Ore.	08:05	13.6	17.5	126.7
		Center		13.5	17.5	126.4
		Wash.	08:10	13.5	17.5	126.4
Cook	161.0	Ore.	08:30	13.5	17.4	125.7
		Center		13.5	17.5	126.4
		Wash.	08:40	13.4	17.5	126.2
Stevenson	150.0	Ore.	09:05	13.6	17.1	123.8
		Center	09:10	13.5	17.6	127.2
		Wash.	09:15	13.4	17.6	126.9
Bonneville Forebay	146.0	Ore.	09:35	13.3	17.6	126.7
		Center		13.2	17.6	126.4
		Wash.	09:25	13.4	17.6	126.9
June 12		——— Approximately 22 hour time lapse ———				
Bonneville Forebay	146.0	Center	07:40	13.6	16.4	118.8
Bonneville Power House	145.0	Center	08:50	13.8	16.5	120.0
Bonneville Spillway	145.0	Ore.	08:55	13.8	18.6	135.3
Tanner Creek	144.4	Ore.	09:10	13.8	16.9	122.9
		Center		13.8	17.4	126.5
		Wash.	09:15	13.8	19.7	143.3

Table 2 -- Continued

Sample Site	River Mile	Location in River	Time of Sample	Temp.	N_2 ml/l	N_2 %
Dodson	140.2	Ore.	09:45	13.8	18.0	130.9
		Center		13.8	18.5	134.5
		Wash.	09:55	13.8	19.1	138.9
Rooster Rock	130.0	Ore.	13:10	14.6	18.6	137.5
		Center	13:15	14.2	18.6	136.4
		Wash.	13:20	14.2	18.7	137.4
Troutdale	118.5	Ore.	16:05	14.8		
		Center	16:10	14.4	18.5	136.1
		Wash.	16:15	14.4	18.7	137.6
Vancouver	107.0	Ore.	18:15	15.0	18.1	134.8
		Center	18:17	14.6	18.4	136.0
		Wash.	18:20	14.7	18.5	136.9
Above Willamette River	101.0	Center	19:55	14.8	18.2	135.0
Willamette River	103.0	Center	20:10	15.8	16.9	127.8
Morgan Turn	99.0	Ore.	20:50	14.6	17.9	132.3
		Center	20:55	14.6	18.1	133.8
		Wash.	21:00	14.4	18.3	134.6
Sauvie[1/]	88.0	--	--	--	--	--
June 13						
Kalama	78.0	Ore.	06:25	14.4	17.3	127.3
		Center	06:20	14.2	17.5	128.3
		Wash.	06:15	14.3	16.9	124.2
Prescott	72.0	Ore.	08:35	14.5	16.6	128.4
		Center	08:25	14.4	17.4	128.0
		Wash.	08:20	14.3	17.5	128.6
Eagle Cliff	51.0	Ore.	15:00	14.9	16.8	124.9
		Center	14:55	14.6	16.8	124.2
		Wash.	14:50	14.5	16.6	122.4
June 14						
Astoria	14.0	Ore.	07:50	15.0	15.5	115.4
		Center	08:10	14.4	15.3	112.6
		Wash.	08:20	14.3	15.7	115.4

[1/] Sample omitted by error

Bonneville and Prescott and about 18% between Bonneville Dam and Astoria, Oregon. The Bonneville average flow during June 12-14 was 413 KCFS while the average spill was 288 KCFS.

In summary it was noted that: (1) during both surveys side to side mixing of the surface water, in reference to N_2 level, occurred at Rooster Rock, 15 river miles below Bonneville Dam, (2) both surveys showed approximately 10% equilibration between Bonneville Dam and Prescott, Oregon, (3) 18 to 20% equilibration occurred between Bonneville Dam and Astoria, Oregon, (4) no significant gas equilibration occurred between The Dalles and Bonneville Dams, and (5) side to side mixing was characteristic in all transects between The Dalles and Bonneville forebay. These conclusions would be considered valid only in relation to flows (total and spill) which occurred during the surveys.

BIOASSAY OF PREVAILING COLUMBIA RIVER NITROGEN AND TEMPERATURE CONDITIONS

Bioassay tanks

Six large redwood tanks were used to hold the test fish. Each tank was supplied with Columbia River water at a minimum rate of 50 L/min (13 gpm). The holding tanks were lined with partitioned nets that could be drawn to the surface to check fish mortality. The tanks were separated into two groups of three; each group contained: (1) a shallow (1.8 m x 1 m) control tank with gas equilibrated water supply, (2) a shallow (1.8 m x 1 m) tank with unaltered Columbia River water supply and (3) a deep tank (1.8 m x 2.5 m) tank with unaltered water supply. Two groups of tanks were necessary

to accommodate 3 species of fish. Table 3 summarizes tank size, water depth, fish species and number of fish in each test.

Test Fish and Study Duration

Three species of juvenile test fish were used; (1) chinook *(Oncorhynchus tshawytscha)*, average length 70 mm (2) steelhead trout *(Salmo gairdneri)*, average length 193 mm and (3) cutthroat trout *(Salmo clarki clarki)*, average length 241 mm. The chinook and steelhead were obtained from the Big Creek Hatchery, Fish Commission of Oregon; the cutthroat from the Beaver Creek Hatchery, Washington Department of Game. The fish were transported to the Prescott Facility in a 1,500 L tank filled with hatchery water. They were held at the test facility pre-test in water of the same temperature at which they were acclimated.

On the morning of May 1, 1974 the fish were split into lots and placed in the test tanks. The test was discontinued on June 24 (lapsed time, 55 days) when it became evident that a few of the control fish were dying from causes other than gas bubble disease (fungus infection).

Water Quality

Water quality samples were taken daily from the Columbia River and intermittently from the test and control (equilibrated) tanks. All samples were taken at the surface and reported as surface values. Following is an outline of parameters monitored, method of analysis and the units that the data are reported in:

1. Dissolved oxygen (D.O.) -- Winkler method (Welsh, 1948) and gas chromatograph - mg/l.
2. Nitrogen gas (N_2) -- Van Slyke and gas chromatograph (Swinnerton, 1962) - ml/l.

Table 3 -- Tank size, species and number of fish used in each bioassay tanks; also included is an indication if water supply was gas equilibrated.

	TANKS					
	Deep	Shallow	Control Shallow	Deep	Shallow	Control Shallow
Tank Size	1.8 x 3 m	1.8 x 1.2 m	1.8 x 1.2 m	1.8 x 3 m	1.8 x 3 m	1.8 x 1.2 m
Water Depth	2.5 m	1 m	1 m	2.5 m	1 m	1 m
Gas Equilibrated	No	No	Yes	No	No	Yes
Fish Species[1/] and Number	Stld (80) Ch (112)	Stld (90) Ch (96)	Stld (76) Ch (85)	Cutt (48)	Cutt (48)	Cutt (49)

[1/] Stld = Steelhead
Ch = Chinook
Cutt = Cutthroat

3. Carbon dioxide (CO_2) -- Titremetric phenolphthalein method (Standard Methods, 1971) - ppm.
4. pH -- Expanded scale pH meter - pH units.
5. Turbidity -- Hach turbidimeter - Jackson Turbidity Units, JTU.
6. Conductivity -- Conductivity meter - micromhos per centimeter, umho/cm.
7. Water temperature -- Daily continuous record from thermograph in Columbia River, also standard laboratory thermometer for river and test tanks - degrees centigrade, C.
8. Alkalinity -- Bromcresol green-methyl method (Standard Methods, 1971) - ppm.
9. Ammonia (NH_3) -- Specific ion electrode - ppm.

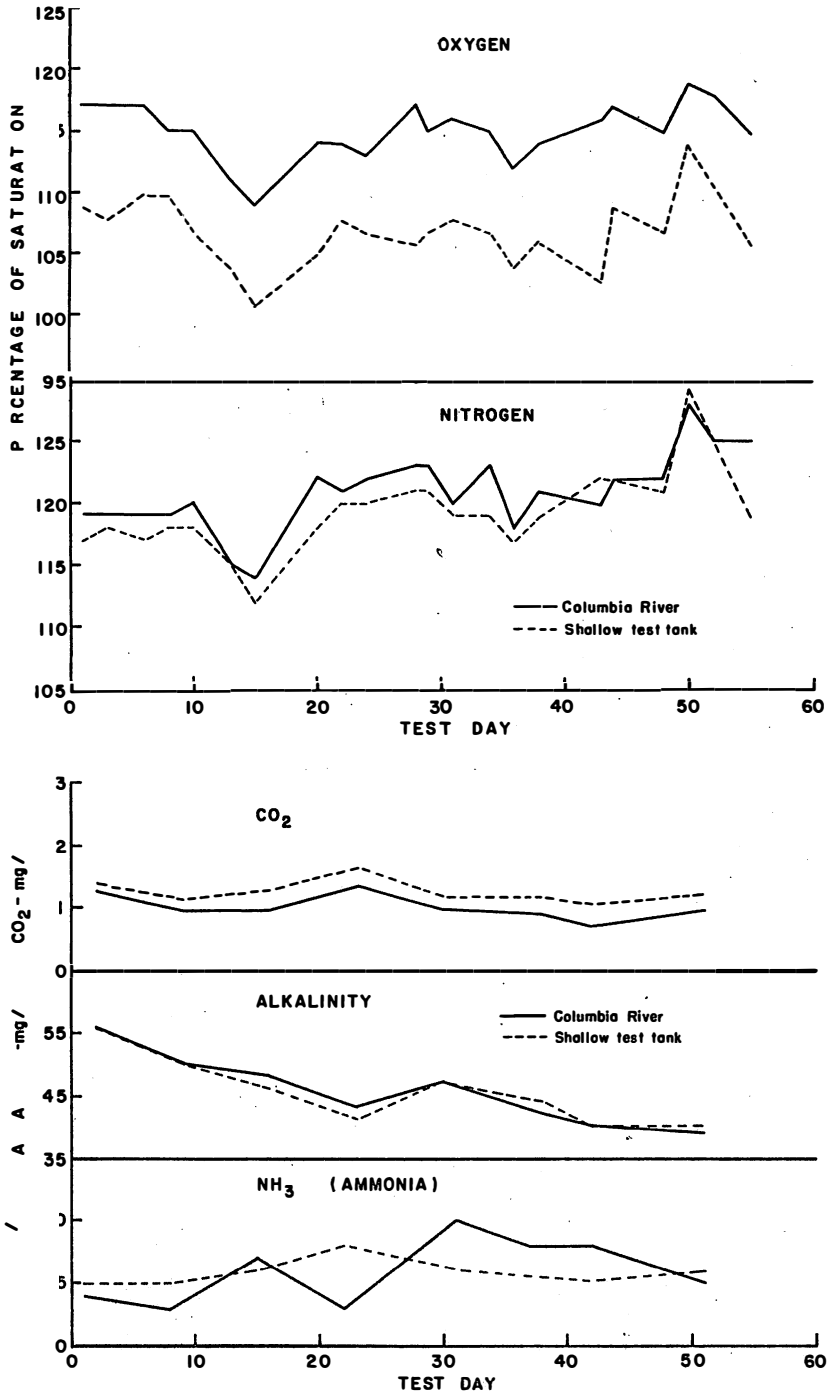
The levels of the various parameters monitored in the tanks closely reflected those which occurred in the Columbia River during the same period. Figure 4 is a graphic comparison of water quality parameters in the Columbia River and one of the shallow test tanks. Water quality parameters remained in acceptable biological ranges. All water quality data is compiled and included in the appendix.

Mortality in the Bioassay Tanks

Following is a summary of the percent mortality that occurred in each test tank.

	Deep Tank	Shallow Tank	Control Tank (Shallow)
	Percent Mortality		
Chinook	11	80	0
Steelhead	6	80	8
Cutthroat	27	42	8

Accumulative mortality is displayed on a time base in figure 5.



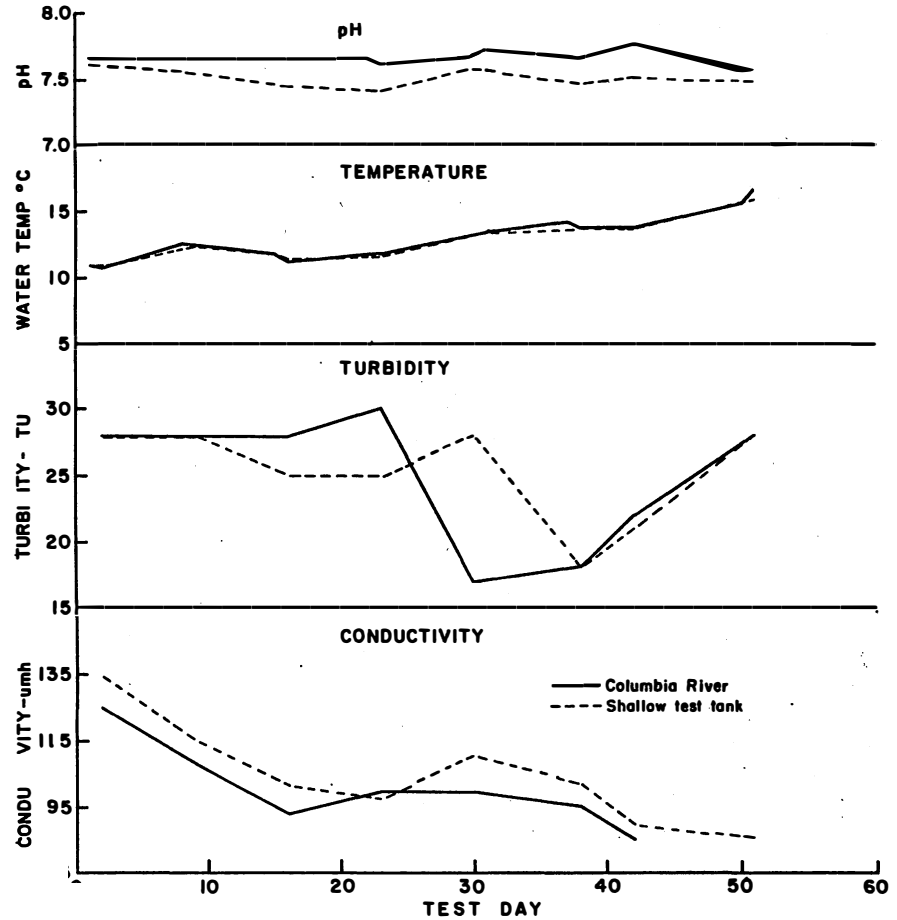


Figure 4—Levels of various water quality parameters as they occurred in the Columbia River 1974, and a shallow test tank, during a bioassay test to determine the effect of prevailing Columbia River gas saturation on the survival of juvenile salmonids.

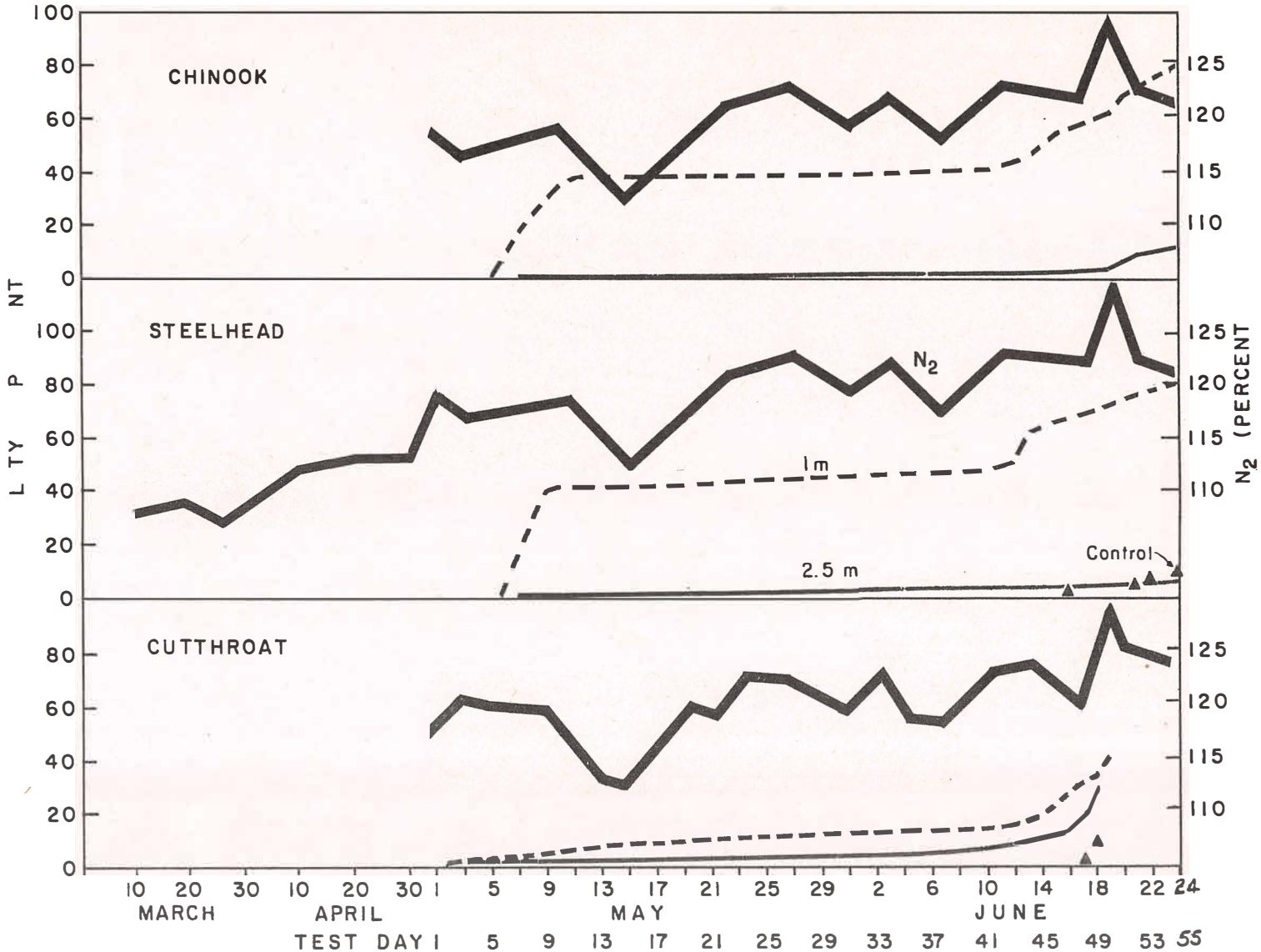


Figure 5.--Accumulative percent mortality from deep (2.5 m) and shallow (1 m) tanks during bioassay of naturally prevailing gas saturation in the Columbia River at Prescott, Oregon during spring of 1974. The N_2 curves reflect the percent saturation that occurred in each of the test tanks.

The benefit of water depth is obvious; as the hydrostatic pressure increased the percent of gas saturation decreases which is reflected by less mortality in the deep tanks. Examining figure 5 we see that the cutthroat are apparently the more tolerant of the three species. With the chinook and steelhead the initial die off is associated with an increase in N_2 level in the river; the rate of mortality then plateaus for approximately 28 days, while the N_2 level in the river (at Prescott) averages approximately 120% saturation. During the last days of June the N_2 level increased slightly, but steadily, to 125% with which is associated the last increase in mortality. Day by day mortality in each tank is summarized in the appendix. The mortality that occurred in the shallow tanks is about what one would predict knowing that the fish were held to a 1 m depth. The mortality in the deep tank is probably more representative of that which could occur in the river at Prescott. At the conclusion of the test it was found that a majority of the survivors in the shallow tanks had definite external gas bubble disease symptoms while all the fish that died in the shallow tanks had "symptoms". There was less than 5% of the fish (dead or alive) in the deep tank that had obvious "symptoms". Gas bubble disease symptoms were not present on any of the control fish. The necessary nitrogen information (gathered over the last 5 years by various agencies) is available to provide a basis on which to predict mortality in the river if fish depth distribution is accurately known.

VERTICAL DISTRIBUTION OF FISH BY USING DEPTH SOUNDING GEAR

In 1972 a Benmar depth sounder was modified for use in a 1.8 x 3 m redwood test tank. Preliminary tests (see 1973 report to Corps of Engineers

Contract #DACW57-73-F-0314) in the tank indicated that the sounding gear would work satisfactorily to help determine depth distribution of fish. After examining the resulting tapes of several 24 hour tests we determined that the fish were generally staying below the midline of the 2.5 m water depth (which would generally enhance their survival from that in a 1 m deep tank). A printer/counter system in conjunction with electronic gates provided a readout of number of fish in each 0.6 m interval of water in the 2.5 m tank. (A paper is being prepared on the technical aspects of the system and will be available early in 1975.) In the test tank, with the captive fish, two transducers were used one at the surface and one on the bottom.

The next logical step was to test this equipment in the river. The two transducer arrangement was modified to a 10 transducer array (figure 6) which could be placed on the bottom of the river at gently sloping beaches. This configuration has been used at two locations near Prescott for a total of 75 hours during day and night. Figure 7 summarizes the results; of 776 fish detected, approximately 72% were detected between .9 to 2.1 m (3 and 7 feet). Many more fish were detected during darkness than daylight. While species could not be differentiated by the sounder a minimum seine effort (2 nets) on the beaches netted 37 juvenile chinook, 21 crappie, 17 perch, 16 stickleback, 9 flounder, 2 peamouth chum and a whitefish. This indicates that the "sounder" results can be approximately quantified for species composition with a minimum beach seining effort. We feel that this method of determining vertical fish distribution will prove fruitful and eliminate some of the problems associated with gill netting. A proposal for cooperative funding to continue this effort has been prepared and accepted by the Corps.

Figure 6 -- Ten transducer sonic array and recorder.

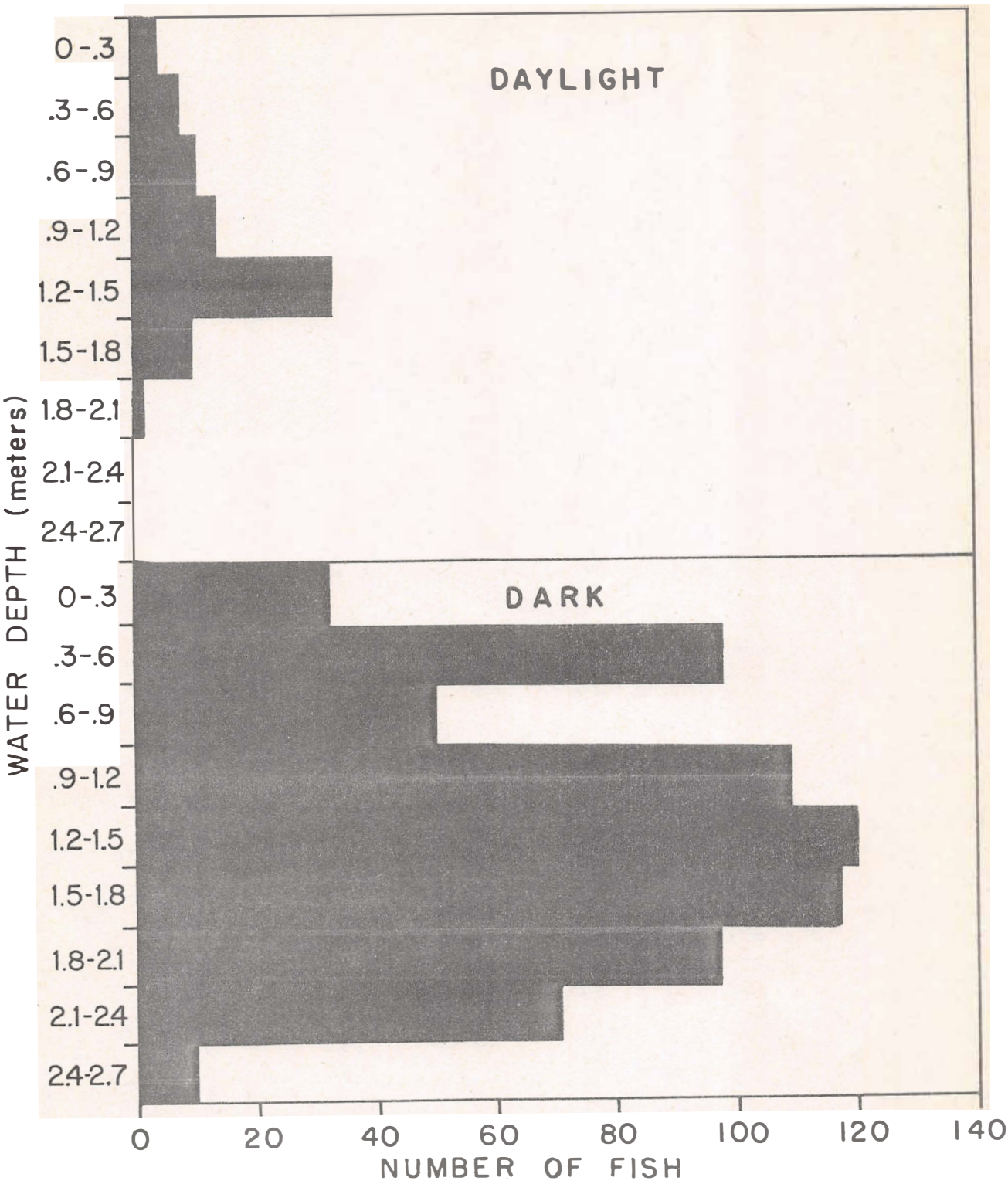


Figure 7 -- Numbers of fish detected (at .3 m intervals) by sonic gear during 75 hours of operation at Columbia River beaches near Prescott, Oregon.

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Appendix A -- Parameters monitored in Columbia River (Oregon side) throughout test period.

PHYSICAL AND CHEMICAL PARAMETERS

te	Temp ture °C	pH	Alka inity	NH_3	Turbidity JTU	Conductivity umho/cm	CO_2 mg/1	O_2 mg/1	O_2 Percent Saturation	N_2 ml/1	N_2 Percent Saturation
1	10.8	7.65		.04				12.92	116.8	17.45	119.2
2	10.7		56		28	125	1.23	12.72	114.7	17.02	116.0
3	10.8	7.75						12.76	115.4	17.27	117.9
5	11.5							12.83	117.8	17.57	121.9
6	12.0	7.55						12.63	117.4	16.94	119.3
7	12.2							12.55	116.5	17.00	119.6
8	12.4	7.65		.03				12.38	115.1	16.79	118.6
9	12.4		50		28	108	.95	12.36	115.8	17.08	120.7
10	12.2	7.60						12.36	115.4	17.03	119.8
13	12.4	7.60						11.89	111.4	16.26	114.9
15	11.8	7.65						11.78	109.0	16.30	114.1
16	11.3		48		28	93	.96				
17	11.4	7.65									
20	11.3	7.65						12.52	114.4	17.60	121.7
22		7.65		.03				12.37	113.9	17.38	120.8
23	11.7	7.60	43		30	100	1.32	12.39	114.3	17.15	119.4
24	11.6	7.62						12.30	113.3	17.51	121.7
26	12.5							12.18	114.5	16.93	119.9
28	13.2							12.30	117.4	17.06	122.6
29	13.2	7.65						12.02	114.7	17.14	123.2
30	13.2	7.65	47		17	100	.98	11.98	114.3	16.93	121.6
31	13.5	7.70		.10				12.08	116.0	16.59	119.9

Appendix A -- Continued

PHYSICAL AND CHEMICAL PARAMETERS

Date	Temperature °C	pH	Alkalinity	NH_3	Turbidity JTU	Conductivity umho/cm	CO_2 mg/l	O_2 mg/l	O_2 Percent Saturation	N_2 ml/l	N_2 Percent Saturation
June											
2	14.2							11.99	117.6	17.02	125.3
3	14.3	7.70						11.78	115.3	16.69	122.0
4	14.0							11.65	113.2	16.54	120.7
5	14.2	7.66		.08				11.52	112.0	16.20	118.2
	13.8	7.65	42		18	95	.80	11.56	111.8	16.14	117.4
7	13.8	7.70						11.80	114.1	16.56	120.5
8	13.4							11.18	107.2	16.23	117.0
9	13.4							11.21	107.5	16.17	116.5
10	13.9	7.65						12.24	118.7	16.67	121.4
11	13.9	7.75	40	.08	22	85	.70	11.86	115.0	16.90	123.1
12	14.1							11.86	115.5	16.46	120.4
13	14.5							11.88	116.7	16.48	121.6
14	14.7							11.70	115.5	16.50	122.1
16	15.1							11.50	114.4	16.60	123.8
17	15.2							11.49	114.7	16.24	121.5
18	15.6							11.77	118.4	16.34	123.0
19	15.8							11.80	119.2	16.88	127.7
20	16.2	7.55	39				.96	11.32	115.4	16.42	125.3
21	16.0							11.62	118.0	16.44	124.9
22	16.0							11.59	117.7	16.56	125.9
23	16.0							11.46	116.3	16.57	125.9
24	15.6							11.42	114.9	16.48	124.5
Ave.	13.4	7.65	46	.06	24	101	.99	11.99	114.9	16.77	121.0

Appendix B -- Tabulation of mortality and parameters monitored in shallow control tank (gas equilibrated - 1 m water depth) throughout test period.

	PHYSICAL AND CHEMICAL PARAMETERS											MORTALITY DATA			
Date	Temperature °C	pH	Alkalinity	NH_3	Turbidity JTU	Conductivity umho/cm	CO_2 mg/l	O_2 mg/l	O_2 Percent Saturation	N_2 ml/l	N_2 Percent Saturation	Mortality	Number Dead with Symptoms	Remaining Total	Percent Acc. Mortality
May															
1	11.6	7.40		.05				8.4	77.3	15.0	104.2				
2	10.7		58		28	135	2.08								
3	10.8	7.40						8.78	79.4	14.59	99.6				
6	11.8	7.35						8.94	82.7	14.28	99.6				
8	12.2	7.35		.10				8.30	77.5	14.18	99.8				
9	12.0		52		28	123	2.10								
10	12.0	7.30						8.31	77.2	14.34	100.6				
13	12.0	7.25						8.30	77.1	14.15	99.1				
15	11.6	7.89		.17				7.89	72.7	14.2	98.6				
16	11.4		46		18	102	2.22								
17	11.4	7.25					2.28								
20	11.7	7.26						9.78	90.2	15.13	105.4				
22	11.7	7.40		.10				9.56	88.2	15.21	105.9				
23	12.1	7.25	43		20	98	1.74								
24	12.0	7.22						9.43	87.6	14.97	104.9				
28	13.0							8.84	84.0	14.36	102.7				
29	13.0	7.38						8.60	81.7	14.56	104.1				
30	13.2	7.20	52		17	110	2.38								
31	13.2	7.20		.07				8.08	77.1	14.52	104.3				
June															
3	14.3	7.10						6.95	68.0	14.33	105.0				
5	14.2	7.22						7.80	76.1	13.7	100.4				

Appendix B -- Continued

	PHYSICAL AND CHEMICAL PARAMETERS											MORTALITY DATA			
Date	Temperature °C	pH	Alkalinity	NH_3	Turbidity JTU	Conductivity umho/cm	CO_2 mg/l	O_2 mg/l	O_2 Percent Saturation	N_2 ml/l	N_2 Percent Saturation	Mortality	Number Dead with Symptoms	Remaining Total	Percent Acc. Mortality
June															
7	14.0	7.25						7.90	76.8	14.42	105.3				
10	14.2	7.22													
11	14.2	7.15	41	.06	23	89	2.20	7.45	72.7	14.48	106.2				
13	14.6							7.00	68.9	14.24	105.3				
17	15.5							6.44	64.7	13.6	102.3	1		49	2
18												3		46	8
19	15.8			.06				6.60	66.7	13.44	101.7				
20	16.0	7.10	41		27	87	2.28								
24	16.0	7.10	41	.06	27	87	2.28	6.60	66.7	13.44	101.7				
Ave.	13.0	7.29	47	.08	24	104	2.17	8.10	76.8	14.30	102.7	Tot. 4			

Appendix C -- Tabulation of mortality and parameters monitored in shallow test tank (river conditions - 1 m water depth) throughout test period.

	PHYSICAL AND CHEMICAL PARAMETERS											MORTALITY DATA			
Date	Temperature °C	pH	Alkalinity	NH_3	Turbidity JTU	Conductivity umho/cm	CO_2 mg/l	O_2 mg/l	O_2 Percent Saturation	N_2 ml/l	N_2 Percent Saturation	Mortality	Number Dead with Symptoms	Remaining Total	Percent Acc. Mortality
May															
1	10.8	7.60		.05				12.4	112.1	17.3	118.2				
2	10.8		58		28	135	1.54								
3	10.8	7.60						12.1	109.4	17.4	118.8	1	1	47	
6	12.1	7.55						11.9	110.8	16.9	118.7				
8	12.3	7.60		.05				11.8	110.4	16.8	118.5	1	1	46	4
9	12.4		52		28	118	1.25								
10	12.2	7.50						11.5	107.4	16.8	118.2	1	1	45	6
13	12.5	7.53						11.3	106.2	16.1	114.0				
14												1	1	44	8
15	11.8	7.55		.03				11.1	102.7	16.0	111.6				
16	11.4		46		25	105	1.21								
17	11.4	7.45													
20	11.3	7.50						11.6	106.0	17.1	118.1				
22	11.6	7.70		.04				11.8	108.7	17.3	120.2	1	1	43	10
23	11.6	7.50	46		30	99	1.46								
24	11.6	7.50						11.8	108.7	17.4	120.9				
28	13.2							11.4	108.8	17.0	122.1				
29	13.2	7.62						11.2	106.9	16.8	120.7				
30	13.2	7.60	48		26	110	1.10								
	13.5	7.60		.07				11.2	107.6	16.4	118.5				

Appendix C -- Continued

	PHYSICAL AND CHEMICAL PARAMETERS											MORTALITY DATA			
Date	Temperature °C	pH	Alkalinity	NH_3	Turbidity JTU	Conductivity umho/cm	O_2 mg/l	O_2 mg/l	O_2 Percent Saturation	N_2 ml/l	N_2 Percent Saturation	Mortality	Number Dead with Symptoms	Remaining Total	Percent Acc. Mortality
June															
3	14.4	7.55						11.0	107.8	16.3	119.9				
5	14.2	7.59						10.7	104.4	16.1	118.0				
6	13.8	7.58	41		18	105	1.08								
7	13.9	7.55						10.9	105.4	16.4	119.4				
10	13.6	7.50													
11	13.8	7.55	39	.05	20	90	1.07	11.0	106.4	16.9	122.9	2	2	41	15
13	14.4							11.3	110.8	16.6	122.1	1	1	40	17
14												1	1	39	19
17	15.3							10.8	108.0	16.0	119.9	6	6	33	31
18												1	1	32	33
19	15.9							11.6	117.4	17.2	130.4	4	4	28	42
Ave.	13.3	7.56	45	.05	25	109	1.24	11.4	108.3	16.7	119.6 Tot.	20	20	28	42

Appendix D -- Tabulation of mortality and parameters monitored in deep test tank (river conditions - 2.5 m water depth) throughout test period.

	PHYSICAL AND CHEMICAL PARAMETERS											MORTALITY DATA			
Date	Temp a e °C	pH	Alkalinity	NH_3	Turbidity JTU	Conductivity umho/cm	CO_2 mg/1	O_2 mg/1	O_2 Percent Saturation	N_2 ml/1	N_2 Percent Saturation	Mortality	Number Dead with Symptoms	Remaining Total	Percent Ac . Mortality
May															
1	10.8	7.60		.02				12.0	108.5	17.1	116.8				
2	10.8		56		28	135	1.28								
3	10.8	7.60						12.1	109.4	17.5	119.5	1		47	2
6	12.1	7.55						11.8	109.9	16.9	118.7				
8	12.3	7.55		.05				11.7	109.4	16.8	118.5				
9	12.4		52		28	118	1.28								
10	12.2	7.55						11.5	107.4	16.8	118.2				
13	12.5	7.45						11.1	104.3	15.9	112.6				
15	11.8	7.45		.05				10.9	100.8	16.0	111.6				
16	11.4		44		25	100	1.25								
17	11.4	7.45													
20	11.3	7.45						11.6	106.0	17.2	118.8				
22	11.6	7.48		.05				11.7	107.7	17.0	118.1				
23	11.6	7.35	44		28	98	1.59								
24	11.6	7.42						11.5	105.9	17.5	121.6				
28	13.2							11.4	108.8	16.9	121.4				
29	13.2	7.55						11.2	106.9	16.75	120.3				
30	13.2	7.60	48		26	105	1.20								
31	13.5	7.60		.04				11.2	107.6	16.4	118.5				
June															
3	14.4	7.55						11.1	108.8	16.6	122.1				
5	14.2	7.56						10.5	102.4	16.1	118.0	1		46	4

Appendix D -- Continued

	PHYSICAL AND CHEMICAL PARAMETERS												MORTALITY DATA			
Da e	Temp ature °C	pH	Alkalinity	NH_3	Turbidity JTU	Conductivity umho/cm	CO_2 mg/1	O_2 mg/1	O_2 Percent Saturation	N_2 ml/1	N_2 Percent Saturation		Mortality	Number Dead with Symptoms	Remaining Total	Percent Ac . Mortality
June																
6	13.8	7.55	44		18	102	1.17									
7	13.9	7.55						10.9	105.4	16.2	118.0					
10	13.6	7.50														
11	13.8	7.48	40	.10	20	89	1.08	10.6	102.5	16.8	122.2					
12													2		44	8
13	14.5							11.0	108.1	16.7	123.2					
14													1		43	10
16													1		42	13
17	15.4							10.5	105.2	15.9	119.4		3	1	39	19
18													4		35	27
19	15.9							11.1	112.3	17.0	128.9					
Ave.	12.8	7.52	47	.05	25	107	1.26	11.3	106.9	16.7	119.3	Tot.	12	1	35	27

Appendix E -- Tabulation of mortality and parameters monitored in shallow control tank (gas equilibrated - 1 m water depth) throughout test period.

	PHYSICAL AND CHEMICAL PARAMETERS											MORTALITY DATA							
												Chinook				Steelhead			
Date	Temperature °C	pH	Alkalinity	NH_3	Turbidity JTU	Conductivity umho/cm	CO_2 mg/l	O_2 mg/l	O_2 Percent Saturation	N_2 ml/l	N_2 Percent Saturation	Mortality Number Dead with Symptoms	Remaining	Total	Percent Acc. Mort lity	Mortal Number Dead with Symptoms	Remaining	Total	Perc t Acc. Morta ity
May																			
1	10.8	7.65		.10				10.8	97.6	15.45	105.5								
2	10.8		56		28	132	1.03												
3	10.8	7.70						11.0	99.5	15.0	102.5								
6	12.1	7.65						10.5	97.8	14.5	101.8								
8	12.3	7.65		.07				10.4	97.3	14.7	103.7								
9	12.4		50		28	115	1.03												
10	12.2	7.60						10.2	95.2	14.6	102.7								
13	12.5	7.55						10.4	97.7	14.3	101.3								
15	11.8	7.60		.10				10.4	96.2	14.3	99.8								
16	11.4		46		25	102	1.03												
17	11.4	7.55																	
20	11.3	7.51						10.8	98.7	15.3	105.7								
22	11.6	7.48		.10				10.5	99.7	15.1	104.9								
23	11.6	7.55	41		27	96	1.38												
24	11.6	7.50						10.3	94.8	15.0	104.2								
28	13.2							9.85	94.0	14.2	102.0								
29	13.2	7.60						10.1	96.4	14.6	104.9								
30	13.2	7.55	47		29	110	1.10												
31	13.5	7.55		.10				10.0	96.1	14.6	105.5								
June																			
3	14.4	7.52						10.0	98.0	14.7	108.2								
5	14.2	7.54						9.1	88.8	13.7	100.4								
6	13.8	7.60	44		18	105	.99												

Appendix E -- Continued

	PHYSICAL AND CHEMICAL PARAMETERS											MORTALITY DATA						
												Chinook				Steelhead		
Date	Temperature °C	pH	Alkalinity	NH_3	Turbidity JTU	Conductivity umho/cm	CO_2 mg/l	O_2 mg/l	O_2 Percent Saturation	N_2 ml/l	N_2 Percent Saturation		Mortality Number Dead with Symptoms	Remaining Total	Percent Acc. Mortality	Mortality Number Dead with Symptoms	Remaining Total	Percent Acc. Mortality
June																		
7	13.9	7.58						10.3	99.9	14.5	105.6							
10	13.6	7.50																
11	13.8	7.45	40	.12	20	88	1.09	9.7	93.8	15.0	109.1							
13	14.4							9.3	91.2	14.2	104.5							
17	15.3							8.8	88.0	13.2	98.9					2	74	3
19	15.9							9.6	97.2	14.4	109.2							
20	16.2	7.48	39	.10	26	82	1.08											
21	16.0							8.46	85.9	13.55	103.0					1	73	4
22																2	71	7
24	15.8							7.97	80.5	13.57	102.3					1	70	8
Ave.	13.1	7.56	45	.10	25	104	1.09	9.93	94.7	14.5	103.9	Tot.				6	70	8

Appendix F -- Tabulation of mortality and parameters monitored in shallow test tank (river conditions - 1 m water depth) throughout test period.

	PHYSICAL AND CHEMICAL PARAMETERS											MORTALITY DATA							
												Chinook				Steelhead			
Date May	Temperature °C	pH	Alkalinity	NH_3	Turbidity JTU	Conductivity umho/cm	CO_2 mg/1	O_2 mg/1	O_2 Percent Saturation	N_2 ml/1	N_2 Percent Saturation	Mortality Number Dead	with Symptoms Remaining	Total	Percent Acc. Mortality	Mortality Number Dead	with Symptoms Remaining	Total	Percent Ac Mortality
1	10.8	7.60						12.0	108.5	17.1	116.8								
2	10.8		56		28	135	1.38												
3	10.8	7.60						11.9	107.6	17.2	117.5								
6	12.1	7.45						11.8	109.9	16.7	117.3	11	10	86	11	2	2	88	2
7												6	6	80	18	11	11	77	14
8	12.3	7.55		.05				11.8	110.4	16.9	119.2	6	6	74	24	13	13	64	29
9	12.4		50		28	115	1.17					5	5	69	29	10	10	54	40
10	12.2	7.55						11.5	107.4	16.9	118.2	6	6	63	35	2	2	52	42
11												2	2	61	37				
13	12.5	7.45						11.1	104.3	16.2	114.7								
15	11.8	7.45		.06				10.9	100.8	16.1	112.1								
16	11.4		46		25	102	1.28												
17	11.4	7.55																	
20	11.3	7.48						11.5	105.1	17.1	118.1	1	1	60	38	1	1	51	43
22	11.6			.08				11.7	107.7	17.3	120.2								
23	11.6	7.40	41		25	98	1.62									1	1	50	44
24	11.6	7.49						11.6	106.8	17.3	120.2								
28	13.2							11.1	105.9	16.9	121.4								
29	13.2	7.57						11.2	106.9	16.9	121.4								
30	13.2	7.55	47		28	110	1.12												
31	13.5	7.55		.06				11.2	107.6	16.5	119.2								

Appendix F -- Continued

	PHYSICAL AND CHEMICAL PARAMETERS											MORTALITY DATA							
												Chinook				Steelhead			
Date	Temperature	pH	Alkalinity	NH_3	Turbidity JTU	Conductivity umho/cm	CO_2 mg/l	O_2 mg/l	O_2 Percent Saturation	N_2 ml/l	N_2 Percent Saturation	Mortality Number Dead with Symptoms	Remaining	Total	Percent Acc. Mortality	Mortality Number Dead with Symptoms	Remaining	Total	Percent Acc. Mortality
June																			
3	14.4	7.50						10.9	106.9	16.3	119.2					2	2	48	47
5	14.2	7.55						10.7	104.4	16.0	117.3								
6	13.8	7.45	44		18	102	1.13												
7	13.9	7.55						11.0	106.4	16.3	118.7								
10	13.6	7.50										2	2	58	40	1	1	47	48
11	13.8		40	.05	21	90	1.06	10.6	102.5	16.8	122.2	3	3	55	43				
12																3	3	44	51
13	14.4							11.1	108.8	16.6	122.1	2	2	53	45	9	9	35	61
14												3	3	50	49	3	3	32	64
15												5	5	45	54	1	1	31	66
16												1	1	44	55	1	1	30	67
17	15.3							10.7	107.0	16.1	120.6								
19	15.9							11.3	114.4	17.0	128.9	7	7	37	62	5	5	25	72
20	16.2	7.48	40	.06	28	85	1.21					6	6	31	68	3	3	22	76
21	16.0							10.9	111.0	16.3	124.5	3	3	28	71				
22												4	4	24	75	2	2	20	78
23																1	1	19	79
24	15.8							10.5	106.0	15.7	118.8	5	5	19	80	1	1	18	80
Ave.	13.4	7.50	45	.06	25	102	1.22	11.2	107.2	16.6	119.8	Tot.78	77	19	80	72	72	18	80

Appendix G -- Tabulation of mortality and parameters monitored in deep test tank (river conditions - 2.5 m water depth) throughout test period.

	PHYSICAL AND CHEMICAL PARAMETERS											MORTALITY DATA					
												Chinook			Steelhead		
Date	Temperature °C	pH	Alkalinity	NH_3	Turbidity JTU	Conductivity umho/cm	CO_2 mg/l	O_2 mg/l	O_2 Percent Saturation	N_2 ml/l	N_2 Percent Saturation	Mortality Number Dead with Symptoms Remaining Total		Percent Acc. Mortality	Mortality Number Dead with Symptoms Remaining Total		Percent Acc. Mortality
May																	
1	10.8	7.60		.09				12.3	111.2	17.4	118.9						
2	10.8		56		28	130	1.31										
3	10.8	7.55						12.0	108.5	17.1	116.8						
6	12.1	7.45						11.6	108.0	16.7	117.3						
7												1	111	.9	1	79	1
8	12.3	7.55		.06				11.6	108.5	16.7	117.8						
9	12.4		52		32	115	1.27										
10	12.2	7.55						11.5	107.4	16.8	118.2						
13	12.5	7.50						11.1	104.3	16.3	115.4						
15	11.8	7.53		.06				11.0	101.8	16.1	112.4						
16	11.4		46		25	97	1.26										
17	11.4	7.53															
20	11.3	7.48						11.5	105.1	17.1	118.1						
22	11.6	7.45		.04				11.7	107.7	17.3	120.2						
23	11.6	7.45	43		28	99	1.60										
24	11.6	7.48						11.6	106.8	17.5	121.6						
28	13.2							11.4	108.8	17.1	122.8						
29	13.2	7.55						11.1	105.9	16.75	120.3						
30	13.2	7.48	49		24	105	1.35										
31	13.5	7.50		.05				11.2	107.6	16.5	119.2						
June																	
3	14.4	7.48						10.9	106.9	16.5	121.4						
5	14.2	7.52						10.5	102.4	16.2	118.8						

Appendix G -- Continued

	PHYSICAL AND CHEMICAL PARAMETERS											MORTALITY DATA						
												Chinook				Steelhead		
Date	Temperature °C	pH	Alkalinity	NH_3	Turbidity JTU	Conductivity umho/cm	CO_2 mg/1	O_2 mg/1	O_2 Percent Saturation	N_2 ml/1	N_2 Percent Saturation	Mortality Number Dead with Symptoms Remaining Total		Percent Acc. Mortality		Mortality Number Dead with Symptoms Remaining Total		Percen Acc. Mortal
June																		
6	13.8	7.45	44		18	100	1:18											
7	13.9	7.55						10.9	105.4	16.2	118.0							
10	13.6	7.55																
11	13.8	7.45	40	.06	22	88	1.02	10.6	102.5	16.9	122.9							
13	14.5							11.0	108.1	16.6	122.4							
15												1	1	110	2			
17	15.4							10.7	107.2	16.2	121.6							
19	15.9			.05				11.1	112.3	17.1	129.6	1		109	3			
20	16.4	7.45	42		29	86	1.40					4	2	105	6			
21	16.0							10.5	106.6	16.0	122.0	3		102	9	2	77	4
24	15.8							10.3	104.0	15.9	120.3	2	1	100	11	2	75	6
Ave.	13.6	7.50	46	.06	25	100	1.28	11.1	106.7	16.6	121.0	Tot12	4	100	11	5	75	6