FINAL REPORT

The Effect of Spillway Flow Deflectors At Bonneville Dam on Total Gas Supersaturation and Survival of Juvenile Salmon

by

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and

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INTRODUCTION

Supersaturation of dissolved gases in water of the Columbia River caused by spillway discharges was documented in the late 1960's as a problem to migrating salmon and steelhead trout. The Army Corps of Engineers funded several studies to determine ways of decreasing the amount of gas forced into solution as water passed through the dam. A spillway design termed "flip bucket" was examined for effect on dissolved gas at several discharges and found to be significantly better than the typical spillway design used on the Columbia River. Engineers of the Northwest Pacific Division utilized this concept and designed a flow deflector that could be attached to the standard spillbays. In theory, water passing over a spillway with deflector would move straight down stream and be deflected over the top of the stilling basin structures thus hydraulic pressures would be decreased and less entrained air would be forced into solution.

A prototype flow deflector was placed at Bonneville Dam in 1971 and tested in 72 and 73 to determine whether dissolved gas concentrations would be reduced. These tests indicated a substantial reduction in the amount of supersaturation produced in comparison to standard spillbays. As a result the Corps designed and built three additional deflectors at Bonneville to ascertain effects of multiple flow deflectors on; (1) dissolved gas content of discharges, and (2) anadromous fish passage through and around the spill discharge.

This report describes the (1) determination of dissolved gases at various flows through standard and modified (deflector) spillways and (2) success of passage of juvenile chinook salmon through a standard and a modified spillway. This research was completed in calendar year 1974.

Effect of Spillway Deflectors on Total Dissolved Gas Supersaturation

Procedure

Tests for gas content were made below spill deflectors of bays 13, 14 and 15 on March 26, 28 and 29; April 26; and May 15. Flow characteristics were observed from a spillway model at the Bonneville Hydraulics Laboratory. A spill pattern utilizing 3 deflectors and various gate openings on all 18 bays was given consideration in developing the sampling plan. From the model observations tests were made at predetermined spill volumes and tailwater elevations. Water flows and tailwater heights were selected to cover those found typically during periods of fish migration (freshet condition. Bays 4, 5 and 6 or 2, 3 and 4 (Standard spillway bays) were used as the control for comparisons with test results and were operated concurrently with and identically to the deflector bays.

Sampling procedure similar to that used in previous tests included the following. Near surface waters were collected from a boat in conjunction with samples taken from the shore at predetermined sites which appeared to have either test or control water. Fifteen to sixty minutes of flushing at the desired flow preceded collection of a series of 3 to 8 samples over 15 to 40 minutes depending upon discharge rate. Volumes of flows tested were about 6.7, 9.7, 13, 17 and 20 kcfs per bay at tailwater elevations of 5.18, 7.31, 7.62 and 8.53 meters. Analysis of dissolved gas content was performed within 24 hours using standard techniques.

Gas Saturation Levels

The following analysis is based upon the assumption that data were not substantially affected by mixing of standard spillway water and deflector water or by waters passed previously at different flow volumes. Observations of the

model indicated there was a certain amount of mixing under all circumstances. We believe that contamination of water in the deflector bays from water in the bays without spillway deflectors was minimal. During the full scale testing sequence, no mixing could be detected and samples collected seemed representative of the test discharges. Any discrepancy due to mixing would have tended to increase absolute gas content of the deflector water samples but would not have affected standard spillbay samples (determined by observation of the model).

Dissolved gas content of the forebay water was nearly 110% throughout all tests and temperatures ranged from 6.9 to 11.7°C (slightly lower than the usual range recorded during spring migration of anadromous fish because of cool weather). Gas concentrations of water passing over the spillway deflector were 6 to 12% less than those in water passing through the control bays (Fig. 1). At a spill volume normal for tailwater elevation 5.18 meters (about 6.7 kcfs/bay through 5 of 16 bays) there was about 117% saturation N_2 + Ar (Ar is present in small quantities and is included with all N_2 values mentioned in the report) in water passing through the deflector bays compared to about 129% N_2 through the control bays; for tailwater of 7.31 to 7.62 meters (about 9.4 kcfs/bay--through all bays) the saturation below deflectors was 123% N_2 while below control bays it was about 130%; at 8.53 meters tailwater (about 13.8 kcfs/bay--through all bays) the supersaturation was about 123% compared to an estimated 132% for control. Raw data from the 4 days of testing are presented in Appendix Table 1.

If we assume that a full complement of deflectors will be placed in the spillway at Bonneville and these gas analysis data from our studies are representative of that condition, then a total river flow of about 300 kcfs (about 7.62 meter tailwater depth) and a forebay saturation of 110% (proposed

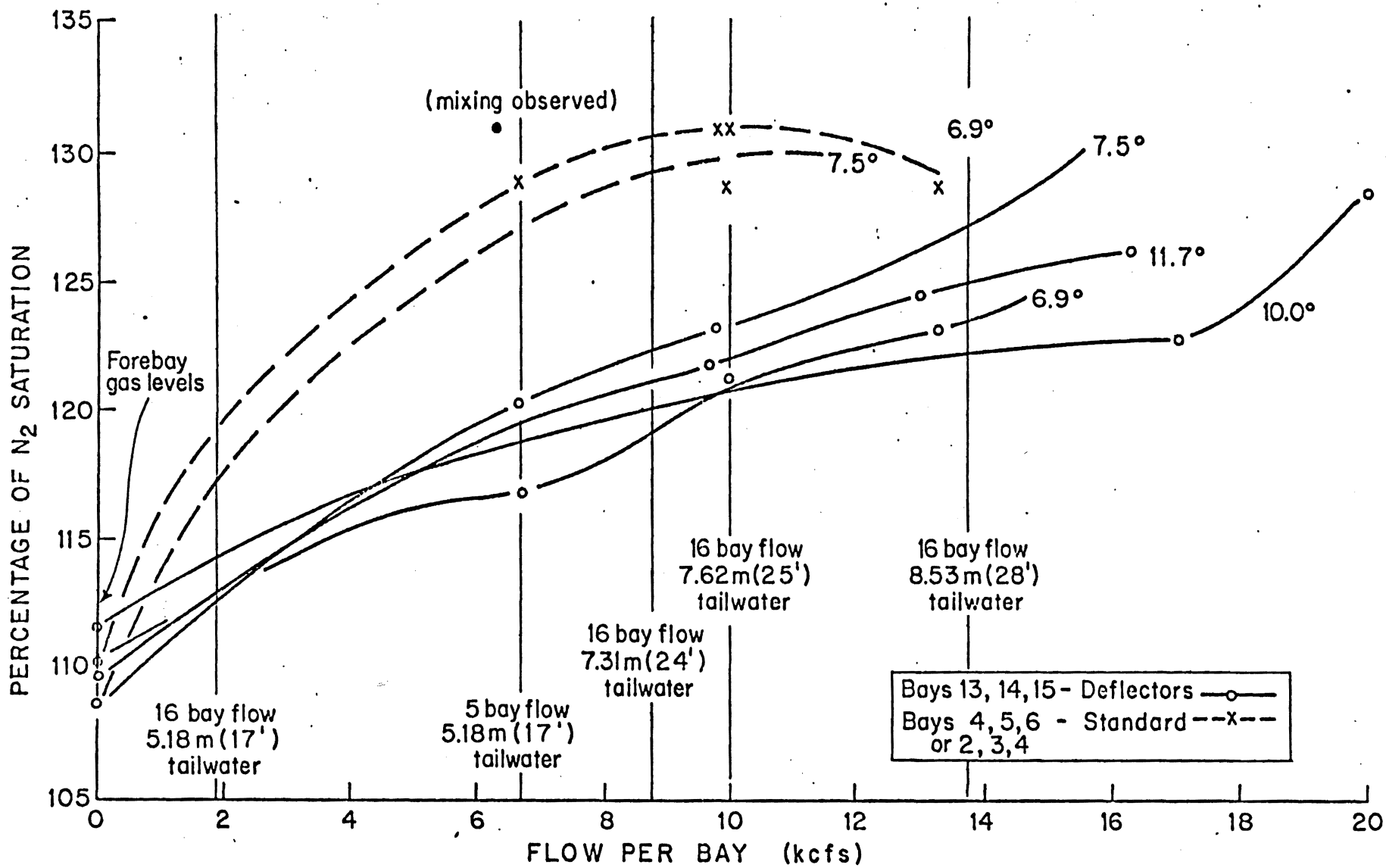

Figure 1. Dissolved gas concentrations at various temperatures (centrigrade) and spill discharges through multiple spill deflector and control bays at tailwater elevations of 5.18, 7.31, 7.47, 7.62, and 8.53 meters.

maximum limit) would produce saturation levels below the spillway of 123%; this would result in a mixed river condition downstream of 116.9%. A spillway operation without deflectors would result in about 130% saturation with a mixed condition of 120.7% or 3.8 higher. A river flow of about 360 kcfs (8.53 m tailwater) with 110% saturation in the forebay would produce a tailrace condition with deflectors of about 123% and a mixed river condition of about 117.9%, whereas the flow over a normal spillway would result in 132% (estimated saturation from NMFS dissolved gas data for the Columbia River 1966-74) and 123.4% mixed condition downstream (5.5% higher). NMFS dissolved gas data indicates spillway and powerhouse discharges from Bonneville are not completely mixed until they reach Vancouver, WA (Blahm personal communication)[1/]. We conclude that the decrease in supersaturation indicated by extrapolation of these data to a complete spillway modification at Bonneville would be of major importance in increasing the survival of anadromous fish species in that area. Lower gas levels could significantly improve survival of juvenile migrants. Bioassay data from tests in deep and shallow tanks indicate that small increases in saturation over 120% result in logrithmic increase in mortality rate of both juvenile and adult fish tested. Thus, small decreases in saturation from use of deflectors after concentrations exceed 120% should result in substantial increases in survival. Reductions of 6-12% in saturation are highly significant when concentrations exceed 120%.

Effect of Spillway Deflectors on Juvenile Salmon

Procedure

Survival of juvenile samon through modified and standard spillways was examined in July and early August of 1974. Marked fish were released for

1/ Theodore Blahm 1964. Fishery Biologist, National Marine Fisheries Service Prescott field station, Prescott, WA.

passage over the spillway (test) and below the dam (control). A small group of fish was released about 127 km downstream to obtain gear efficiency estimates. Recovery of fish was made with a beach seine at Jones Beach on the Oregon shore near Puget Island (Fig. 2) about 160 kilometers downstream.

Juvenile fall chinook salmon used in these experiments were obtained from Little White Salmon National Fish Hatchery. In preparation for release, three groups of about 150,000 juvenile fall chinook salmon were marked distinctively according to the release point by freeze branding with liquid nitrogen (Mighell, 1969) one month prior to release. This species was selected because they represent the largest group of salmonids passing over Bonneville Dam and are also available to recapture by beach seine, a proven and relatively inexpensive sampling tool (Sims & Johnsen, 1974). Prior to marking, fish from different ponds were mixed to insure a similar size distribution in all marked groups; a sub-sample from each mark lot was examined for retention of mark, and measured to determine mean size. All fish were transported from the hatchery to release sites in tank trucks described by Ebel (1970).

Release of test and control fish (Table 1) was made on July 10th during an average spillway flow of 180.5 kcfs and total discharge of 316 kcfs. Test releases were made simultaneously through 10.16 cm hoses placed about 30.48 cm above the spillgate opening in bay 11 (standard spillway) and 14 (modified spillway). Introduction of the fish into this high velocity flow insured immediate passage through the spillway. Spillgates No. 10-15 were identically set at 4 dogs (a 4 dog opening equals 2.07m) to pass approximately 13 kcfs in each bay for more than one hour prior to and after release. Control fish were released about 1.6 km below the spillway from the Washington shore.

Fish used to establish gear efficiency were released at Rainier, Oregon, July 12th at dusk, and was timed so that their arrival at the recovery site would coincide with the expected arrival of fish released at Bonneville Dam further upstream.

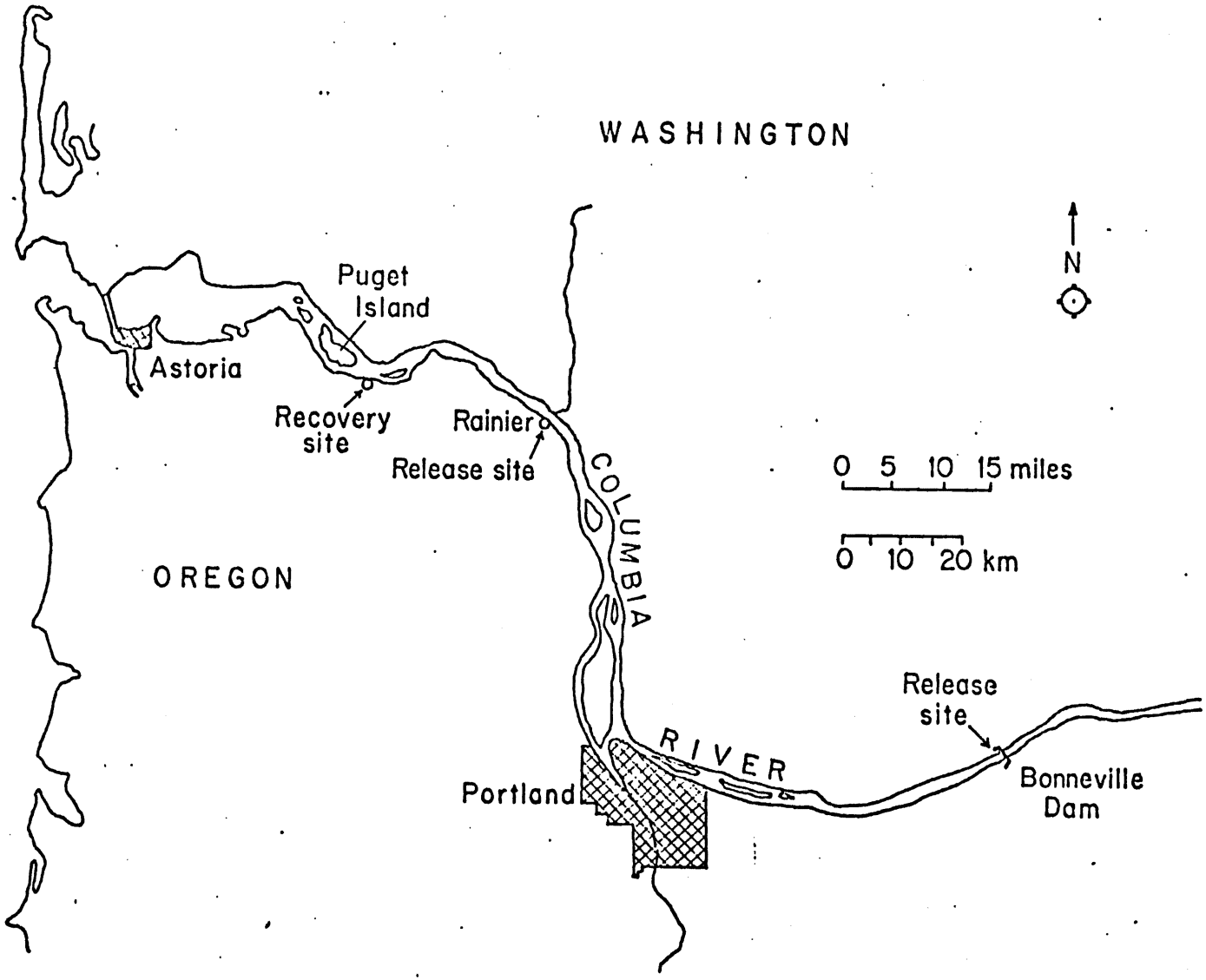

Figure 2. Release and recovery sites located on lower Columbia River to examine the survival of juvenile fall chinook passing over spillbays with deflectors and spillbays without deflectors.

Table 1.--Numbers of branded fall chinook salmon released into the Columbia River at Bonneville Dam and Rainier, Oregon.

Release Site	Date Released	Brand[1/]	No. Fish Released[2/]
Bonneville Dam			
Control	7/10	LA T	134,669
Modified Spillway	7/10	LA U	151,869
Standard Spillway	7/10	RA U	144,915
Rainier			
Gear Efficiency	7/12	LA	49,695

1/ LA is left anterior area on fish; RA is right anterior.

2/ Number adjusted for handling mortality and estimated delayed mortality.

Survival of Juvenile Chinook

The number of fish recovered by beach seine were within the range normally expected and the rate of movement was normal for fish of this size (average 90mm). Rate of movement to the point in time when 50% of fish were recovered (Appendix Table 2) was 27 km/day (nearly maximum for this size fish). The timing of the arrival of the marked groups at our sampling site was coincident with high catches of other fall chinook migrants, further indicating that the movement was normal and similar to other stocks of fall chinook.

Measurements of mark loss prior to release of the test and control groups indicated that it was negligible for all groups. Mean fork lengths of fish from each group released was 89-92 mm and the pattern of recovery in the beach seine indicates mixing of all marked groups (Fig. 3). First recoveries for each group released were made the same day at the seine site and cumulative recovery percentages were nearly identical throughout the recovery period. A total of 600 fish were recovered from nearly 431,500 juvenile fall chinook released at Bonneville Dam. Recoveries per group are listed below with daily recaptures listed in Appendix Table 2.

Relative survival of groups released at Bonneville are compared to the group released at Rainier, Oregon. Assuming 100% survival of the Rainier release, control and test recoveries were:

Release Group	Release Site	Recovery No.	Recovery %	Estimated Relative Survival %
Control	Bonneville Dam	226	0.167	45.6
Spill Deflector	" "	221	0.145	39.6
Standard Spillway	" "	233	0.160	43.7
Gear Efficiency	Rainier, Oregon	182	0.366	100.0

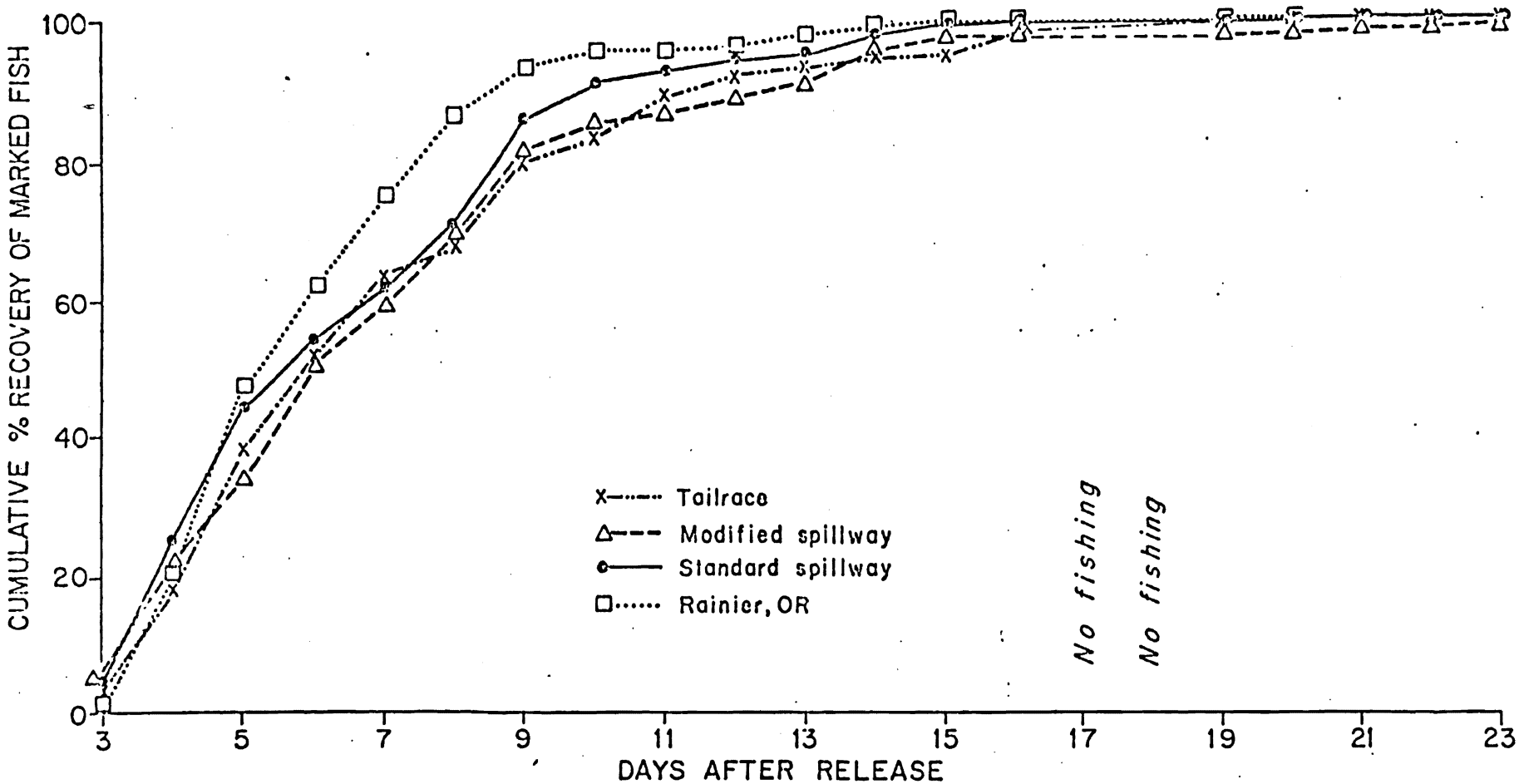

Figure 3. Recovery of marked juvenile fall chinook salmon by beach seine at Jones Beach after release at and below Bonneville Dam to examine effect of modified spillway on survival.

Little difference in survival was found between groups released at the dam. Chi-square values of 7.59 with a probability greater than 0.10 (4 d.f.) indicate no significant differences in survival between test groups of fish passing over flow deflector or standard spill or the groups released below the dam. We conclude that spillway deflectors are not detrimental to their survival and believe the effect of complete modification of the spillway at Bonneville Dam (18 bays) will not adversely affect the survival of juvenile fall chinook salmon passing through the spillway.

Literature Cited

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APPENDIX TABLE 1.

NATIONAL MARINE FISHERIES SERVICE COASTAL ZONE AND ESTUARINE STUDIES
BONNEVILLE SPILLWAY DEFLECTOR--DISSOLVED GAS ANALYSIS---COMPENSATED FOR TEMPERATURE AND ALTITUDE

LOCATION	DATE DY	MO	YR	DEPT FT	TEMP C	OXYGEN MG/L	OXYGEN SAT	ATMOSPHERIC NITROGEN ML/L	ATMOSPHERIC NITROGEN SAT	TOTAL PRESSURE MM HG	TOTAL PRESSURE SAT	NO. GATE OPEN	HOURLY FLOW KCFS SPILL	HOURLY FLOW KCFS TOTAL	SAMPLE ELEV FEET
BONNEVILLE FOREBAY SPILL SIDE	26	3	74	40	6.9	12.70	104.7	17.50	109.9	823.7	108.6	0	0.0	0.0	74
BONNEVILLE TAILRACE BAY 13,14,15 DEFLE	26	3	74	0	6.8	14.42	118.4	19.10	119.4	903.7	118.9	3	30.0	170.0	17
BONNEVILLE TAILRACE BAY 13,14,15 DEFLE	26	3	74	0	6.8	14.24	117.0	19.50	121.9	916.2	120.6	3	30.0	170.0	17
BONNEVILLE TAILRACE BAY 13,14,15 DEFLE	26	3	74	0	6.8	14.42	118.4	19.60	122.5	922.2	121.4	3	30.0	170.0	17
BONNEVILLE TAILRACE 1/4 MI DN SPILL SI	26	3	74	0	6.8	14.24	117.0	19.40	121.3	912.5	120.1	3	30.0	170.0	17
BONNEVILLE TAILRACE BAY 13,14,15 DEFLE	26	3	74	0	6.8	14.22	116.7	19.06	119.1	899.4	118.4	3	20.0	160.0	17
BONNEVILLE TAILRACE BAY 13,14,15 DEFLE	26	3	74	0	6.8	13.70	112.5	18.60	116.3	875.9	115.3	3	20.0	160.0	17
BONNEVILLE TAILRACE BAY 13,14,15 DEFLE	26	3	74	0	6.8	13.70	112.5	18.40	115.0	868.4	114.3	3	20.0	160.0	17
BONNEVILLE TAILRACE BAY 13,14,15 DEFLE	26	3	74	0	6.8	14.46	118.7	19.78	124.6	929.3	122.3	3	40.0	180.0	17
BONNEVILLE TAILRACE BAY 13,14,15 DEFLE	26	3	74	0	6.8	14.60	119.9	19.70	123.2	928.2	122.2	3	40.0	160.0	17
BONNEVILLE TAILRACE BAY 13,14,15 DEFLE	26	3	74	0	6.9	14.42	118.7	19.60	122.8	924.3	121.7	3	40.0	180.0	17
BONNEVILLE TAILRACE 1/4 MI DN POWER SI	26	3	74	0	6.8	12.65	103.7	17.70	110.7	828.6	109.0	0	0.0	140.0	17
BONNEVILLE FOREBAY SPILL SIDE	26	3	74	40	7.0	12.81	105.9	17.70	111.4	834.8	110.1	0	0.0	0.0	74
BONNEVILLE TAILRACE BAY 4,5,6	26	3	74	0	6.9	15.67	129.0	20.79	130.3	985.2	129.7	3	30.0	170.0	17
BONNEVILLE TAILRACE BAY 4,5,6	26	3	74	0	6.9	15.67	129.0	20.89	130.9	988.9	130.1	3	30.0	170.0	17
BONNEVILLE TAILRACE BAY 4,5,6	26	3	74	0	6.9	15.67	129.0	20.89	130.9	988.9	130.1	3	30.0	170.0	17
BONNEVILLE TAILRACE 1/4 MI DN SPILL SI	26	3	74	0	6.9	15.50	127.6	20.79	130.3	982.8	129.4	3	30.0	170.0	17
BONNEVILLE TAILRACE BAY 4,5,6	26	3	74	0	6.9	15.40	126.7	20.20	126.6	959.2	126.2	3	20.0	160.0	17
BONNEVILLE TAILRACE BAY 4,5,6	26	3	74	0	7.0	15.67	129.4	20.59	129.4	960.0	129.0	3	20.0	160.0	17
BONNEVILLE TAILRACE BAY 4,5,6	26	3	74	0	6.9	15.85	130.5	20.89	130.9	991.2	130.5	3	20.0	160.0	17
BONNEVILLE TAILRACE BAY 4,5,6	26	3	74	0	6.9	15.42	126.9	20.57	128.9	973.3	128.1	3	40.0	180.0	17
BONNEVILLE TAILRACE BAY 4,5,6	26	3	74	0	6.9	15.50	127.6	20.39	127.8	968.0	127.4	3	40.0	180.0	17
BONNEVILLE TAILRACE BAY 4,5,6	26	3	74	[illegible]	6.9	15.67	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

NATIONAL MARINE FISHERIES SERVICE COASTAL ZONE AND ESTUARINE STUDIES
BONNEVILLE SPILLWAY DEFLECTOR--DISSOLVED GAS ANALYSIS---COMPENSATED FOR TEMPERATURE AND ALTITUDE

LOCATION	DATE DY	MO	YR	DEPT FT	TEMP C	---OXYGEN--- MG/L	SAT	ATMOSPHERIC --NITROGEN-- ML/L	SAT	-TOTAL PRESSURE MM HG	GAS- SAT	NO. GATE OPEN	HOURLY ----KCFS---- SPILL	FLOW TOTAL	SAMPLE ELEV FEET
BONNEVILLE FOREBAY SPILL SIDE	26	3	74	40	7.0	12.74	105.3	17.40	109.5	822.7	108.5	0	0.0	0.0	74
BONNEVILLE FOREBAY SPILL SIDE	28	3	74	40	7.4	12.35	103.1	16.95	107.7	800.1	106.6	0	0.0	0.0	74
BONNEVILLE TAILRACE BAY 18 SOUTH PIER	28	3	74	0	7.4	13.04	108.7	17.82	113.0	850.1	111.9	1/3	20.0	270.0	24
BONNEVILLE TAILRACE BAY 18 SOUTH PIER	28	3	74	0	7.4	13.90	115.9	19.33	122.5	918.0	120.8	1/3	40.0	330.0	24
BONNEVILLE TAILRACE BAY 13,14,15 BEACH	28	3	74	0	7.4	14.36	119.7	19.68	124.8	937.3	123.4	3	40.0	330.0	24
BONNEVILLE TAILRACE BAY 13,14,15 BEACH	28	3	74	0	7.4	14.42	120.2	20.12	127.6	954.6	125.7	3	40.0	330.0	24
BONNEVILLE TAILRACE BAY 13,14,15 BEACH	28	3	74	0	7.4	14.42	120.2	19.57	124.1	934.0	123.0	3	40.0	330.0	24
BONNEVILLE FOREBAY SPILL SIDE	28	3	74	40	7.4	12.49	104.3	17.23	109.4	820.3	108.2	0	0.0	0.0	74
BONNEVILLE TAILRACE BAY 2,3,4	28	3	74	0	7.4	15.16	126.5	20.01	126.9	960.4	126.4	2/3	30.0	300.0	25
BONNEVILLE TAILRACE BAY 2,3,4	28	3	74	0	7.4	14.42	120.2	19.13	121.3	917.5	120.8	2/3	30.0	300.0	25
BONNEVILLE TAILRACE BAY 2,3,4	28	3	74	0	7.4	14.25	118.8	19.02	120.6	911.2	120.0	2/3	30.0	300.0	25
BONNEVILLE TAILRACE BAY 2,3,4 BEACH	28	3	74	0	7.4	14.94	124.5	20.33	128.9	969.6	127.6	3	30.0	300.0	25
BONNEVILLE TAILRACE BAY 2,3,4 BEACH	28	3	74	0	7.4	14.76	123.1	19.79	125.5	946.8	124.6	3	30.0	300.0	25
BONNEVILLE TAILRACE BAY 2,3,4 BEACH	28	3	74	0	7.4	14.59	121.7	20.77	131.7	981.5	129.2	3	30.0	300.0	25
BONNEVILLE TAILRACE BAY 13,14,15 DEFLE	28	3	74	0	7.4	14.76	123.1	19.46	123.4	934.4	123.0	3	30.0	300.0	25
BONNEVILLE TAILRACE BAY 13,14,15 DEFLE	28	3	74	0	7.4	14.60	121.7	19.46	123.4	932.0	122.7	3	30.0	300.0	25
BONNEVILLE FOREBAY SPILL SIDE	28	3	74	40	7.4	12.42	103.7	16.04	107.0	804.9	106.1	0	0.0	0.0	74
BONNEVILLE FOREBAY SPILL SIDE	29	3	74	40	7.6	12.37	103.8	16.99	108.4	813.4	107.3	0	0.0	0.0	74
BONNEVILLE TAILRACE BAY 13,14,15 BEACH	29	3	74	0	7.6	14.25	119.4	19.35	123.3	927.7	122.1	3	30.0	300.0	24
BONNEVILLE TAILRACE BAY 13,14,15 BEACH	29	3	74	0	7.6	14.07	117.9	19.35	123.3	925.5	121.8	3	30.0	300.0	24
BONNEVILLE TAILRACE BAY 13,14,15 BEACH	29	3	74	0	7.5	14.07	117.6	19.46	123.7	927.5	122.1	3	30.0	300.0	24
BONNEVILLE TAILRACE BAY 13,14,15 BEACH	29	3	74	0	7.5	13.73	114.7	18.01	119.5	898.3	118.3	3	20.0	270.0	25
BONNEVILLE TAILRACE BAY 13,14,15 BEACH	29	3	74	0	7.5	13.90	116.2	19.02	120.9	908.0	119.6	3	20.0	270.0	25

NATIONAL MARINE FISHERIES SERVICE COASTAL ZONE AND ESTUARINE STUDIES
BONNEVILLE SPILLWAY DEFLECTOR--DISSOLVED GAS ANALYSIS---COMPENSATED FOR TEMPERATURE AND ALTITUDE

LOCATION	DATE DY	MO	YR	DEPT FT	TEMP C	OXYGEN MG/L	OXYGEN SAT	ATMOSPHERIC NITROGEN ML/L	ATMOSPHERIC NITROGEN SAT	TOTAL GAS PRESSURE MM HG	TOTAL GAS PRESSURE SAT	NO. GATE OPEN	HOURLY FLOW KCFS SPILL	HOURLY FLOW KCFS TOTAL	SAMPLE ELEV FEET
BONNEVILLE TAILRACE BAY 13,14,15 BEACH	29	3	74	0	7.5	13.90	116.2	19.02	120.9	908.8	119.6	3	20.0	270.0	25
BONNEVILLE TAILRACE BAY 13,14,15 BEACH	29	3	74	0	7.5	14.76	123.4	20.55	130.6	977.8	128.7	3	40.0	330.0	24
BONNEVILLE TAILRACE BAY 13,14,15 BEACH	29	3	74	0	7.5	14.76	123.4	20.55	130.6	977.8	128.7	3	40.0	330.0	24
BONNEVILLE TAILRACE BAY 13,14,15 BEACH	29	3	74	0	7.5	14.59	121.9	20.12	127.8	959.1	126.3	3	40.0	330.0	24
BONNEVILLE FOREBAY SPILL SIDE	29	3	74	40	7.5	12.42	103.9	17.28	110.0	823.3	108.6	0	0.0	0.0	74
BONNEVILLE FOREBAY SPILL SIDE	29	3	74	40	7.6	12.52	105.1	17.28	110.2	826.5	109.0	0	0.0	0.0	74
BONNEVILLE TAILRACE BAY 2,3,4 BEACH	29	3	74	0	7.6	14.82	124.1	19.95	127.0	957.7	126.1	3	30.0	300.0	24
BONNEVILLE TAILRACE BAY 2,3,4 BEACH	29	3	74	0	7.6	14.59	122.3	20.88	133.0	990.1	130.3	3	30.0	300.0	24
BONNEVILLE TAILRACE BAY 2,3,4 BEACH	29	3	74	0	7.6	15.11	126.6	20.77	132.3	992.8	130.7	3	30.0	300.0	24
BONNEVILLE FOREBAY SPILL SIDE	26	4	74	50	10.0	12.17	108.2	16.57	111.5	839.2	110.7	0	0.0	0.0	72
BONNEVILLE TAILRACE BAY 13,14,15 BEACH	26	4	74	0	10.1	13.20	118.1	18.21	122.7	921.9	121.4	3	51.0	369.0	27
BONNEVILLE FOREBAY SPILL SIDE	26	4	74	50	10.0	12.17	108.2	16.57	111.5	839.2	110.7	0	0.0	0.0	72
BONNEVILLE TAILRACE BAY 13,14,15 BEACH	26	4	74	0	10.0	13.89	123.3	19.08	128.2	962.8	126.8	3	60.0	379.0	28
BONNEVILLE TAILRACE BAY 13,14,15 BEACH	26	4	74	0	10.0	14.01	124.4	19.23	129.2	970.6	127.8	3	60.0	379.0	28
BONNEVILLE TAILRACE BAY 13,14,15 BEACH	26	4	74	0	10.0	13.82	122.7	18.92	127.1	955.4	125.8	3	60.0	379.0	28
BONNEVILLE FOREBAY SPILL SIDE	26	4	74	50	10.0	12.16	108.1	16.65	112.1	842.1	111.0	0	0.0	0.0	72
BONNEVILLE FOREBAY SPILL SIDE	15	5	74	50	11.6	11.32	104.4	15.74	109.6	821.8	108.4	0	0.0	0.0	74
BONNEVILLE TAILRACE BAY 13,14,15 BEACH	15	5	74	0	11.4	12.76	117.1	17.46	120.9	909.5	119.7	3	29.0	296.0	24
BONNEVILLE TAILRACE BAY 13,14,15 BEACH	15	5	74	0	11.6	12.64	116.5	17.38	120.8	908.3	119.6	3	29.0	296.0	24
BONNEVILLE TAILRACE BAY 13,14,15 BEACH	15	5	74	0	11.7	12.76	117.9	17.46	121.6	915.3	120.5	3	29.0	296.0	24
BONNEVILLE TAILRACE BAY 13,14,15 BEACH	15	5	74	0	11.7	12.66	116.9	17.46	121.6	913.7	120.3	3	29.0	296.0	24
BONNEVILLE TAILRACE BAY 13,14,15 BEACH	15	5	74	0	11.7	12.76	117.9	17.61	122.7	921.7	121.3	3	29.0	296.0	24
BONNEVILLE TAILRACE BAY 13,14,15 BEACH	15	5	74	0	11.7	12.76	117.9	17.38	121.1	912.0	120.1	3	29.0	296.0	24

NATIONAL MARINE FISHERIES SERVICE COASTAL ZONE AND ESTUARINE STUDIES
BONNEVILLE SPILLWAY DEFLECTOR--DISSOLVED GAS ANALYSIS---COMPENSATED FOR TEMPERATURE AND ALTITUDE

LOCATION	DATE DY	MO	YR	DEPT FT	TEMP C	OXYGEN MG/L	OXYGEN SAT	ATMOSPHERIC NITROGEN ML/L	ATMOSPHERIC NITROGEN SAT	TOTAL PRESSURE MM HG	GAS SAT	NO. GATE OPEN	HOURLY FLOW KCFS SPILL	HOURLY FLOW KCFS TOTAL	SAMPLE ELEV FEET
BONNEVILLE TAILRACE BAY 13,14,15 BEACH	15	5	74	0	11.7	12.88	119.0	17.46	121.6	917.0	120.7	3	29.0	296.0	24
BONNEVILLE TAILRACE BAY 13,14,15 BEACH	15	5	74	0	11.8	12.76	118.1	17.53	122.4	920.4	121.2	3	29.0	296.0	24
BONNEVILLE FOREBAY SPILL SIDE	15	5	74	50	11.4	11.41	104.9	15.82	109.7	822.9	108.5	0	0.0	0.0	74
BONNEVILLE TAILRACE BAY 13,14,15 BEACH	15	5	74	0	11.6	13.01	119.9	17.82	123.9	931.7	122.7	3	39.0	304.0	24
BONNEVILLE TAILRACE BAY 13,14,15 BEACH	15	5	74	0	11.7	13.01	120.1	17.92	124.9	938.1	123.5	3	39.0	304.0	24
BONNEVILLE TAILRACE BAY 13,14,15 BEACH	15	5	74	0	11.7	13.13	121.3	18.24	127.1	952.8	125.4	3	39.0	304.0	24
BONNEVILLE TAILRACE BAY 13,14,15 BEACH	15	5	74	0	11.7	12.88	119.0	17.77	123.0	929.9	122.4	3	39.0	304.0	24
BONNEVILLE TAILRACE BAY 13,14,15 BEACH	15	5	74	0	11.8	12.86	119.3	17.77	124.1	931.9	122.7	3	39.0	304.0	24
BONNEVILLE TAILRACE BAY 13,14,15 BEACH	15	5	74	0	11.7	13.13	121.3	18.08	126.0	946.3	124.6	3	39.0	304.0	24
BONNEVILLE TAILRACE BAY 13,14,15 BEACH	15	5	74	0	11.7	12.90	119.1	17.61	122.7	923.6	121.6	3	39.0	304.0	24
BONNEVILLE TAILRACE BAY 13,14,15 BEACH	15	5	74	0	11.7	12.76	117.9	17.69	123.3	924.9	121.8	3	39.0	304.0	24
BONNEVILLE FOREBAY SPILL SIDE	15	5	74	50	11.6	11.39	105.1	15.75	109.7	823.0	108.5	0	0.0	0.0	74
BONNEVILLE TAILRACE BAY 13,14,15 BEACH	15	5	74	0	11.6	13.25	122.1	18.42	128.0	959.9	126.4	3	49.0	303.0	24
BONNEVILLE TAILRACE BAY 13,14,15 BEACH	15	5	74	0	11.6	13.13	121.0	18.31	127.3	954.0	125.6	3	49.0	303.0	24
BONNEVILLE TAILRACE BAY 13,14,15 BEACH	15	5	74	0	11.6	12.64	116.5	17.30	120.8	908.3	119.6	3	49.0	303.0	24
BONNEVILLE TAILRACE BAY 13,14,15 BEACH	15	5	74	0	11.6	13.25	122.1	18.63	129.5	968.6	127.5	3	49.0	303.0	24
BONNEVILLE FOREBAY SPILL SIDE	15	5	74	50	11.3	11.41	104.6	15.97	110.5	827.5	109.1	0	0.0	0.0	74

1/ Sampling site in highly turbulent area-previous sampling in this area indicate this variation in values is normal, but not indicative of true value for water mass sampled; therefore these values were not used in analysis.

2/ Sample collection presumed to have been made before complete replacement of previous lower discharge in sampling area. (Samples taken of the same discharge 15 min later were used instead, for analysis).

Appendix Table 2. Marked juvenile chinook salmon recaptured in the Columbia River estuary, July 13-August 2, 1974, for spillway deflector evaluation at Bonneville Dam.

Recovery Date	Sets	Control LAT	Control LAH	Control LAL	Control Total	Modified Spillway LAU	Modified Spillway LAC	Modified Spillway LAD	Modified Spillway Total	Standard Spillway RAU	Standard Spillway RAC	Standard Spillway RAD	Standard Spillway Total	Gear Efficiency LAS
7/13	12	5	3	1	9	4	4	5	13	5	3	4	12	4
14	12	8	18	15	41	19	12	13	44	21	15	21	57	46
15	7	11	11	9	31	5	11	2	18	12	14	5	31	34
16	10	16	9	7	32	10	15	12	37	7	8	10	25	27
17	9	3	7	14	24	4	7	7	18	7	7	2	16	22
18	11	2	6	5	13	3	12	7	22	14	9	12	35	24
19	10	12	6	10	28	7	15	6	28	6	9	8	23	13
20	11	4	3	2	9	2	2	3	7	4	2	3	9	4
21	10	2	4	6	12	1	2	2	5	2	4	2	8	-
22	10	2	4	-	6	2	2	-	4	1	-	2	3	1
23	12	1	2	1	4	2	2	1	5	-	2	1	3	3
24	10	-	1	2	3	3	5	2	10	5	-	1	6	1
25	9	2	-	-	2	3	1	-	4	2	-	1	3	1
26	10	2	-	4	6	-	-	-	-	-	-	-	-	-
27	-	-	-	-	-	-	-	-	-	-	-	-	-	-
			No Fishing July 27 & 28											
28	-	-	-x	-	-	-	-	-	-	-	-	-	-	-
29	12	2	2	-	4	-	-	-	-	-	-	-	-	-
30	9	-	-	-	-	1	-	-	1	2	-	-	2	-
31	13	-	-	-	-	-	-	1	1	-	-	-	-	1
8/1	10	-	-	1	1	1	1	-	2	-	-	-	-	-
2	8	1	-	-	1	-	2	-	2	-	-	-	-	1
TOTALS	195	73	76	77	226	67	93	61	221	88	73	72	223	182