Evaluation of Juvenile Salmonid Survival through the Second Powerhouse Turbines and Downstream Migrant Bypass System at Bonneville Dam, 1987

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COASTAL ZONE AND ESTUARINE STUDIES

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INTRODUCTION

Fish guidance efficiency (FGE) testing at the Bonneville Dam Second Powerhouse since 1983 has shown poor guidance of downstream migrant salmonids from turbine intakes equipped with submersible traveling screens (STS) (Krcma et al. 1984; Gessel et al. 1987). Pending resolution of FGE problems, operation of the Second Powerhouse during juvenile migration periods has been curtailed at night and restricted in daytime. During these periods, downstream migrants pass Bonneville Dam via the First Powerhouse turbines and bypass system and over the spillway between the two powerhouses. While it is generally agreed that operation in this manner will maximize survival of migrants passing Bonneville Dam, the rationale for this procedure is based on studies of passage mortality at Bonneville Dam First Powerhouse (Holmes 1952) and at other hydroelectric projects with different operating conditions (Schoeneman 1961). Since survival studies have not been conducted at the Bonneville Dam Second Powerhouse, information specific to this location is needed.

In 1987, the National Marine Fisheries Service (NMFS), in cooperation with the U.S. Army Corps of Engineers (COE), began a multi-year study to evaluate survival of subyearling fall chinook salmon passing through the Bonneville Dam Second Powerhouse turbines and bypass system and through the spillway. Research conducted in 1987 had the following objectives:

(1) Determine short-term comparative survival of juvenile salmon released at upper and lower locations in a Second Powerhouse turbine intake; in the Second Powerhouse bypass system; and below Bonneville Dam at Hamilton Island, Columbia River Kilometer (RKm) 232. Estimates are to be obtained from brand recoveries in the estuary at Jones Beach (RKm 75).

Table 1.--Release schedule for mark groups used to evaluate survival of subyearling fall chinook salmon passing through the Second Powerhouse turbine and bypass systems at Bonneville Dam, 1987.

Release		Treatment groupsL'					
		Upper turbine	Lower turbine	**Bypass** system	Hamilton I. (control)	**Alternate**	
No.	Date	(no./group)	(no./group)	**(no./group)**	**(no./group)**	**No./group**	**Treat.**
1	24 June	20,000	20,000	20,000	20,000	**20,000**	**BY**
2	25 June	20,000	20,000	20,000	20,000	20,000	LT
3	26 June	20,000	20,000	20,000	20,000	20,000	**UT**
4	27 June	20,000	20,000	20,000	20,000	20,000	HI
5	**28 June**	20,000	20,000	20,000	20,000	20,000	**BY**
6	1 **July**	20,000	20,000	20,000	20,000	20,000	LT
7	**2 July**	20,000	20,000	20,000	20,000	20,000	**UT**
8	**3 July**	20,000	20,000	20,000	20,000	20,000	HI

Table 1.--Continued.

9	4 July	20,000	20,000	20,000	20,000	20,000	BY
10	5 July	20,000	20,000	20,000	20,000	20,000	LT
11	8 July	20,000	20,000	20,000	20,000	20,000	UT
12	9 July	20,000	20,000	20,000	20,000	20,000	HI
13	10 July	20,000	20,000	20,000	20,000	20,000	BY
14	11 July	20,000	20,000	20,000	20,000	20,000	LT
15	12 July	20,000	20,000	20,000	20,000	20,000	UT
16	15 July	20,000	20,000	20,000	20,000	20,000	HI
17	16 July	20,000	20,000	20,000	20,000	20,000	BY
18	17 July	20,000	20,000	20,000	20,000	20,000	LT
19	18 July	20,000	20,000	20,000	20,000	20,000	UT
20	19 July	20,000	20,000	20,000	20,000	20,000	HI
Subtotals		400,000	400,000	400,000	400,000	400,000	
Grand total		2,000,000					

a/ **Daily release groups were marked with a unique tag code.**

b/ **Paired with other treatment groups alternating daily: BY = bypass system; LT = Lower turbine; UT = Upper turbine; HI = Hamilton Island (control).**

Releases of marked fish began 24 June and ended 19 July. Specific release locations (Fig. 1) and rationale are as follows:

1. Upper Turbine--released in the intake of Turbine 17, just downstream from Gatewell B, and 1 m below the ceiling (elevation +6.5 m; Fig. 2). This release was made without a screen in place to simulate conditions fish would encounter while passing through an unscreened intake at an elevation where they would have been intercepted by an STS.

2. Lower Turbine--released in the intake of Turbine 17, just downstream from Gatewell A, and 1 m below the effective depth of the STS at that location (elevation +0.2 m; Fig. 3). This release was made with an STS in place to simulate conditions fish would encounter while passing through a screened intake at an elevation too deep to be intercepted.

3. Bypass System--released in the bypass system collection channel (elevation +20.0 m) just downstream from Turbine 17, Gatewell B orifice and upstream from the control weir and downwell (Fig. 4).

4. Hamilton Island (control)--released at the Washington shore boat launch site, approximately 2.5 km downstream from the dam.

The turbine and bypass system releases were made from a 19,000-liter capacity transport tanker into 7.6-cm diameter plastic hoses which directed the fish to the point of release. Vertical distances from transport tanker to water surfaces were about 6 and 9 m for turbine and bypass releases, respectively. Velocity differences between water passing from the ends of release hoses to the surrounding area were calculated to be less than 15 m/sec, the differential velocity initiating mortality of juvenile salmonids in laboratory tests (Groves 1972). The Hamilton Island releases were made directly from a 17,000-liter capacity transport tanker which was **backed** down the boat launching ramp until the release gate was over the water.

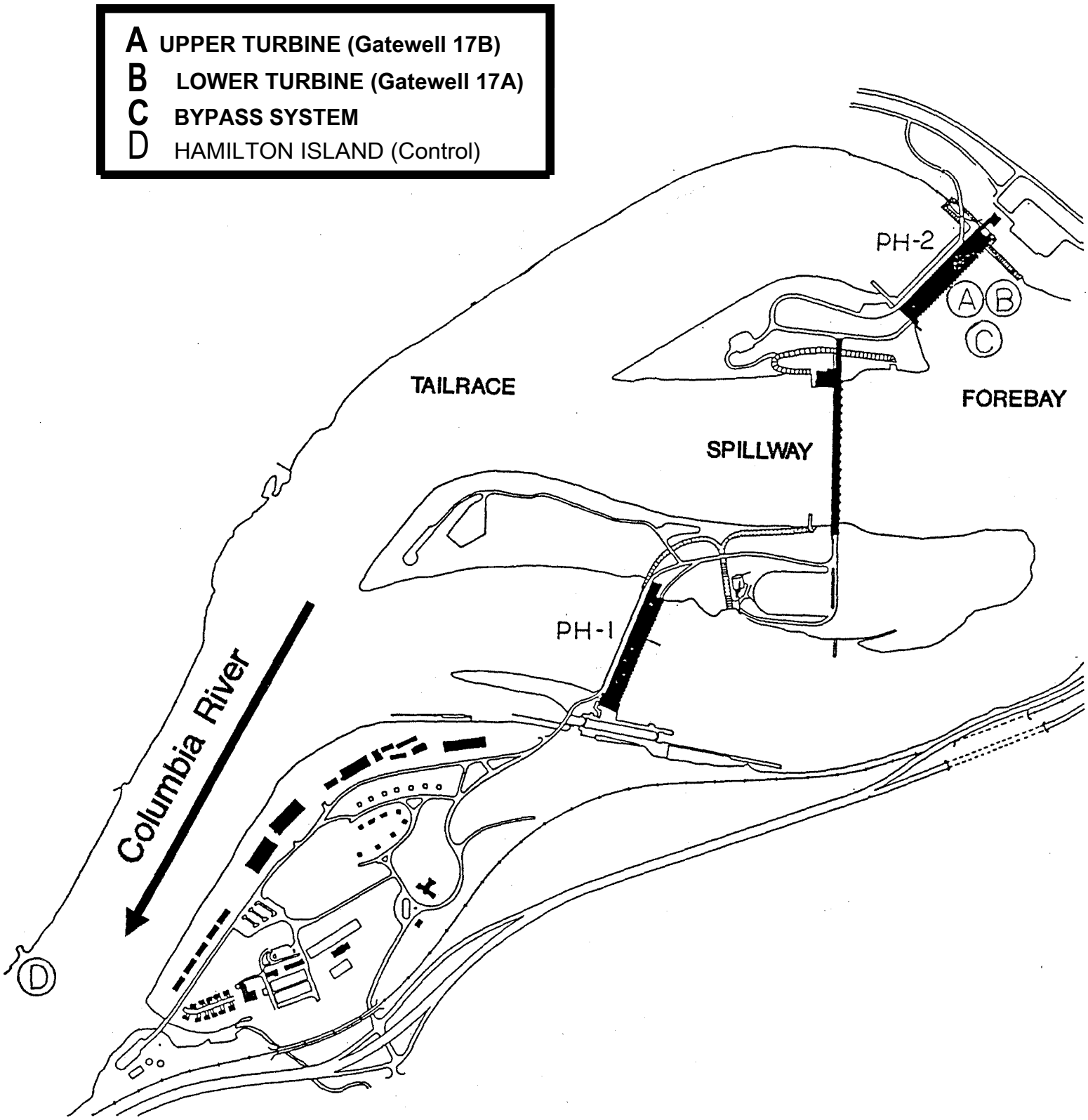


Figure 1.--Release locations for Bonneville Dam fish passage survival study, 1987; PH = powerhouse (see Figures 2-4 for specific description of release locations A, B, C.

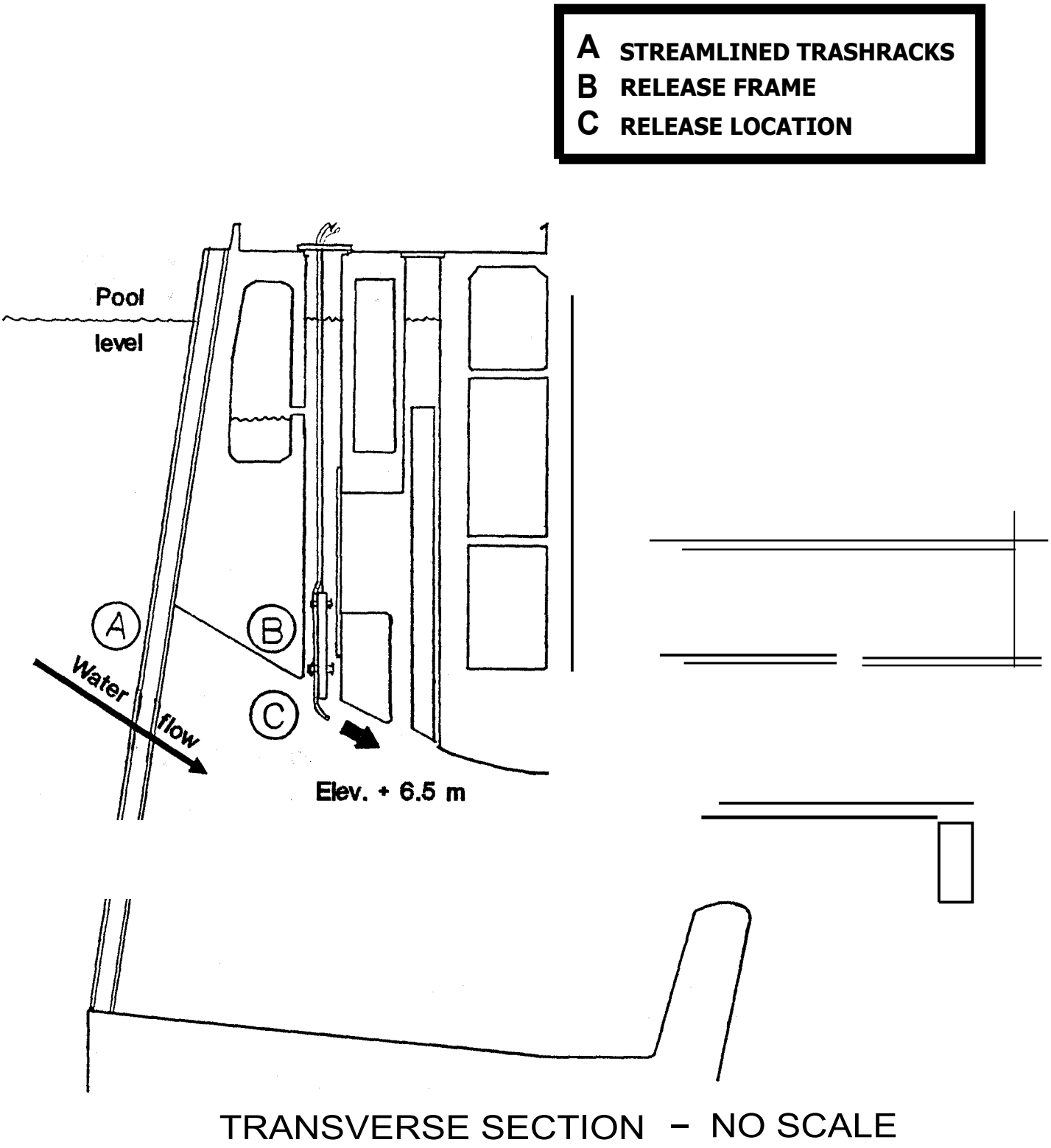
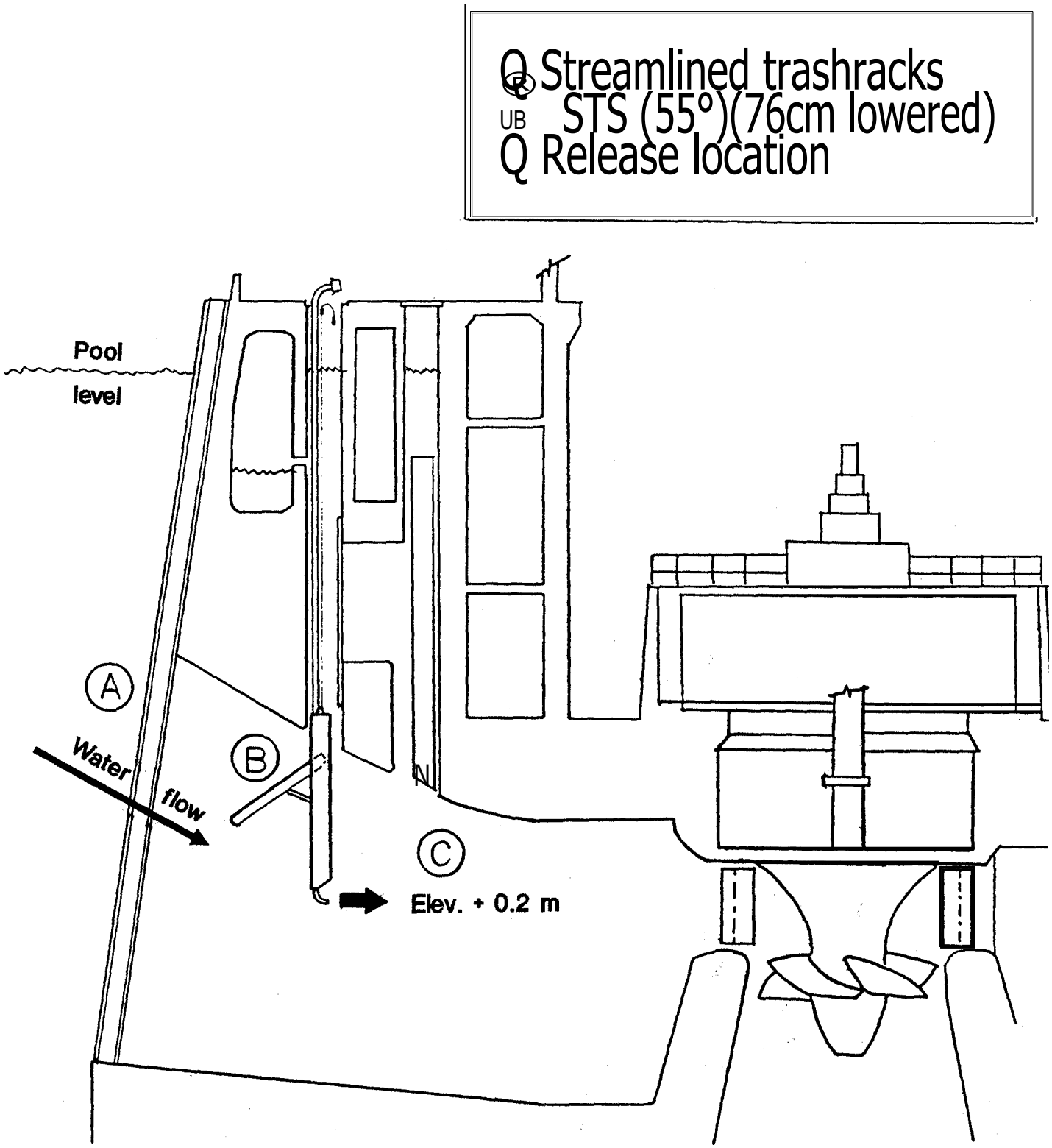


Figure 2.--Cross section of Bonneville Dam Second Powerhouse depicting release location of upper turbine treatment group.



TRANSVERSE SECTION - NO SCALE

Figure 3.--Cross section of Bonneville Dam Second Powerhouse depicting release location of lower turbine treatment group.

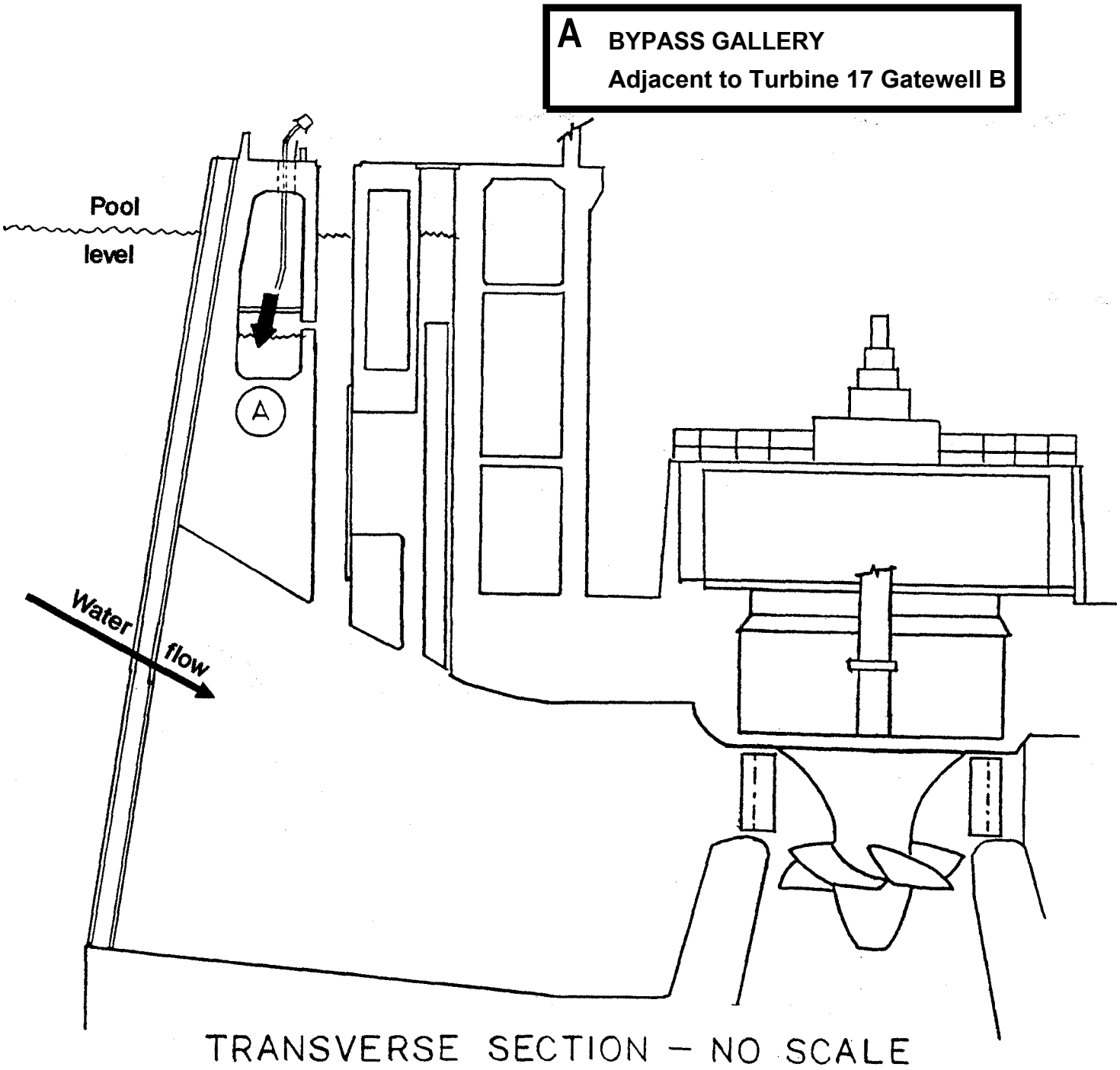


Figure 4.--Cross section of **Bonneville** Dam Second Powerhouse depicting release location **of bypass system treatment group.**

Marking Procedure

The marking sequence began with transfer by Bonneville Hatchery personnel of unmarked fish from Battery C and Battery D ponds to Pond 5, Battery A. Fish were transferred 1-3 days prior to marking, using a 3,800-liter distribution tanker. Starting at 0530 h, and at 4- to 6-h intervals throughout the day, NMFS personnel pumped unmarked fish from Pond 5 into a 2.4- X 6.1-m holding tank at the north side of the Battery A ponds. Fish were anesthetized with benzocaine in compartments within this tank, then hand- netted into an adjacent 20-station branding trailer. To provide the best possible mixing of unmarked fish among the treatment groups, fish for all five release groups were branded concurrently.

Branded fish were routed via 7.6-cm diameter PVC pipe to clipping and tagging stations (2 stations/treatment group) located in three trailers. From the time fish entered the branding trailer until they exited the tagging units, they remained anesthetized in chilled, recirculated water containing MS-222. At the completion of the marking process, fish were routed to separate holding divisions of Pond 1, Battery A. Since transport took place the day after marking, fish from two marking days were on hand from 0600 to 1800 h most days, and 10 divisions were necessary in Pond 1, Battery A.

To assess overall tag loss and brand retention, approximately 100 fish/day from each treatment were held after marking for a minimum of 30 days. Samples were counted into 76-liter plastic containers and transported to holding tanks at the former Bonneville Hydraulics Laboratory.

Release Procedure

The typical release sequence began at 1800 h (a minimum of 20 h post-marking) with the loading of marked groups into separate compartments of 17,000- and 19,000-liter capacity tank trucks. Fish were then transported to the Bonneville Dam Second Powerhouse, where water temperature in the trucks was gradually raised to river temperature. Second Powerhouse Turbines 11, 16, 17, and 18 were started at 0130 h. Releases began at 0200 h and were usually concluded by 0330 h. The bypass group was released first, followed by the upper and lower turbine groups, and finally the Hamilton Island group. During releases, the release unit (Turbine 17) was operated near peak efficiency, from 66 to 67 MW electrical load, and passed about 0.4 $k \cdot m^3$/sec of water. The turbine blade is 8.4 m in diameter and operates at about 69.2 revolutions/min. The discharge from the entire Second Powerhouse ranged from 1.5 to 1.7 $k \cdot m^3$/sec. Turbines continued operation until 0530-0600 h to provide flow for fish movement out of the Second Powerhouse tailrace. Operational and river conditions were recorded at times of release (Appendix Table 2).

Recovery at Jones Beach

Preliminary analyses of immediate survival among treatments and success of release strategies (Objective 1) were made from comparisons of brand recoveries at Jones Beach. Sampling began 23 June, the first week as a training session for new crew members, and continued through 27 August. The primary sampling sites were at or lateral to Jones Beach, RKm 75, near the upstream extent of the estuary. Beach seine sites were on the Oregon shore at Jones Beach, the Washington shore at Cape Horn, and the southeast shore of

Puget Island. The purse seine site was in mid-river, north of the ship channel. In this area, the river is approximately 1.6 km wide with a central ship channel maintained at a depth of approximately 14 m (Fig. 5). The gradually-sloped sandy beach and debris-free channel make the site ideal for sampling. Tidal effects are semidiurnal (roughly 7.5 h of ebb and 5.0 h of flood tide); water flow reversal generally occurs during flood tides.

Sampling procedures were consistent between sites within the restraints dictated by river and weather conditions. New procedures (discussed below) were implemented for this study to provide greater recovery rates than in previous years (Dawley et al. 1985a). Generally, sampling began at sunrise and continued for about 7 h, 7 days/week. Daily sampling was generally done with two crews. One crew made 10 beach seine sets on the Oregon shore and the other crew made a combination of purse seine and beach seine sets at other sites to a maximum of 10 sets (Appendix Table 3).

The beach seine was 95 m long and 5 m deep with 1- to 2-cm (stretch measure) webbing. The standard net-setting procedure (Sims and Johnsen 1974) of towing the net by boat upstream along the 1-m depth contour at set time was altered. To increase efficiency, the net was pulled by truck upstream along the beach 30 min prior to set time. At set time, it was towed in an arc offshore, downstream, and back to shore. The net was then pulled to shore by hand. Some deviation from this procedure occurred at sites other than the Oregon shore due to logistics and river conditions. The effective fishing depth was about 3 m.

The purse seine was 206 m long and 11 m deep with 1- to 2-cm (stretch measure) webbing (Durkin and Park 1967). It was towed open-end facing upstream in a "U" configuration for 10 min prior to closing the net bottom (pursing); this was double the time used in the standard sampling technique

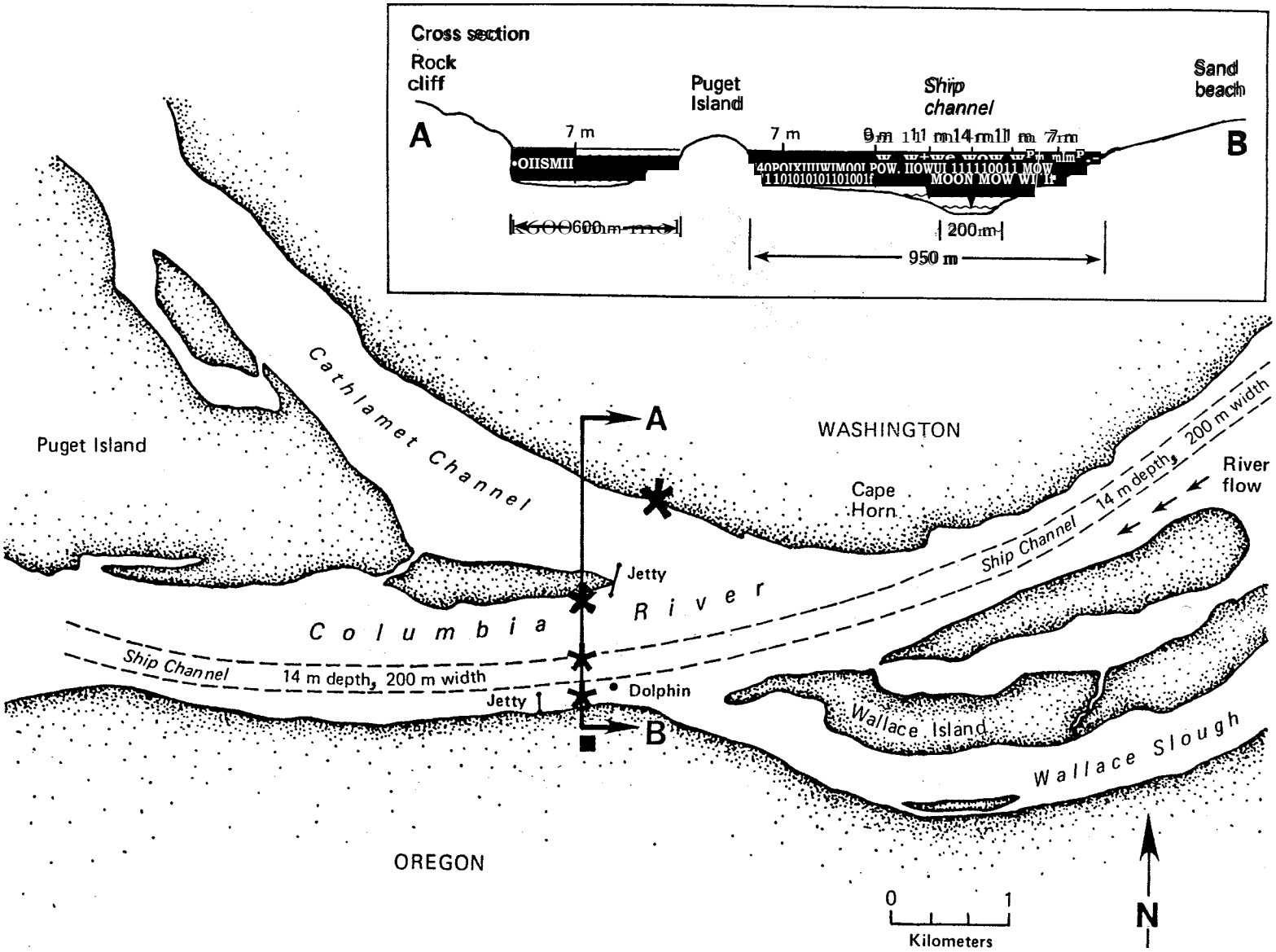


Figure 5.--Jones Beach, Oregon, sampling sites, 1987. The primary beach and purse seining areas are denoted by asterisks.

for past years. The effective fishing depth was about 6 m. Variation, caused by river flow and tidal fluctuations, in the amount of water strained by the purse seine was minimized by maintaining constant towing power.

Captured fish were processed similarly at all sites. The catch from each set was anesthetized with a solution of ethyl p-aminobenzoate (the approximately 50 mg/liter concentration was varied with water temperature and fish size). Subyearling fall chinook salmon were examined for excised adipose fins and brands. Fork lengths of study fish were measured to the nearest mm.

To evaluate brand illegibility, after 28 July all fall chinook salmon captured with an illegible brand or an excised adipose fin, and within the size range of the study fish, were sacrificed for CWT identification.

To evaluate error in brand application or reading, on 13 August the entire catch of fall chinook salmon with an excised adipose fin and within the size range of the study fish was sacrificed for CWT identification.

Final assessment of survival differences among treatments (Objective 2) will be made subsequent to compilation of adult recovery data.

RESULTS

A total of 1,857,394 fish were marked and released with freeze brands, binary coded wire tags, and adipose fin clips. A daily summary of brands, tag codes, and number marked by treatment is given in Appendix Table 1. Seven sets of uniquely-branded release groups were used for Jones Beach recovery comparisons (Table 2).

Initial recoveries of test fish at Jones Beach were about a week later than expected from previous recovery data for URB fall chinook salmon from Bonneville Hatchery (Dawley et al. 1985b). The difference was due in part to low river flows and, we believe, to the small size (4.4 - 4.6 g) and unsmolted

Table 2.--Brand groups released at various sites for study of passage survival of juvenile fall chinook salmon at Bonneville Dam, 1987.

Upper turbine		Lower turbine		Bypass system		Hamilton I. (control)	
Brands./ (Sy Ro)	No.k/ (thou)	BrandAJ (Sy Ro)	No.ki (thou)	Brands✓ (Sy Ro)	No.bf (thou)	Brands./ (Sy Ro)	No.J (thou)
			Released 25-28 June				
Y 1	71.1	5 1	71.0	W 1	76.0	U 1	72.0
			Released 1 July				
IY 1	17.6	13 1	19.6	IN 1	15.2	2L 1	17.2
			Released 2-5 July				
Y 3	67.62)	5 3	58.4L'	W 3	79.2	U 3	76.6
			Released 8 July				
IY 3	19.9	13 3	19.9	IN 3	20.0	2L 3	20.0
			Released 9-12 July				
Y 2	81.3	5 2	80.8	W 2	81.9	U 2	80.0
			Released 24 June, 15-19 July				
Y 4	111.7	5 4	109,4	W 4	110.7	U 4	113.5
			Replicate groups released 24 June-19 July				
F 2	60.6	2X 1	59.2	F 4	83.4	F 3	81.7
2X 3	19.9						
			Grand total				
	449.7		418.3		466.4		461.0

A/ All brands were right side dorsal (RD); Sy = brand symbol and Ro = rotation for which 1 = upright, 2 = 900 rt. rotation, 3 = 180° rt. rotation, and 4 = 270° rt. rotation.

b/ No adjustments for brand retention.

c/ Assumes a 50% mortality of upper turbine and 100% mortality of lower turbine release groups on 5 July.

condition (based on external appearance and low Na^+-K^+ ATPase levels at the hatchery) of the migrants. Recoveries steadily increased from 6 July to a peak of 1,328 fish on 30 July. Recoveries then decreased steadily to 24 recovered on 27 August, at which time sampling was terminated. Fork lengths measured at recovery suggested that test fish in all mark groups grew extensively during their slow migration (Fig. 6). Na^+-K+ ATPase levels were low at release and higher in migrants captured at Jones Beach. Na^+-K^+ ATPase levels at the hatchery were lowest in the first week of release, increased in the second and third weeks, and decreased in the fourth week (Table 3). Recovery rates at Jones Beach showed a similar pattern over time to that of hatchery Na^+-K^+ ATPase levels (Table 4). Movement rates, however, steadily increased through the season while river flows remained fairly constant (Tables 3 and 4).

Recovery data were examined for randomness to evaluate the validity of treatment group comparisons. Three data comparisons were made to examine variation among treatment groups:

1) Comparison between sampling sites, for recovery differences among treatments-- data for each of the three primary recovery sites (Washington, mid-river, and Oregon shore beach seine) appeared consistent when separated by week of release or combined (Table 5).

2) Evaluation of fork length differences among treatments-- mean fork lengths of fish recovered from each treatment were compared and no substantial differences were observed (Fig. 7).

3) Evaluation of migration timing differences among treatments-- movement rates by mark group were examined and little difference was noted among treatments {Table 6).

There were no indications of non-random recoveries of treatment groups at the estuarine sampling sites (Fig. 8).

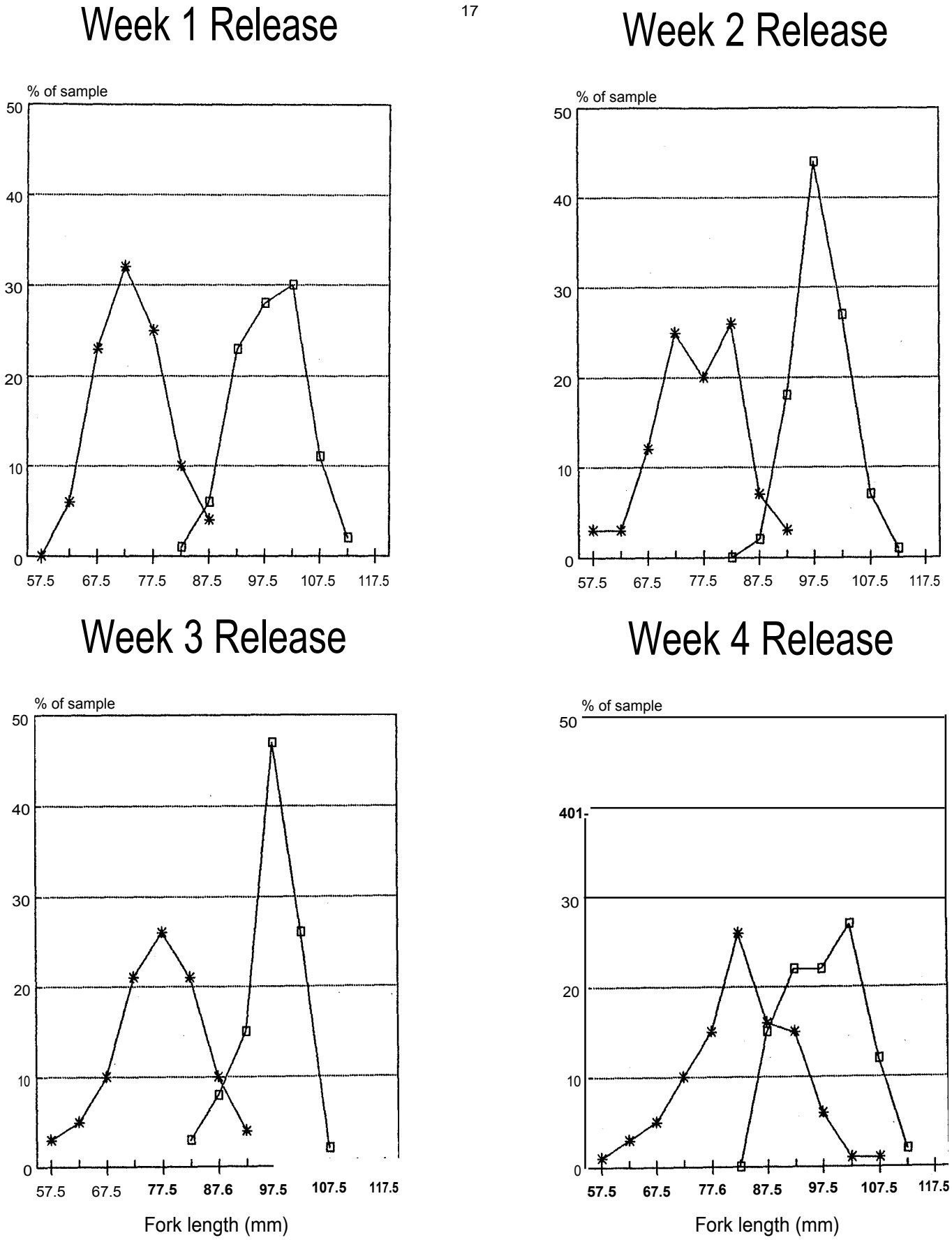


Figure 6.--Fork lengths before release at **Bonneville** Dam and at recovery in the estuary for fall chinook salmon from the fish passage survival study, 1987 (* = before release and a = at recovery).

Table 3.--Na^+-K^+ ATPase levels, fork lengths, recovery rates, movement rates, and river flow for weekly release groups at Bonneville Dam, 1987.

Release group	ATPase[1]	Mean len. (mm)	Recov. rate (%)	Movemt. rate (km/day)	River flow (km^3/sec)[2]
Week 1 (24 June)	12.2	73.6	0.52	5.8	3.2
Week 2 (30 June)	12.9	76.6	0.68	6.6	3.1
Week 3 (7 July)	17.7	76.8	0.71	7.2	3.2
Week 4 (14 July)	14.2	82.7	0.43	8.6	3.2

[1] Na^+-K^+ ATPase activity expressed as micromoles ATP hydrolyzed per milligram protein per hour.

[2] Average daily flow at Bonneville Dam for seven days centered on the date of median fish recovery.

Table 4.--Temporal changes in Na^+-K^+ ATPase levels of fish recovered at Jones Beach, Oregon, 1987. Na*-K* ATPase levels measured by W. Zaugg (NMFS, Cook, WA); expressed as micromoles ATP hydrolyzed per milligram protein per hour.

Recovery date	Release group			
	Week 1	Week 2	Week 3	Week 4
15 July	32.1	32.5		
22 July	27.6	28.9	29.0	
5 August	33.6	34.6	36.2	34.1
13 August	-	22.4	22.6	23.0
20 August	-		19.9	20.0

Table 5.--Beach seine recovery data separated to assess mixing among treatment groups released at Bonneville Dam and recovered at three sampling sites at Jones Beach, Oregon, 1987.

Beach seine site	Treatments							
	Upper turbine		Lower turbine		Bypass system		Hamilton I (control)	
	Number	%	Number	%	Number	%	Number	%
Released 25-28 June								
Wash.	72	0.10	83	0.12	71	0.09	66	0.09
Mid.L'	4	0.01	8	0.01	13	0.02	13	0.02
Ore.	178	0.25	210	0.30	166	0.22	148	0.21
Released 1 July								
Wash.	30	0.17	29	0.15	28	0.18	29	0.17
Mid.	3	0.02	5	0.03	2	0.01	2	0.01
Ore.	67	0.38	83	0.42	54	0.36	47	0.27
Released 2-5 July								
Wash.	128	0.19DJ	100	0.17k)	150	0.19	131	0.17
Mid.	36	0.05/	15	0.02	23	0.03	19	0.02
Ore.	272	0.40k	223	0.38k'	349	0.44	327	0.43

Table 5.--Continued.

Released 8 July								
Wash.	41	0.21	28	0.14	34	0.17	37	0.19
Mid.	10	0.05	5	0.03	10	0.05	6	0.03
Ore.	127	0.64	126	0.63	114	0.57	90	0.45
Released 9-12 July								
Wash.	116	0.14	138	0.17	107	0.13	103	0.13
Mid.	40	0.05	41	0.05	34	0.04	34	0.04
Ore.	427	0.55	413	0.51	358	0.44	369	0.46
Released 24 June, 15-19 July								
Wash.	116	0.10	126	0.12	84	0.08	93	0.08
Mid.	52	0.05	33	0.03	39	0.04	41	0.04
Ore.	318	0.28	336	0.31	301	0.27	306	0.27
Grand total all release dates)								
Wash.	503	0.14	504	0.14L1	474	0.13	459	0.13
Mid.	145	0.04L''	107	0.031	126	0.03	115	0.03
Ore.	1389	0.39 '	1391	0.39k	1342	0.37	1287	0.36

a/ Mid-river island sites; beach seine recovery data.

b/ Adjusted for 50% mortality of upper turbine and 100% of lower turbine release groups on 5 July.

c/ Replicate groups not included in analysis at this time.

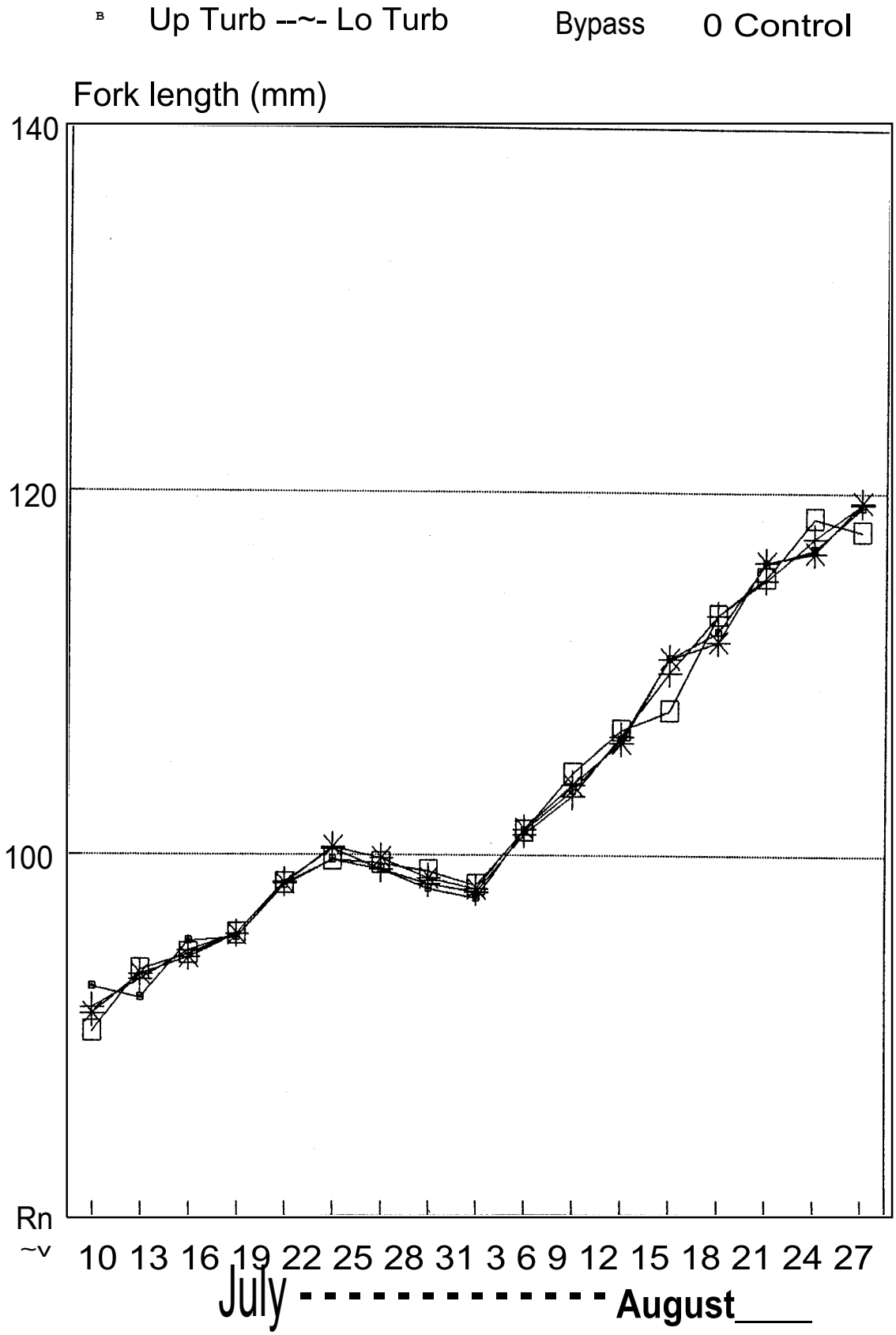


Figure 7.--Temporal changes in mean fork lengths from recoveries at Jones Beach, Oregon, comparing treatment groups from the fish passage survival study at Bonneville Dam, 1987.

Table 6.--Movement rates of juvenile fall chinook salmon from Bonneville Dam to Jones Beach, Oregon, comparing treatment groups by release date, 1987.

	Treatments				
Release date	Upper turbine (km/day)&'	Lower turbine (km/day)a√	Bypass system (km/day)ai	Hamilton I. control (km/day)a√	Total (km/day)a./
25-28 June	5.8	5.4	6.1	5.8	5.8
1 July	6.5	6.5	6.7	6.5	6.5
2-5 July	6.6	6.5k/	6.6	6.3	6.6
8 July	6.7	6.7	7.0	7.0	7.0
9-12 July	7.6	6.92.r	7.6	7.6	7.2
15-19 July 4/	8.6	9.7	8.2	8.2	8.6

a/ Based on recoveries from beach seine catches from Oregon shore adjusted to 10 sets/day. Movement rate = distance (RKm 230-RKm 75)/days to median recovery from mean release day.

b/ Adjusted for 100% mortality of 5 July release group.

c/ Movement rate is corrected for protracted release of RD 5 2 into the 4th week of release, due to brand-rotation error.

d/ Adjusted to represent only fish from the 4th week of release.

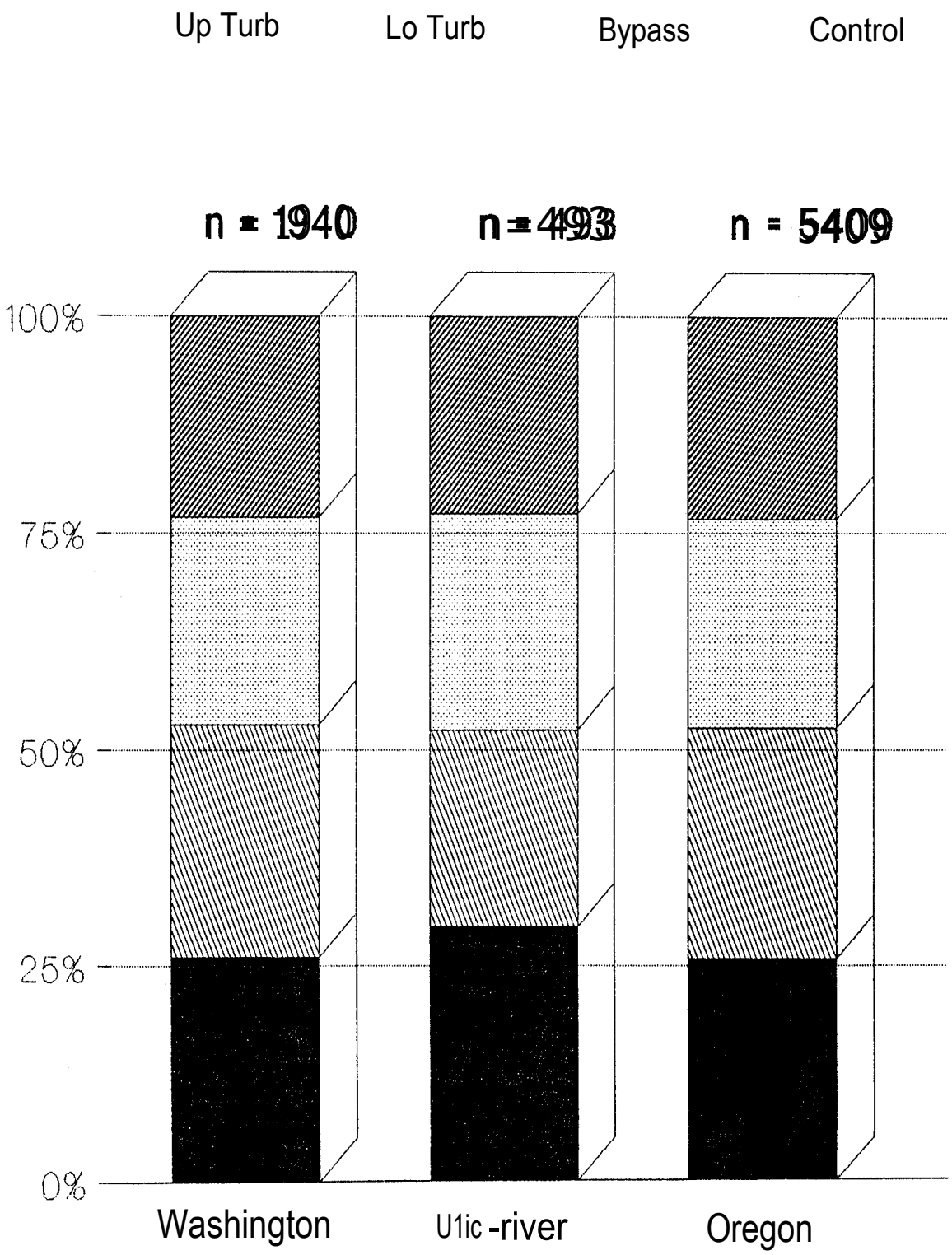


Figure 8.--Beach seine recovery data separated to assess mixing among treatment groups at the Washington shore, mid-river islands, and Oregon shore sampling sites, 1987 .

Estimates of brand illegibility for combined treatment groups varied from 1.1 to 3.0% among the treatments and appeared not to affect results of the comparisons. Illegibility estimates for individual brands (Table 7) were derived from the fish sampled each day at the hatchery site after marking and from fish collected at Jones Beach after 28 July which were sacrificed for CWT identification. In this study, 156 fish were sacrificed. Analysis of brand vs tag data showed 1.5% error between treatments from misread brands (134-fish sample). There was a 15% error of brand rotation at application for lower turbine groups for 2 days within the fourth week of release (RD 5 4 released as RD 5 2). Final data will be adjusted to represent estimates for each brand with illegibility percentages extracted from release numbers and a correction for rotation error.

Preliminary evaluation of brand recoveries at Jones Beach indicates that recovery rates for the turbine release groups were statistically greater than for bypass or control release groups, at the 99% confidence level. Differences of recovery percentages among treatment groups appear consistent throughout the recovery period (Fig. 9). Overall recovery percentages from the upper turbine, lower turbine, bypass, and control groups were 0.63, 0.63, 0.56, and 0.54%, respectively {Table 8).

On 5 July a massive mortality of test fish was observed just prior to release from the tank truck. The mortality, from accidental anoxia, was estimated at 50% of the lower turbine group and 10% of the upper turbine group. We compared the Jones Beach recovery percentages of those brand groups to percentages from other periods of release and found it more likely that 100% of the lower turbine group and 50% of the upper turbine group died. Recovery data presented reflect our best estimate of mortality. Adjustments were made to mark groups from the second week of release, the replicates, and

Table 7.--Percentage of illegible brands and lost tags by treatment groups in: (1) samples held at Bonneville Hatchery and (2) brand groups released at Bonneville Dam and recovered at Jones Beach, Oregon, 1987.

	treatnents																	
	Upper turbine				Lower turbine					Bypass systeo				Banilton I. (control)				
	Bonn. Bat.		Jones B.		Bonn. Bat.		Jones B.			Bonn. Hat.		Jones B.		Bonn. Hat.		Jones B.		
Hark	-- Seep. (no.i	Illeg. or lost (t)	Illeg. or lost Saep. Inc.)	(II	Bark	Illeg. or lost hap. (no.)	(ti	Meg. or lost Sup. (no.)	(t)	Bark	Meg. or lost hap. (no.l	(t)	Illeg. or lost Sup. (no.)	(t)	Bark	Illeg. or lost Seep. (no.)	(t)	Illeg. or lost Seep. (no.(	(t)
										BRBBBSV								
										Released 25-28 June								
Y 1	400	1.5	70	5.7	5I	400	7.3	121	5.0	81	400	1.3	71	0.0	01	400	3.8	64	0.0
										Released 1 July								
IY 1	100	0.0	32	0.0	13 1	100	0.0	41	2.4	IB 1	100	0.0	30	0.0	2L 1	100	1.0	30	0.0
										Released 2-5 July								
Y 3	400	0.5	209	2.4	5 3	400	2.3	163	1.8	8 3	400	0.5	237	0.4	If 3	400	1.3	236	1.3
										Released 8 July								
IT 3	100	0.0	118	0.0	13 3	100	1.0	118	2.5	IB 3	100	0.0	112	0.0	2L 3	100	0.0	99	0.0
										Released 9-12 July								
T 2	400	1.0	473	2.5	5 2	400	1.3	508	1.0	7 2	400	2.3	419	2.4	U 2	400	1.5	400	1.5
										Released 24 June. 15-19 July								
Y 4	600	1.3	478	1.3	5 4	600	3.3	479	0.8	Y 4	600	1.8	417	2.6	0 4	600	2.3	422	0.9
										Replicate groups released 24 June - i9 July								
F 2	300	2.3	256	2.3	21 1	400	1.3	332	0.3	F 4	450	7.1	313	3.8	F 3	400	7.5	292	6.2
21 3	100	0.0	134	0.0															
Total	2.400	1.1	1.770	1.9		2.400	2.9	1.772	1.3		2.450	2.4	1.599	2.1		2.400	3.0	1.543	2.0
										tags!/								
										Total--all release groups								
	2.288	10.5	29	6.9		2.164	7.1	48	2.1		2.091	8.3	31	3.2		2.196	9.4	34	2.9

1' Brand symbol and rotation.

İ.,' Of 136 illegible brands at Jones Beach, 9.6% had lost tags.

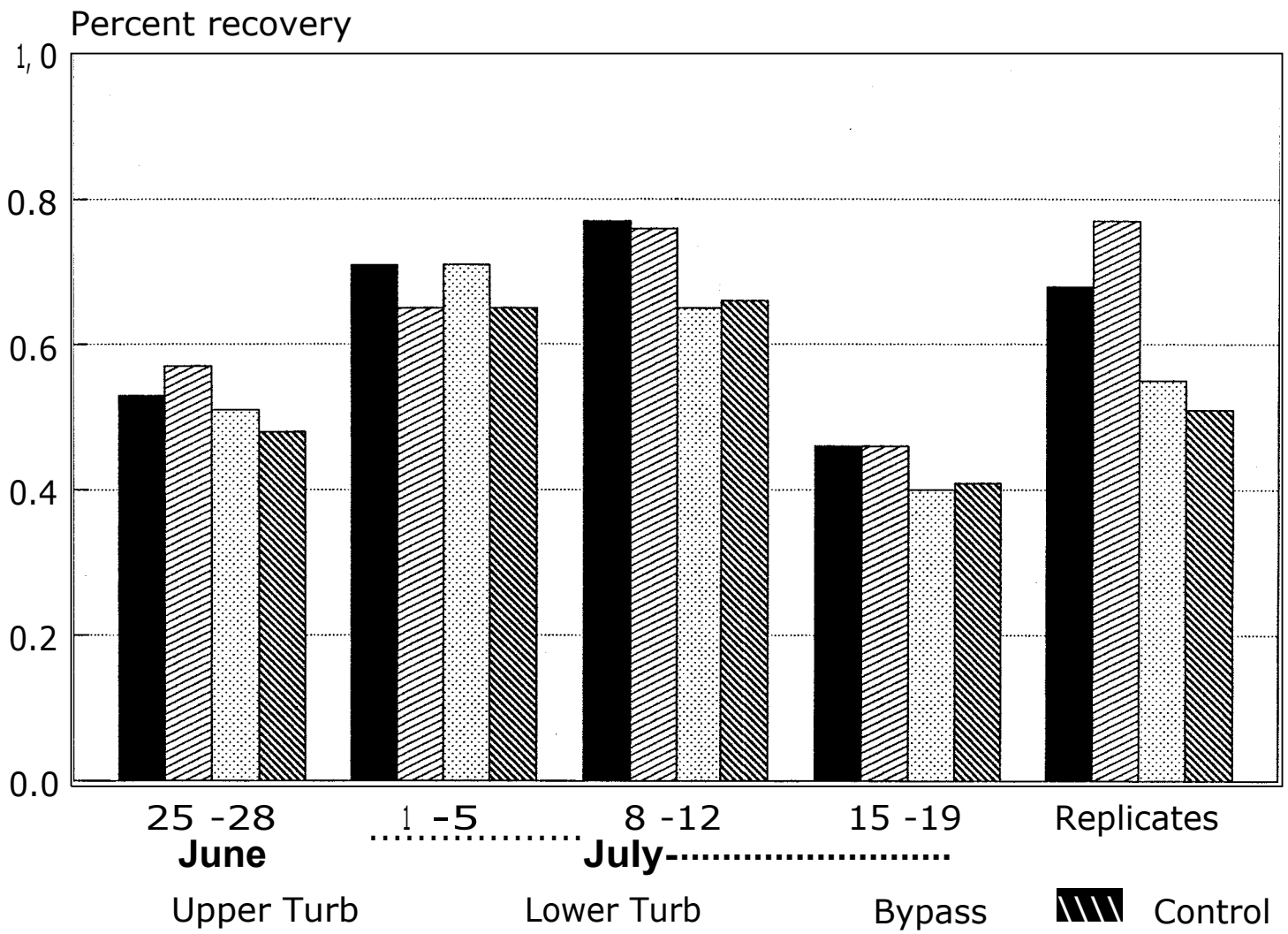


Figure 9.-- Recovery data pooled by week of release, comparing treatment groups from the fish passage survival study at Bonneville Dam, 1987. July 15-19 release group includes fish released on 24 June. Replicate groups were released throughout the date range.

Table 8.--Recoveries, by treatment group, of branded fish released during the juvenile salmon passage study at Bonneville Dam, 1987, and recovered at Jones Beach, Oregon.

Upper turbine		Lower turbine		Bypass system		Hamilton I (control)	
Number	%	Number	%	Number	%	Number	%
			Released 25-28 June				
374	0.53	402	0.57	387	0.51	347	0.48
			Released 1 July				
127	0.72	137	0.70	109	0.72	92	0.53
			Released 2-5 July				
481	0.71'	369	0.63./	558	0.70	518	0.68
			Released 8 July				
185	0.93	163	0.82	159	0.80	139	0.70
			Released 9-12 July				
594	0.73	604	0.75	507	0.62	517	0.65
			Released 24 June, 15-19 July				
510	0.46	506	0.46	441	0.40	469	0.41
			Replicate groups released 24 June - 19 July				
547	0.68	453	0.77L'	460	0.55	419	0.51
			Grand total (all release dates)				
2818	0.63L'	2634	0.63L'	2621	0.56**	2501	0.54**
			Grand total (excluding date-periods affected by mortality)				
1790	0.59	1812	0.60	1603	0.53**	1564	0.52**

a/ Adjusted for 50% mortality of upper turbine and 100% mortality of lower turbine releases on 5 July.

b/ Third position brands and replicate groups extracted from data to eliminate inaccuracies from estimated mortality.

** G statistic analysis indicates significant difference from turbine release groups at the 99% confidence level.

the grand total. As a precautionary measure, a subset of data uncompromised by the affects from this mortality was examined (6,769 recoveries); differences between the turbine groups and the bypass and control groups were still apparent at the 99% confidence level (Table 8).

Tag loss for treatment groups varied from 7.1 to 10.5% as estimated from combined daily samples of fish collected after marking and held 30 days or longer. Tag loss was 9.6% in recoveries at Jones Beach, evaluated for fish with illegible brands collected after 28 July (136 total). Final release data used for adult recovery comparisons will include a correction for those estimates.

Results presented here were based only on preliminary evaluation of brand recoveries of juveniles. Final evaluation will be based on adult recovery information.

DISCUSSION AND CONCLUSIONS

In estuarine sampling, the lower recovery rates for control and bypass-released fish, compared to turbine-released fish, caused serious concern about release sites, release procedures, and unidentified hazards in migration routes. By releasing the control group of fish 2.5 km downstream from Bonneville Dam at Hamilton Island, we anticipated high survival because this group of fish would be unaffected by the dam complex and by predators inhabiting the adjacent areas. Theoretically, differences in recovery rates between control and treatment groups would represent the impact of the treatment on survival. Instead, apparently, one or more unexpected factors overshadowed the possible impact of turbine-related mortality on test fish. We also anticipated relatively high survival for the bypass treatment groups because these fish do not pass through the turbines. We assume that there would be increased mortality of fish passing through the turbines. This

project-related mortality cannot now be assessed because of the apparent greater mortality of control and bypass fish.

We hypothesize that control fish released on the shoreline at Hamilton Island were subjected to more predation than were groups released in mid-river. Previous observations of similar juvenile fall chinook salmon from estuarine sampling suggest that shoreline migration is likely for: 1) fish recently released from a hatchery; 2) small fish; and 3) non-smolted fish (Dawley et al. 1986). We assume that fish released in mid-river traveled some distance downstream before establishing shoreline migration behavior, and that the mid-river portion of their migration produced less contact with predators than the shoreline route **probably** taken by the control fish. A mid-river release site for control fish will be established for next year.

The causes of slightly lower recovery rates, compared to both the upper and lower turbine treatment groups, for fish released into the bypass are not known at this time. The outlet structure of the bypass system places fish a considerable distance from shore and slightly downstream and between the discharge boils of Turbines 17 and 18. The migration route of those fish would seem similar to that of treatment fish released into Turbine 17, although the exit from the bypass is very localized compared to a broader distribution for turbine-released fish. The bypass exit structure was purposely placed in an area of high current (assumed to be greater than 1.2 m/sec), designed to provide little sanctuary for resident predators. Therefore, large differences in predation between bypass and turbine fish groups seem unlikely. The bypass system will be inspected prior to next year's releases.

The importance of estuarine sampling of juveniles at Jones Beach was clearly demonstrated in this study. Had no assessment of the marked fish been

made prior to the return of adults, survival comparisons with the control release group, apparently lost for 1987 releases, may have been lost for the following 2 years as well.

The small size of the test fish, 4.4 to 4.6 g at marking and release, is of paramount concern. Branding was difficult due to the small body size. This was probably responsible for the high rate of illegibility for some brands. Previous adult recovery data suggest that our expectations for obtaining 0.5% recovery may be unrealistic; adult recovery data used in forecasts were from juveniles released at a larger size (Table 9). For next year's test, we have requested the largest fish practical from the 1987 brood; eggs will come from the earliest-returning adults.

Table 9.--Size at release related to adult recoveries for upriver bright fall chinook salmon.

Release information					
Tag A./	Release site	Brood yr.	Release date	Size (g)	**Adult survival** (estim. %) k.[b]
07,22,07	Bonneville	79	6/30	6	0.88
07,17,34	Bonneville	79	11/11	32	1.99
07,25,06	Bonneville	80	6/12	7	0.61
07,25,07	Bonneville	80	7/30	13	1.23
07,24,24	Bonneville	81	6/4	6	0.43
07,24,26	Bonneville	81	8/3	11	0.61
63,21,55	Priest Rapids	80	6/23	5	0.46
63,22,61	Priest Rapids	80	5/18	7	0.94
63,22,52	Priest Rapids	81	5/18-6/16	5	0.51
63,24,56	Priest Rapids	81	5/18	7	0.86
63,26,11	Priest Rapids	82	5/24	5	0.43
63,2.6,12	Priest Rapids	82	6/21	7	0.61

A/ Binary coded wire tag: Agency code, data 1, data 2.

b/ Jacks not included and 5-year fish not in 82 brood year data.

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Krcma, R. F., M. H. Gessel, W. D. Muir, C. S. McCutcheon, L. G. Gilbreath, and B. H. Monk.

1984. Evaluation of juvenile collection and bypass system at **Bonneville** Dam - 1983. U.S. Dep. Commer., Natl. Oceanic Atmos. Admin., Natl. Mar. Fish. Serv., Northwest and Alaska Fish. Centr., Seattle, WA. 68 p. (Report to U.S. Army Corps of Engineers, Portland, OR, Contract, DACW57-83-F-0315).

Schoeneman, D.E., R.T. Pressey and C.O. Junge.

1961. Mortalities of downstream migrant salmon at McNary Dam. Trans. Amer, Fish. Soc. 90(1):58-72.

Sims, C. W., and R. C. Johnsen.

1974. Variable mesh beach seine for sampling juvenile salmon in Columbia River estuary. U.S. Natl. Mar. Fish. Serv., Mar. Fish. Rev. 36(2):23-26.

LITERATURE CITED

Dawley, E. M., R.D. Ledgerwood, T.H. Blahm, C.W. Sims, J.T. Durkin, R.A. Kirn, A.E. Rankis, G.E. Monan, and F.J. Ossiander. 1986. Migrational characteristics, biological observations, and relative survival of juvenile salmonids entering the Columbia River estuary, 1966-1983. U.S. Dep. Commer., Natl. Oceanic Atmos. Admin., Natl. Mar. Fish Serv., Northwest and Alaska Fish. Cent., Seattle, WA. 256p. (Final Report to the Bonneville Power Administration, Portland, OR. Contract DE-A179-84BP39652, Project No. 81-102).

Dawley, E. M., R. D. Ledgerwood, and A. L. Jensen. 1985a. Beach and purse seine sampling of juvenile salmonids in the Columbia River estuary and ocean plume, 1977-1983. Volume I: Procedures, sampling effort, and catch data. U.S. Dep. Commer., NOAA Tech. Memo. NMFS N/NWC-74:1-260.

Dawley, E. M., R. D. Ledgerwood, and A. L. Jensen. 1985b. Beach and purse seine sampling of juvenile salmonids in the Columbia River estuary and ocean plume, 1977-1983. Volume II: Data on marked fish recoveries. U.S. Dep. Commer., NOAA Tech. Memo. NMFS N/NWC-75:1-397.

Durkin, J. T., and D. L. Park.

1967. Purse seine for sampling juvenile salmon. Prog. Fish-Cult. **29:56-59.**

Gessel, M. H., L. Gilbreath, W. D. Muir, Bruce H. Monk, and R. F. Krcma.

1987. Evaluations of juvenile salmonid collection and bypass at Bonneville Dam, 1986. U.S. Dep. Commer., Natl. Oceanic Atmos. Admin., Natl. Mar. Fish. Serv., Northwest and **Alaska** Fish. Cent., Seattle, WA. 99 p. (Annual Report to U.S. Army Corps of **Engineers**, Portland , OR. Contract DACW57-86-F-0270).

Groves, Alan B.

1972. Effects of hydraulic shearing actions on juvenile salmon (summary report). Northwest and Alaska Fish. Centr., Natl. Marine Fish. Serv., Natl. Oceanic Atmos. Admin., 2725 **Montlake Blvd.** E., Seattle, **WA.** 98112. Processed Report, 7 p.

Holmes, H.B.

1952. Loss of fingerlings in passing Bonneville Dam as determined by marking experiments. U.S. Fish and **Wildlife Service,** unpublished manuscript.

Appendix Table 1.--Survival study releases of marked subyearling fall chinook salmon at Bonneville Dam, June and July 1987.

Mark date	Release date	Number released)	Right dorsal brand (symbol - rotation)	Wire tag code (AG D1 D2)
- - - - - - - - - - - - - -	Upper Turbine Releases	- - - - - - - - - - - - - -		
June 22	June 24	11,051	Y - 4	23 20 52
23	25	16,807	Y - 1	23 20 57
24	26	14,406	Y - 1	23 20 62
		17,535	F - 1	23 21 02
25	27	18,852	Y - 1	23 21 04
26	28	21,071	Y - 1	23 21 09
	Subtotal	**99,722**		
June 29	July 01	17,644	IY - 1	23 21 14
30	02	**19,546**	Y - 3	**23** 21 19
		19,729	F - 2	23 21 22
July 01	03	18,244	Y - 3	23 21 24
02	04	**19,883**	**Y - 3**	23 21 29
03	05	**9,959k/**	Y - 3	23 21 34
	Subtotal	105,005		
July 06	July 08	**19,892**	IY - 3	23 21 39
		19,937	2X - 3	23 21 42
07	09	20,597	Y - 2	23 21 44
08	10	20,449	Y - 2	23 21 **49**
09	11	19,912	Y - 2	23 21 **54**
10	12	20,372	Y - 2	23 21 **59**
		20,422	F - 2	23 21 62
	Subtotal	141,581		
July 13	July 15	**20,368**	Y - 4	23 22 01
14	16	20,181	Y - 4	23 22 06
15	17	**19,426**	Y - 4	23 22 11
16	18	20,237	Y - 4	23 22 16
		20,457	F 2	23 22 19
17	19	20,460	Y - 4	23 22 21
	Subtotal	**121,129**		
Release group total		467,437		

Appendix Table 1.--Continued.

Mark **date**	Release **date**	Number **released**	Right dorsal brand **(symbol -** rotation)	Wire tag code **(AG** D1 D2)
- - - - - - - - - - - - - -		Lower Turbine Releases	- - - - - - - - - - - - - -	
June 22	June 24	**9,494**	5 - 4	**23** 20 53
23	25	**16,882**	5 - 1	23 20 **58**
		17,213	F - 1	23 20 60
24	26	18,105	5 - 1	23 20 63
25	27	18,235	5 - 1	23 21 05
26	28	17,760	5 - 1	**23** 21 10
	Subtotal	**97,689**		
June 29	July 01	**19,560**	13 - 1	23 21 15
		18,260	**2X -** 1	23 21 17
30	02	18,718	5 - 3	23 21 20
July 01	03	**19,864**	5 - 3	23 21 25
02	04	19,790	**5 - 3**	23 21 30
03	05	OJ	**5 - 3**	23 21 35
		0-	2X - 1	23 21 37
	Subtotal	**96,192**		
July 06	July 08	**19,873**	13 - 3	**23** 21 40
07	09	20,137	**5 - 2**	23 21 **45**
08	10	**20,335**	5 - 2	23 21 50
09	11	20,420	**5 - 2**	**23** 21 **55**
		20,461	2X - 1	23 21 57
10	12	**19,948**	5 - 2	23 21 60
	Subtotal	121,174		
July 13	July 15	19,112	5 - 4	23 22 02
14	16	20,310)	**5 - 4**	23 22 07
15	17	20,45511	5 - 4	23 22 12
		20,460	2X - 1	23 22 14
16	18	20,377	5 - 4	23 22 17
17	19	**19,696**	5 - 4	**23** 22 22
	Subtotal	120,410		
Release group total		**435,465**		

Appendix Table 1.--Continued.

Mark date	Release date	Number released	Right dorsal brand (symbol - rotation)	Wire tag code (AG D1 D2)
- - - - - - - - - - - - - -		Bypass System Releases	- - - - - - - - - - - - - -	
June 22	June 24	**9,630**	W - 4	23 **20** **54**
		11,344	**F - 4**	23 20 **55**
23	25	17,730	W - 1	23 20 **59**
24	26	**19,556**	W - 1	23 21 01
25	27	19,226	W - 1	23 21 06
26	28	**19,498**	W - 1	23 21 11
		8,043	F - 1	**23** 21 12
		11,622	F - 4	23 21 12
	Subtotal	**116,649**		
June 29	**July** 01	15,170	IN - 1	23 21 16
30	02	**19,549**	W - 3	23 21 21
July 01	03	**19,930**	W - 3	**23** 21 26
02	**04**	**19,849**	W - 3	23 21 31
	,t	19,641	**F - 4**	23 21 32
03	05	19,912	W - 3	23 21 36
	Subtotal	114,051		
July 06	**July 08**	**19,959**	IN - 3	23 21 41
07	09	20,497	W - 2	23 21 **46**
08	10	**20,448**	W - 2	23 21 51
		20,341	F - 4	23 21 52
09	11	20,455	W - 2	23 21 **56**
10	12	**20,453**	W - 2	23 21 61
	Subtotal	122,153		
July 13	July 15	**20,366**	W - 4	**23** 22 03
14	16	20,415	W - 4	**23** 22 **08**
¹/	¹¹	20,404	F - 4	23 22 09
15	17	20,450	W - 4	23 22 13
16	18	20,421	W - 4	23 22 18
17	19	**19,444**	W - 4	23 **22** 23
	Subtotal	121,500		
Release group total		474,353		

Appendix Table 1.--Continued.

Mark **date**	Release **date**	Number released	Right dorsal brand (symbol - rotation)	Wire tag code (**AG** D1 D2)
- - - - - - - - - - - -	**Hamilton Island Releases**			- - - - - - - - - - - - - - -
June 22	June 24	12,335	U - 4	23 20 **56**
23	25	17,164	U - 1	23 20 61
24	**26**	17,715	U - 1	23 21 03
25	27	18,215	U - 1	23 21 08
		19,042	F - 1	23 21 07
26	28	**18,896**	U - 1	23 21 13
	Subtotal	103,367		
June 29	July 01	17,304	2L - 1	23 21 18
30	02	**19,691**	**U - 3**	23 21 23
July 01	03	17,064	**U - 3**	**23** 21 28
		20,117	F - 3	23 21 27
02	04	**19,916**	**U - 3**	23 21 33
03	05	**19,946**	U - 3	23 21 **38**
	Subtotal	**114,038**		
July 06	July 08	**19,964**	2L - 3	**23** 21 43
07	09	**19,963**	U - 2	23 21 **48**
		20,777	F - 3	23 21 47
08	10	19,973	U - 2	**23** 21 53
09	11	20,156	U - 2	23 21 **58**
10	12	19,937	U - 2	23 21 63
	Subtotal	120,770		
July 13	July 15	20,423	U - 4	23 22 05
		20,353	F - 3	23 22 04
14	16	19,870	**U - 4**	23 22 10
15	17	**20,459**	U - 4	23 22 15
16	18	20,451	U - 4	23 22 20
17	19	**19,959**	U - 4	**23 22** 25
		20,449	F - 3	23 22 **24**
	Subtotal	141,964		
Release group total		480,139		
Project total		**1,857,394**		

Appendix Table 1.--Continued.

-' Marking mortalities have been deducted from daily totals.

bJ **Assumed 50% loss of the 19,918-fish group during transport and following release.**

nJ Assumed 100% loss of the 19,891-fish group during transport and following release.

a' Assumed 100% loss of the 19,963-fish group during transport and following release.

g.' **Brand RD 5 2 incorrectly applied to 15% of fish in this group.**

Appendix Table 2.--Flow data, operating conditions, and timing of survival study releases of subyearling fall chinook salmon at Bonneville Dam, June and July 1987 (metric and English units).

Metric

Date	Columbia R. Flora[1] lkia[3] 1s1	Columbia R. Teal). (Ct	Second Powerhouse Forebay (m1	Second Powerhouse Tailrace (ni	Second Powerhouse Flow4.& (k'a[3] /si	Turbine 17 nowt/ had fk•m[3] /sl	Turbine 17 fa;	Turbine 17 Loads. lbGI	Release tines if OT	LT	BY	RI	Tempering time (hi
06//24	2.9	11.8	22.1	3.1	1.6	0.4	19.6	66	0319	0330	0345	0430	1.00
06/25	3.9	18.4	22.8	3.9	1.6	**0.4**	18.9	66	0315	0330	0345	0430	1.00
06/26	3.7	18.4	23.0	3.8	1.7	0.4	19.3	66	0210	0200	0225	0315	2.00
06j27	3.5	20.0	22.9	3.7	1.7	0.4	19.2	66	0202	0215	0225	0250	2.00
06/28	2.9	18.9	22.9	3.4	1.7	0.4	19.5	66	0150	0215	0225	0255	3.00
07/01	3.9	20.6	23.1	4.1	1.6	0.4	19.0	66	0209	0158	0235	0305	3.00
07/02	3.9	20.6	23.0	**4.0**	1.6	0.4	19.0	66	0225	0209	0196	0255	2.50
07 / 03	3.4	20.0	23.3	3.8	1.6	**0.4**	19.5	66	0230	0200	0210	0310	4.00
07/04	2.9	20.0	23.3	3.4	1.6	**0.4**	19.9	66	0215	0230	0200	0306	3.00
07/05	2.8	19.5	23.2	3.1	1.6	0.4	20.1	66	0250	0300	0200	0345	4.00
07/08	2.8	19.5	22.9	3.0	1.6	0.4	19.9	66	0241	0224	0158	0315	2.25
07/09	3.7	19.5	23.1	3.7	1.6	**0.4**	19.4	66	0220	0208	0155	0245	3.25
07/10	**3.4**	19.5	23.0	3.7	1.6	0.4	19.3	66	0241	0220	0203	0255	3.00
01111	3.9	19.5	23.0	**4.0**	1.6	0.4	19.0	66	0221	0237	0158	0250	3.25
07/12	3.1	20.0	23.2	3.4	1.6	0.4	19.8	67	0217	0205	0155	0340	2.75
07115	3.4	20.6	23.0	3.8	1.6	0.4	19.2	67	0236	0220	0156	0252	3.25
07116	**3.4**	20.6	23.1	3.8	1.6	0.4	19.3	67	0234	0221	0158	0250	3.00
07117	3.4	20.6	23.2	3.8	1.6	0.4	19.4	67	0211	0226	0157	0240	3.50
07118	2.9	20.6	23.2	3.3	1.6	0.4	19.9	66	0224	0214	0155	0240	3.50
07119	2.7	20.6	23.2	3.1	1.6	0.4	20.1	67	0223	0214	0156	0240	3.25

Appendix Table 2.--Continued.

English

Date	Columbia R. FloAf./ (k· ft[a] /si	Temp. (- Ti	Second Powerhouse Forebay (fti	Tailrace (ft1	nowt· (k•ft[a] lsa	Turbine 17 FloaUU ik•ft[a] /s	Read (fti	Loads., (HH(	Release tines s./ JT	LT	ST	HI	Tempering tide (hl
06124	102.4	64	**74.4**	10.1	55.6	14	64.3	66	0315	0330	0345	0430	1.00
06125	138.7	65	74.9	12.8	57.8	14	62.1	66	0315	0330	0345	0430	1.00
06/ 26	130.0	65	75.6	12.6	60.7	14	63.0	66	0210	0200	0225	0315	2.00
06/27	122.3	68	75.1	12.1	60.0	14	63.0	66	0202	0215	0225	0250	2.00
06128	102.0	66	75.0	11.3	59.7	14	63.7	66	0150	0215	0225	0255	3.00
01/01	138.2	69	75.7	13.5	57.6	14	62.2	66	0209	0158	0235	0305	3.00
0102	136.9	69	75.6	13.1	57.3	**14**	62.5	66	0225	0209	0156	0255	2.50
0743	121.1	68	76.5	12.5	56.0	**14**	64.0	66	0230	0200	0210	0310	4.00
07/04	102.5	68	76.4	11.1	54.8	14	65.3	66	0215	0230	0200	0306	3.00
07/05	97.5	67	76.1	10.3	54.8	14	65.8	66	0250	0300	0200	0345	4.00
07;08	99.3	66	75.1	10.0	56.0	14	65.1	66	0241	0224	0158	0315	2.25
07109	131.1	66	75.8	12.1	56.2	14	63.7	66	0220	0208	0155	0245	3.25
07110	121.2	66	75.5	12.1	56.7	14	63.4	66	0241	0220	0203	0255	3.00
07111	139.2	67	75.6	13.2	57.6	14	62.4	66	0221	0237	0158	0250	3.25
07%12	109.8	68	76.1	11.1	55.9	14	65.0	67	0217	0205	0155	0340	2.75
07/15	120.5	69	75.6	12.6.	57.8	14	63.0	67	0236	0220	0156	0252	3.25
07116	121.0	69	75.7	12.6	57.6	14	63.1	67	0234	0221	0158	0250	3.00
07117	120.6	69	76.1	12.4	57.0	14	63.7	67	0211	0226	0157	0240	3.50
07118	101.6	69	76.0	10.8	54.9	14	65.2	66	0224	0214	0155	0240	3.50
07119	94.3	69	76.2	10.3	55.0	14	65.9	67	0223	0214	0156	0240	3.25

a/ Codes for treatment groups; UT = upper turbine, LT = lower turbine, BY = bypass system, and HI = Hamilton Island (control).

b/ Estimated by COE personnel from model data

c/ During the salmonid outmigration period, the Detailed Fishery Operation Plan for 1987 prescribes operation as near to peak efficiency as possible. From model studies of the Bonneville Second Powerhouse, estimated efficiency ranges from about 92.5 to 93% at 0.37 to 0.42 $k•m^3/s$ (13-15 $k•ft^3/s$) with a 18.3 m (60 ft) head.

Appendix Table 3.--Daily recovery of brands in the Columbia River estuary

from releases at Bonneville Dam, 1987.

| Date | Siteb/ | Daily total | Brandt./ Rotation | | |

Appendix 3.--Continued.

| | | | BrandL[1] | | |