CZES

Coastal Zone and
Estuarine Studies
Division

Northwest Fisheries
Science Center

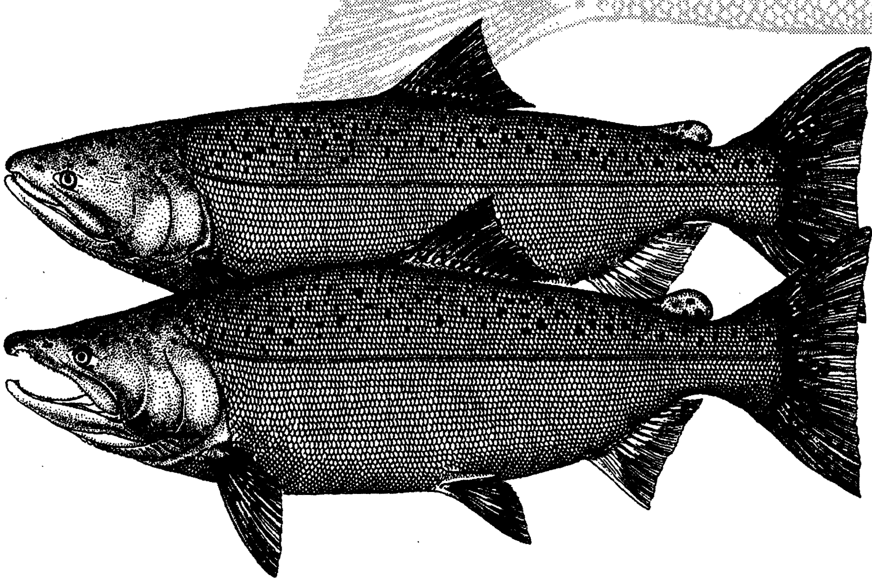
National Marine
Fisheries Service

Seattle, Washington

Relative survival of subyearling chinook salmon at Bonneville Dam, 1992

by
Richard D. Ledgerwood, Earl M. Dawley,
Lyle G. Gilbreath, L. Ted Parker,
Benjamin P. Sandford, and
Stephen J. Grabowski

December 1994



RELATIVE SURVIVAL OF SUBYEARLING CHINOOK SALMON AFTER PASSAGE THROUGH THE BYPASS SYSTEM AT THE FIRST POWERHOUSE OR A TURBINE AT THE FIRST OR SECOND POWERHOUSE AND THROUGH THE TAILRACE BASINS AT BONNEVILLE DAM, 1992

by

Richard D. Ledgerwood
Earl M. Dawley
Lyle G. Gilbreath
L. Ted Parker
Benjamin P. Sandford
and
Stephen J. Grabowski

Funded by

U.S. Army Corps of Engineers
(Contract DACW57-85-H-0001)

and

Coastal Zone and Estuarine Studies Division
Northwest Fisheries Science Center
National Marine Fisheries Service
National Oceanic and Atmospheric Administration
2725 Montlake Boulevard East
Seattle, Washington 98112-2097

December 1994

CONTENTS

INTRODUCTION

By virtue of its position as the lowermost dam, more juvenile salmon (*Oncorhynchus* spp.) must pass Bonneville Dam than any other hydroelectric project on the Columbia River. Hence, improvement in passage survival at Bonneville Dam can positively influence fishery production. In 1987, the National Marine Fisheries Service (NMFS), in cooperation with the U.S. Army Corps of Engineers (COE), began a multiyear study to evaluate relative survival of subyearling fall chinook salmon (*O. tshawytscha*) after passage through various routes at Bonneville Dam.

From 1987 to 1990, this research focused on passage through the Second Powerhouse turbines, juvenile bypass system, and tailrace, and over the spillway located between the First and Second Powerhouses (Ledgerwood et al. 1990, 1991a) (Fig. 1). We compared recovery percentages of juvenile test fish released during those studies and recaptured in the estuary. These recovery data indicated that fish passing through the Second Powerhouse bypass system survived at lower rates than fish passing the turbines or over the spillway. Continuing assessment of these survival differences will be based on recoveries of tagged adult fish in ocean fisheries, Columbia River fisheries, and Columbia River hatcheries.

Because of the similarity of the First and Second Powerhouse bypass systems, it is also important to evaluate survival of juvenile salmonids passing through the First Powerhouse bypass system. Furthermore, it is critical to directly compare the relative survival of fish passing the First and Second Powerhouse turbines.

Research in 1988 and 1989 (Gessel et al. 1989, 1990) indicated that subyearling chinook salmon migrating in summer are not effectively guided into the bypass system at either Bonneville Dam powerhouse: only about 27% were guided at the Second Powerhouse and a dismal 9% were guided at the First Powerhouse. Thus, the vast

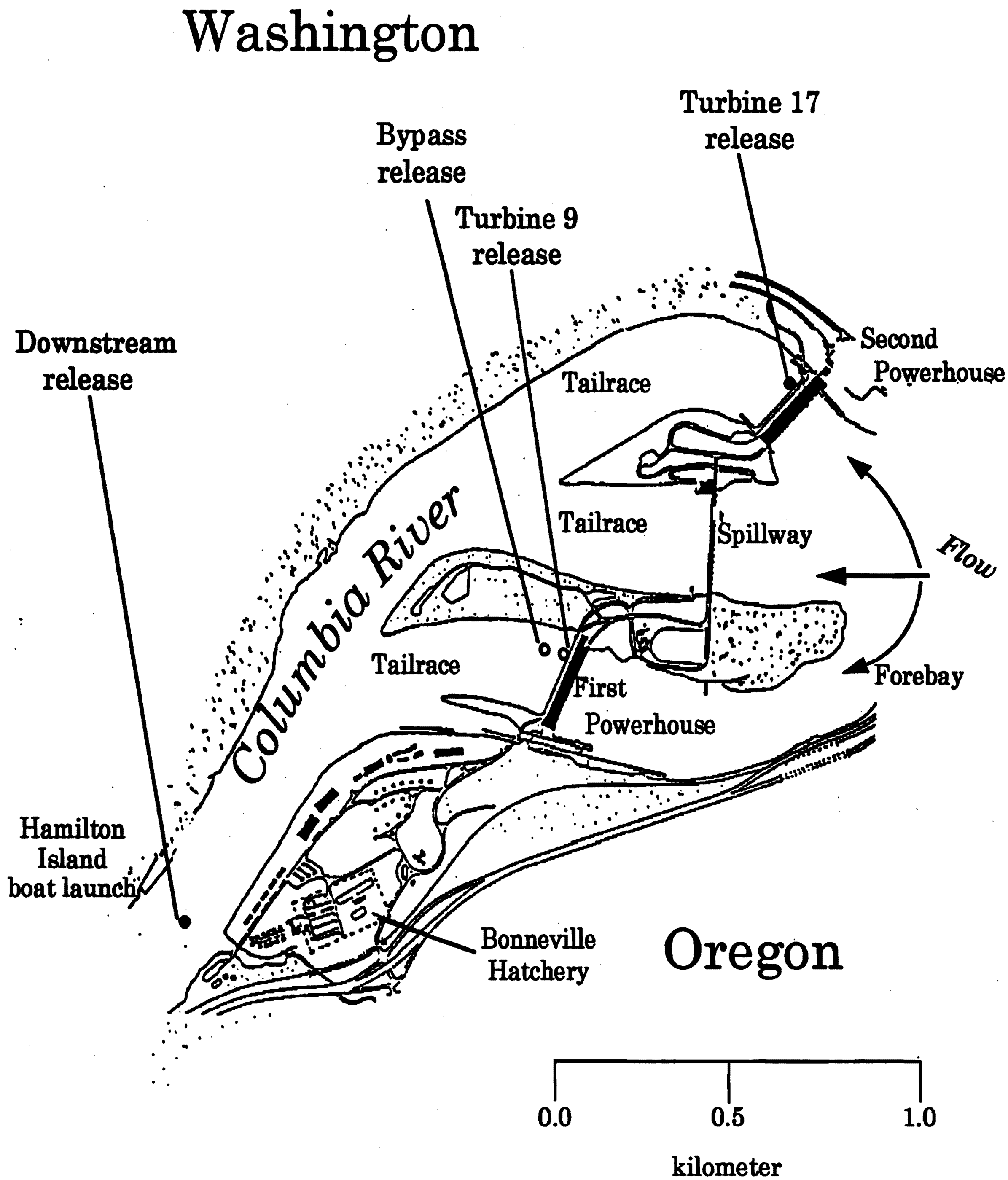


Figure 1.--Release locations for subyearling chinook salmon during the Bonneville Dam survival study, 1992.

majority of the summer migrants pass through turbines at Bonneville Dam, rather than being intercepted by submersible traveling screens (STS) and shunted into the bypass systems.

Past research on survival of juvenile salmonids through turbines at the First Powerhouse (Holmes 1952) indicated 85 to 89% survival; similar survival rates were reported in other studies at low-head Kaplan turbines (Schoeneman et al. 1961, Oligher and Donaldson 1966). Recent studies conducted at Bonneville Dam Second Powerhouse turbines suggested survival through these newer units ranged from 96 to 99% (Ledgerwood et al. 1990, 1991a). Turbines at the Second Powerhouse are more efficient because of an improved design and a 4.3-m deeper average submergence of the blades. Turbine efficiency has been directly correlated to increased juvenile salmon passage survival (Cramer 1965, Oliger and Donaldson 1966, Ruggles 1985). Thus the present operational criteria that favor juvenile salmonid passage through the First Powerhouse over passage through the Second Powerhouse at Bonneville Dam may be flawed.

Another important aspect of passage survival at Bonneville Dam is mortality occurring in the tailrace areas, which is thought to result primarily from predation by northern squawfish (*Ptychocheilus oregonensis*). Fish exit the bypass conduit as a point source release in an area of low velocity, and this likely allows more intensive predation on bypassed fish than for fish passing through the turbines, where they are broadcast over a wide area. Indeed, a U. S. Fish and Wildlife Service (FWS) study in 1990 documented that a higher proportion of bypass-released juvenile salmon were consumed by northern squawfish in the tailrace area of Bonneville Dam than were other groups of juvenile salmon released at the same time (Thomas Poe, FWS, Columbia River Field Station, Cook, WA. Pers. commun.). Consequently, the reduced estuarine recovery percentages of groups that passed Bonneville Dam via the Second Powerhouse bypass system may be at least in part the result of higher predation in the tailrace. In 1988 and 1989, measures of tailrace mortality at the Second Powerhouse were obtained by comparing recovery percentages of fish released directly into the tailrace to those of fish released downstream (mean tailrace mortality 7.6%) (Gilbreath et al. 1993). However, differences in survival between various passage routes and through the tailrace basins may change over time due to changes in river conditions and predator populations. For example, as a result of the system-wide predator control program funded by the Bonneville Power Administration (BPA), over 100,000 northern squawfish have been removed from the tailrace areas of Bonneville Dam in 1991 and 1992 (Willis and Nigro 1993), and removal of these predators has undoubtedly reduced tailrace mortality for juvenile salmon in this area.

In 1992, the NMFS expanded passage survival research at Bonneville Dam to include assessment of passage through the turbines and the bypass system at the First Powerhouse. This assessment was necessary to identify the safest passage routes at Bonneville Dam for juvenile salmon migrating in the summer. The objective of this study was to compare relative survival among marked groups of subyearling chinook salmon released into the bypass system of Bonneville Dam First Powerhouse, the turbines at the First and Second Powerhouses, and at a site in swift water about 2.5 km downstream from the dam. Estimates of long- and short-term relative survival will be developed by comparing recovery percentages of these different groups.

Short-term relative survival is based on recoveries of branded (Mighell 1969) juvenile fish recovered 157 km downstream from the dam, near the upper boundary of the Columbia River estuary at Jones Beach, Oregon (Fig. 2). Long-term relative survival will

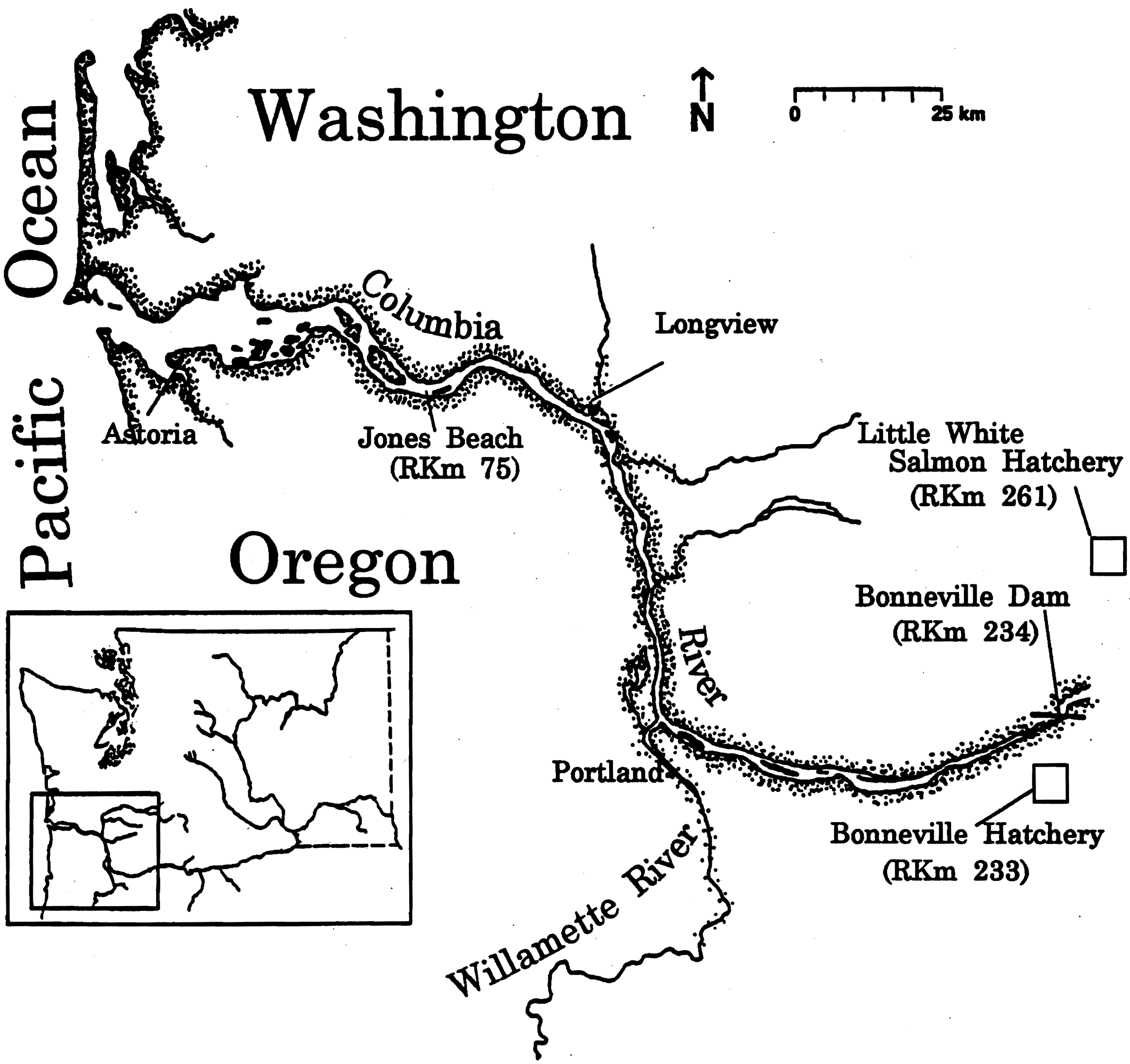


Figure 2.--Columbia River Basin showing the study area.

be based on coded-wire tags (CWT) (Bergman et al. 1968) from adult fish recovered in ocean fisheries, Columbia River fisheries, and Columbia River hatcheries. These comparative survival data are critical for developing dam operation procedures that will ensure maximum protection for juvenile fish and for assessing the necessity for alternate bypass-release sites.

A complementary study by the NBS (Thomas Poe, Principal Investigator) assessed distribution and juvenile salmon consumption rates by northern squawfish in the tailrace basins. Juvenile salmon CWTs recovered from the stomach contents of captured northern squawfish assisted in documenting impacts of predation on summer migrants from different release groups.

METHODS

Experimental Design

In 1992, as in previous years of this study, test dates were chosen to represent the typical conditions encountered by subyearling fall chinook salmon migrating past Bonneville Dam in the summer. Release locations at the First Powerhouse turbine and bypass were new, while those at the Second Powerhouse turbine and at the downstream sites were the same as in previous years. To provide an unbiased comparison of passage survival for the two turbine-release groups, water flow through both powerhouses was equalized for the period of this study. We assume that this provided similar predator attraction in the tailrace basins of each powerhouse.

Test Fish

In previous years, upriver bright stock fall chinook salmon reared at the Oregon Department of Fish and Wildlife Bonneville Hatchery (Fig. 2) were specifically chosen as test fish because of their similarity to summer migrants, availability, low probability of straying, and expected high percentage of adult returns. However, availability of upriver bright stock fish throughout the Columbia River Basin in 1992 was insufficient for the needs of this study. Therefore, tule stock subyearling chinook salmon from Little White Salmon National Fish Hatchery (NFH) were selected as study fish (Fig. 2). By the time the shortage of Bonneville Hatchery fish was confirmed, fish at Little White Salmon NFH had hatched, and disease concerns prevented their transfer to Bonneville Hatchery for rearing. Consequently, test fish were reared and marked at Little White Salmon NFH. Transfer of study fish to Bonneville Hatchery for rearing and marking would have been preferred because of logistics during marking, better expected return rates of adult fish to Bonneville Hatchery, and less straying of returning adult fish to other locations in the Columbia River Basin.

About 1.5 million subyearling chinook salmon were made available by FWS at Little White Salmon NFH. Test fish were the progeny of tule stock fall chinook salmon spawned at Spring Creek NFH and transferred as eyed eggs to Little White Salmon NFH for incubation and rearing. Fish size at release varied from 6.4 to 8.1 g (71.0 to 56.0 fish/lb), and was similar to the size of test fish used in previous years.

Little While Salmon NFH is upstream from Bonneville Dam, and the adult return rates for tule stock relative to upriver bright stock from Bonneville Hatchery are generally poor. Tule stock normally migrate earlier in the spring than upriver bright stock, but the test fish were reared in cold water with reduced rations to provide a size at release similar to the normal summer migrants.

Marking Procedures

Test fish were marked from 9 June to 6 July, Monday through Friday, using two marking crews; one crew worked from 0600 to 1400 h and the second from 1430 to 2230 h. About 60,000 fish were marked each day. The experimental design called for 14 release blocks for each of four treatment groups, with each group consisting of about 30,000 fish. Fewer fish than originally estimated were available at the time of marking, so the number of release blocks was reduced to 13. Each marked group had unique CWTs. Cold brands were used to visually identify fish from the different treatment groups.

Prior to marking, FWS personnel at Little White Salmon NFH transported unmarked fish to a holding pond adjacent to the mobile marking trailer. Fish were dip netted from the pond to the holding tanks in the trailer, apportioned to six marking stations, anesthetized with tricaine methanesulfonate (MS-222), and marked. Marked fish exited the trailer via 7.6-cm diameter PVC pipes that led to subdivided holding ponds.

The following measures were taken to ensure that marked groups did not differ in fish size, fish condition, rearing history, or mark quality: 1) the four marked groups needed for one release block (i.e., a single night's release) were marked simultaneously; 2) differences in mark quality among groups were minimized by rotating marking personnel between stations, and by alternating marks at each station at 4-hour intervals. Thus each marking team and each marking station contributed equivalent numbers of marked fish to each treatment group.

Tag Loss

To assess quality control in the tagging process, samples of about 100 fish from each marked group were collected and checked for the presence of CWTs. These samples were taken periodically at the outfall pipe from the marking trailer. In addition, samples of about 10 fish from each marked group were diverted into a separate holding pond at 2-hour intervals throughout the marking day and held for a minimum of 30 days to determine tag loss and brand retention. Due to space limitations at the hatchery, a single raceway was used to hold this sample. After the holding period, these fish were passed through a tag detector, after which brands (symbol, location, and rotation) were used to assign detection results to particular treatment groups. Estimates of tag loss, based on extended holding of fish from each marked release group, ranged from 0.6 to 9.6% ($\bar{x}$ = 2.8%, n = 6,429; Appendix Table A1). Tag loss estimates made immediately after marking were low (range 0 to 2.5%). This suggested that study fish continued to lose tags at a high rate for several days after tagging, and that tag loss may be related to poor tag placement in the fish (Vreeland 1990). Release data for juvenile and adult recovery comparisons include an adjustment using estimated tag loss for marked fish held a minimum of 30 days.

Release Locations

The specific release locations and rationales for 1992 were as follows:

1) Bypass First Powerhouse: Test fish descended through a 10.1-cm hose and were released about 1.5 m above the water surface of the downstream migrant collection channel adjacent to Gatewell B of Turbine 9 (Fig. 3). Released fish encountered a downwell at elevation 17.7 m, then passed through a 61-cm diameter by 220-m long conduit discharging them into the tailrace about 90 m downstream from the centerline

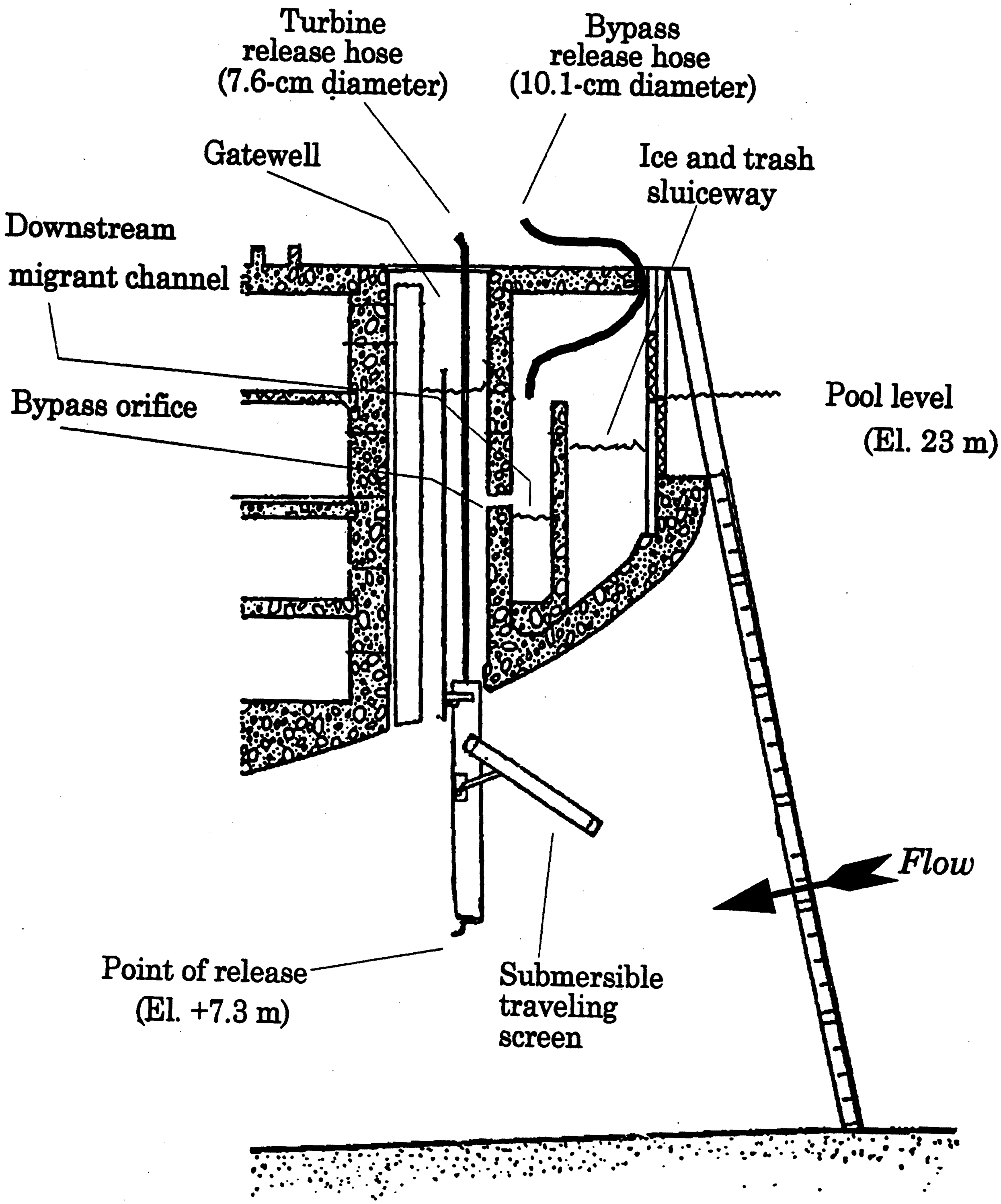


Figure 3.--Cross section of Bonneville Dam First Powerhouse depicting release locations for the turbine and bypass treatment groups.

between Turbines 9 and 10 at elevation 0 m (3 to 7 m below the water surface depending on tailwater elevation)[1].

2) Turbine First Powerhouse: Test fish descended through a 7.6-cm hose through Gatewell A and exited 1 m below the STS water-flow interception line, in the intake of Turbine 9 (Fig. 3). This site was selected to simulate passage of fish traveling too deep to be intercepted by an STS.

3) Turbine Second Powerhouse: As in previous years, test fish descended through a hose through Gatewell A and exited 1 m below the STS water-flow interception line, in the intake of Turbine 17 (Fig. 4). This site was also selected to simulate passage survival of fish traveling too deep in the water column to be intercepted by an STS.

4) Downstream: As in previous years, test fish were released at the river surface in mid-channel adjacent to the Hamilton Island boat launch ramp about 2.5 km downstream from the dam. This group did not pass through the dam or tailrace basins and was presumed to be downstream from effects of the dam and away from predators inhabiting the shoreline. Recoveries of fish released at this site, when compared to recoveries of fish from other treatment groups, isolate the effects of passage through the two powerhouses or bypass system and tailraces.

The turbine release groups entered the tailrace from the turbine discharge boil which dispersed fish over a large area (ca. 700 m^2). These were termed broadcast releases. The bypass and downstream groups entered the river directly from a pipe or hose; these were termed point-source releases.

---

1 All elevations are referenced to mean sea level.

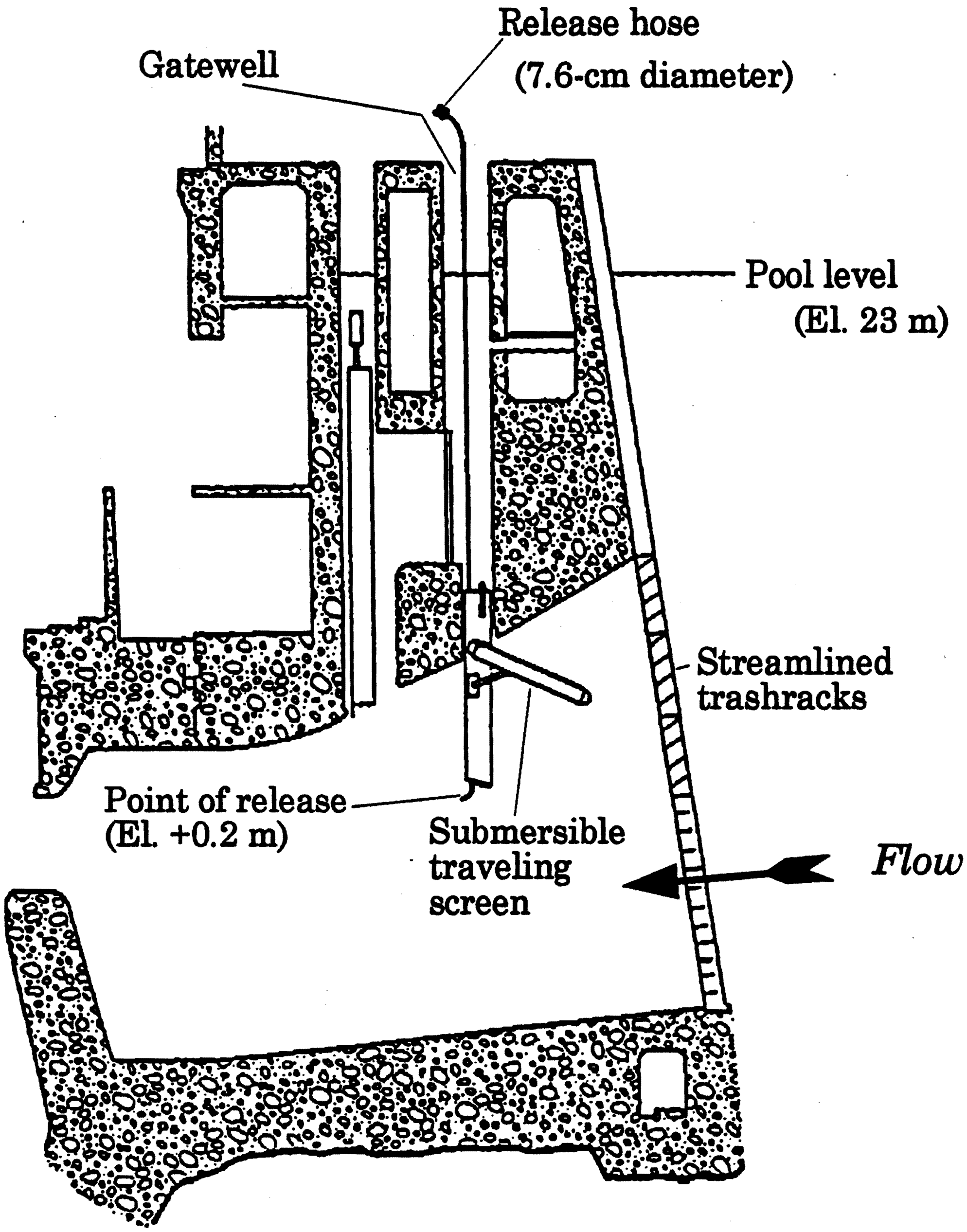


Figure 4.--Cross section of Bonneville Dam Second Powerhouse depicting release site of turbine treatment groups.

Project Operating Parameters

Powerhouse operating conditions were selected to provide conditions comparable to those employed for Second Powerhouse tests in 1987 to 1989 when the powerhouse operated at about one-half capacity, 53 to 60 kcfs (Appendix Table A2). These conditions were necessary because it would be impractical for both powerhouses to run at full capacity (about 250 kcfs) during the summer test period when low flow conditions normally exist. Turbine Units 1, 2, 5, 8, 9, 10 (First Powerhouse[2]) and 11, 16, 17, and 18 (Second Powerhouse) were selected for operation. Simultaneous operation of these units provided similar flows at both powerhouses, minimized tailrace eddies, produced high flow past the juvenile bypass outlet, and maintained attraction flows to the fishway entrances for upstream migrant adult salmonids. Turbines used to pass test fish were operated at full load and maximum efficiency while other turbines were operated within 1% of maximum efficiency from 0001 to 0800 h on test days. At other times from 18 June to 10 July water flows through the powerhouses were about equal with turbines operated within 1% of maximum efficiency which provided comparable tailrace flow conditions.

Release Procedures

On 13 days during the period from 18 June to 9 July, test groups of about 30,000 marked fish were released at the four release sites during the early morning darkness (0200-0300 h). The release days were selected to coincide with the migration period of juvenile upriver bright fall chinook salmon past Bonneville Dam, and also to provide sufficient time for marking yet not require more than 15 days holding prior to release. Uniquely branded fish groups were released at each site during four time series: 18-20 June; 23-25 June; 29 June-2 July; and 7-9 July.

---

[2] Operation of Unit 8 was optional depending on available river flow.

On release days, loading of transport trucks generally began at 2100 h and was completed by about 2400 h. Fish were crowded from the holding pond into a funnel-shaped 450-L transfer container. When sufficient fish were inside the container, a slide gate was closed and the container was lifted over the transport truck. Next, another gate opened, allowing fish and water to drain through the funnel into the transport truck. It required about five lifts to load each 30,000-fish treatment group.

Three transport trucks were used on each release night. Two 17,000-L capacity tank trucks with two compartments were used for releases at the dam. The three treatment groups released at the dam were rotated nightly between the different tank compartments. The tank truck used initially for the downstream release had 4,500-L capacity; however, for the final three releases, a 5,300-L capacity tank truck was used because test fish had grown to a size which approached maximum desirable loading density. Fish loading densities were less than 60 g fish/L water (0.5 lb/gal) for all releases. All releases were made from the transport tanks using smooth-bore plastic hoses to transfer the fish to the release point; a 7.6-cm diameter by 30-m long hose for the turbine releases, a 10.1-cm diameter by 30-m long hose for the bypass releases, and a 10.1-cm diameter by 6-m long hose for the downstream releases. Vertical distances from the transport trucks to the water surface were about 10.7, 6.1, and 1.2 m (35, 20, and 4 ft), respectively, for bypass, turbines, and downstream releases. Bypass and downstream release groups exited the hoses about 1.5 m above the water surface and turbine release groups were subsurface.

Hose discharge velocities were calculated to be 5.1, 3.3, and 4.1 m/second, respectively, for bypass, turbines, and downstream releases. Velocity differences between water exiting the release hoses and the surrounding water were calculated to be less than

4.5 m/second. The lowest differential velocity shown to cause mortality of juvenile salmonids in laboratory tests was 15 m/second (Groves 1972). Releases were timed such that fish from both powerhouses could traverse their respective tailrace basins and pass the downstream site at about the same time as the downstream groups were released: Second Powerhouse at 0200 h; First Powerhouse at 0230 h; and the downstream release at 0300 h.

Sampling at Jones Beach

Short-term survival differences among release groups were assessed from comparisons of tagged fish recovered near the upper boundary of the Columbia River estuary at Jones Beach (RKm 75). Recovery methods and sampling site were those described by Dawley et al. (1985, 1988). In addition to determining recovery differences, captured fish were observed for differences in descaling, injuries, size, food consumption, and migration behavior.

During the period from 15 June through 31 July, sampling was conducted by two or three crews working 7 days per week for 8 to 12 hours per day, beginning at sunrise (Appendix Table A3). On 26-27 June, beach- and purse-seine sampling was extended through the night to determine diel migratory behavior of juvenile salmon. Two stocks of branded/CWT subyearling fall chinook salmon were targeted in estuarine sampling: tule stock used in this study and upriver bright stock used for a concurrent study at release sites near Bonneville Hatchery (Ledgerwood et al. In prep). One group from each stock was released at or just downstream from Bonneville Dam, and within a few hours of one another. The upriver bright stock group was released at about 2200 h on 19 June, and the tule stock group was released at about 0300 h on 20 June. Releases at the same site and on the same day provided the opportunity to compare biological characteristics of the two stocks prior to release and behavioral characteristics after migration to the estuary. Both purse seines (midstream) and beach seines (Oregon shore) were used to determine whether study fish were more abundant in midstream or near shore (Fig. 5) and to maximize effort using the gear type that captured the greatest numbers of study fish.

All captured fish were processed aboard the purse seine vessels. The catch from each set was anesthetized and enumerated by species. Numbers of dead, injured, or descaled salmonids were recorded, and subyearling chinook salmon were examined for excised adipose fins and brands. Marked fish were separated for further processing, while unmarked fish were returned to the river immediately after counting, evaluation, and recovery from anesthesia. Descaling was judged rapidly while counting and separating study fish from non-study fish. Fish were classified as descaled when 25% or more of their scales on one side were missing.

Freeze brands were used to identify study fish; from these fish we collected CWTs, obtained biological samples, compared fish size among treatment groups, and adjusted the daily sampling effort to attain the desired minimum sample size of 0.5% of the number of fish released. Brand information, biological and associated sampling data (i.e., date, vessel code, gear code, set number, time of examination, fork length, and incidence of descaling and mortality) were immediately entered into a computer database and printed. Fork lengths of marked fish were recorded to the nearest mm. All brand- identified study fish (including those with illegible brands) were sacrificed to obtain CWTs, which identified treatment group and day of release.

The heads of branded fish were processed in lots, which were segregated by recovery day and site of capture. An aqueous solution of 40% potassium hydroxide was used to dissolve the heads for ease in extracting CWTs. All CWTs were decoded and later

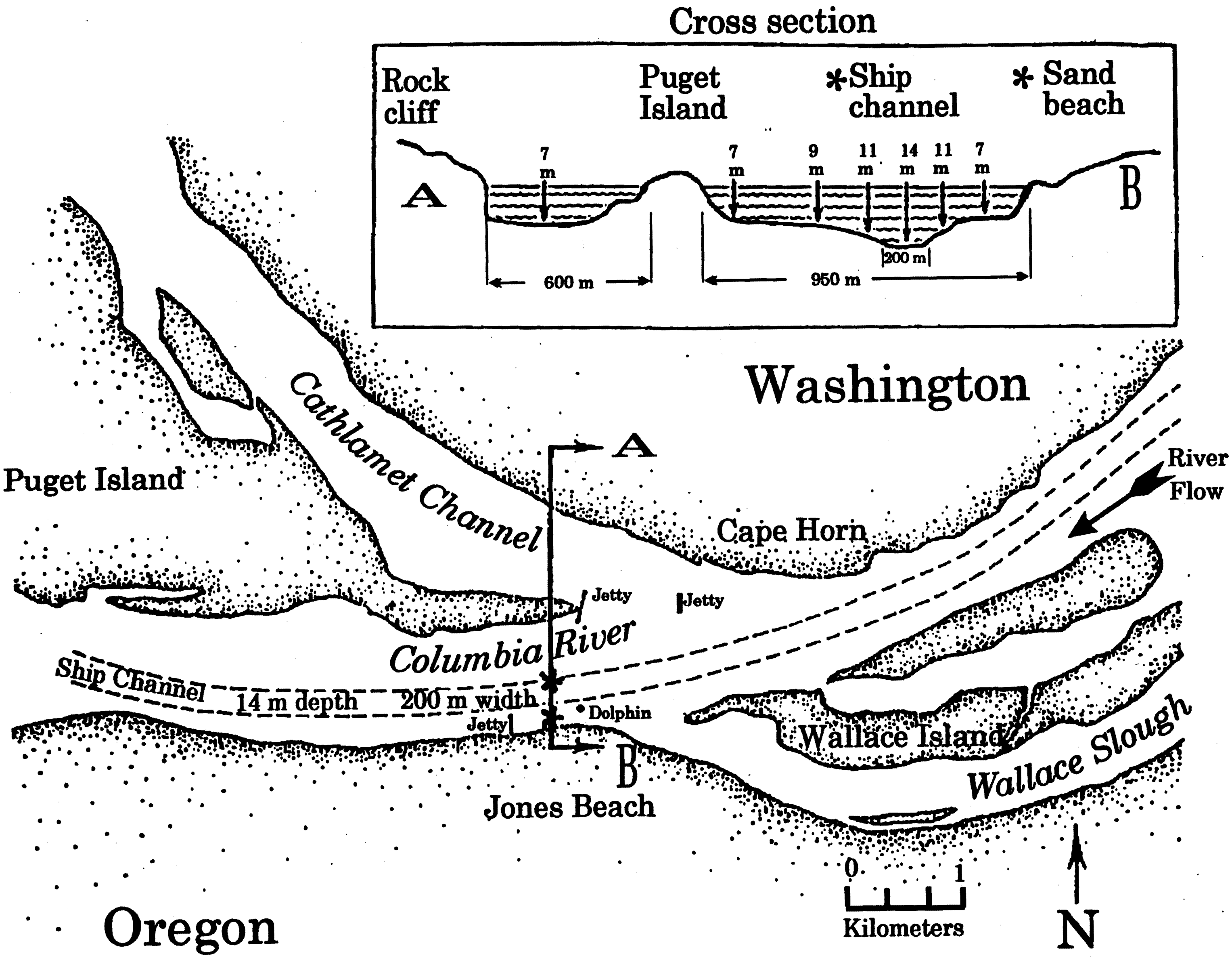


Figure 5.--Jones Beach, Columbia River, sampling sites. The beach and purse seining areas are denoted by asterisks.

verified; additional details of tag processing followed the methods described by Ledgerwood et al. (1990).

Data standardization procedures--All catch data obtained from 19 June to 22 July were adjusted to obtain a standard catch per day per group. Purse-seine data were standardized to a 10-set-per-day effort, while beach-seine data were standardized to a 5-set-per-day effort. The following formula was used to calculate a standardized catch per day for each group:

$$A_i = N_i\,(S \div P_i)$$

where:

A_i = Standardized purse or beach seine catch on day i

N_i = Actual purse or beach seine catch on day i

S = Constant (weighted daily average number of purse seine sets (10) or beach seine sets (5) during the sampling period)

P_i = Actual number of purse or beach seine sets on day i.

On the day when there was no sampling effort for a particular gear type (e.g., beach seine, 25 June), the standardized catch was derived by averaging standardized catches for 1 day prior to and 1 day after the missed day. Dates of median recovery for each marked fish group were determined using the combined standardized data from purse and beach seine catches. Movement rates for each CWT group were calculated as the distance from the downstream release site (RKm 232) to Jones Beach (RKm 75) divided by the travel time (in days) from release date to the date of the median fish recovery.

Biological Samples and Assessments--Samples for physiological analyses of marked fish groups prior to release were collected by NBS personnel (Philip Haner, Cook, WA) at Bonneville Hatchery (upriver bright stock) and Little White Salmon NFH (tule stock) and after migration to Jones Beach. At the hatcheries, sample fish (n = 30) were netted directly from the holding raceways. Physiological samples were obtained at Jones Beach during the diel sampling period on 26-27 June. Fish were identified as to stock by freeze brand, and immediately placed in a lethal dose of MS-222. Fork length and body weight were recorded and a gill sample frozen for later gill Na^+-K^+ ATPase analysis.[3] The fish were then videotaped to measure reflectance[4] and frozen in liquid nitrogen to remove a skin sample for guanine analysis (Beeman et al. 1990). Reflectance is an experimental non-lethal technique to measure silvering of juvenile salmonids as an appraisal of smoltification; the guanine sample was used for confirmation.

Stomachs from 116 upriver bright stock and 126 tule stock fish were collected during the diel sample period. Stomachs were excised (esophagus to pyloric caeca) and cleaned of external fat. A stomach fullness value, based on the proportion of the total stomach length containing food, was estimated. A scale of 1 to 7 was used to quantify the fullness as follows: 1 = empty, 2 = trace of food, 3 = one-quarter full, 4 = one-half full, 5 = three-quarters full, 6 = full, and 7 = distended full (Terry 1977). All stomachs appearing empty were opened for examination, and a value of 2 was assigned if traces of

---

[3] For details of methodology see Schreck, R. C., J. W. Beeman, D. W. Rondorf, and P. V. Haner. A microassay for gill sodium, potassium-activated ATPase in juvenile salmon. Trans. Am. Fish Soc. In press. (Available from National Biological Survey, MP 5.48L Cook-Underwood Rd, Cook, WA 98605-9701.)

[4] Haner, P. V., J. C. Faler, R. C. Schreck, and D. W. Rondorf. Unpublished. Skin reflectance as a non-lethal measure of smoltification for juvenile salmonids. (Available from National Biological Survey, MP 5.48L Cook-Underwood Rd. Cook, WA 98605-9701.)

food were observed. Subsamples of collected stomachs were preserved in 10% buffered formaldehyde solution for weight determination and content analysis as described by Kirn et al. (1986a). Holding time prior to fullness observations was about 35 minutes.

Statistical Analysis

Differences among recovery percentages for each tagged group at Jones Beach were evaluated by analysis of variance (ANOVA) using a randomized block design where each release day was considered a block (Sokal and Rohlf 1981). Transformation of percentages was not required. Differences among descaling percentages of branded groups were also evaluated using ANOVA. Fisher's protected least significance difference procedures were used to rank treatment means for significant F-tests (Petersen 1985). Chi-square goodness of fit was used to test the hypothesis that different marked groups released the same day had equal probability of capture through time (Zar 1974). The mean values of physiological samples (gill Na^+-K^+ ATPase, reflectance, and guanine measurements) were compared using a General Linear Model to test for significant differences among stocks ($P < 0.05$).

RESULTS

In 1992, a total of 1,540,863 fish were marked with freeze brands, CWTs, and excision of the adipose fin (Table 1). A total of 5,063 study fish were recovered in the estuary (ca. 0.3% of those released); most were midriver migrants captured with purse seines (Appendix Table A4). Handling mortality of all captured juvenile salmon was less than 0.5% and descaling rates averaged less than 2%. Only four descaled study fish were captured at Jones Beach, too few for meaningful among-treatment comparison.

Movement Rates and Temporal Catch Patterns

Temporal catch distribution of treatment groups released each day are shown in Figures 6 and 7, and in Appendix Figures A1-A3. Movement rates of study fish between the release site at Bonneville Dam and the collection site at Jones Beach, except for fish released during the final series (7-9 July), ranged from 17 to 39 km/day (Table 2). These rates were somewhat faster than those observed in previous years; however, during the final release series, fish slowed noticeably (movement rates 12.1 to 15.7 km/day) despite about a 17% increase in river flow from the previous series. There were no indications of movement rate differences among treatment groups. Comparisons of fork-length distributions of study fish at release to those at Jones Beach suggest that all fish grew during migration; fish from the final release series were largest (Figs. 8-9). There were no indications of temporal differences in size among treatment groups at recovery (Figs. 10-11). However, fish from the first three release series (18-20 June, 23-25 June, and 29 June-2 July) generally increased in mean length during the period of recovery, while fish from the final release series generally decreased in mean length. Water temperature at Little White Salmon NFH remained a nearly constant 10°C throughout the marking/holding period of study fish, whereas water temperatures of the Columbia

Table 1.--Summary of releases of marked subyearling chinook salmon, Bonneville Dam survival study, 1992.

Marking dates	Release date	Brand[a]	Number released: Total[b]	Untagged[c]	Tagged[d]	Wire tag code (AG D1 D2)[e]
First Powerhouse Turbine-9 releases						
9-10 Jun	18 Jun	RDLT1	29,843	930	28,913	23 27 53
11-12 Jun	19 Jun	RDLT1	29,830	930	28,900	23 27 54
12-16 Jun	20 Jun	RDLT1	27,049	843	26,206	23 27 55
16-17 Jun	23 Jun	RDLT3	29,793	2,872	26,921	23 27 56
17-19 Jun	24 Jun	RDLT3	29,691	2,862	26,829	23 27 57
19-22 Jun	25 Jun	RDLT3	30,168	2,908	27,260	23 27 58
22-24 Jun	29 Jun	LDLT1	29,725	292	29,433	23 27 59
24-25 Jun	30 Jun	LDLT1	28,955	284	28,671	23 27 60
25-27 Jun	1 Jul	LDLT1	29,689	292	29,397	23 27 61
27-30 Jun	2 Jul	LDLT1	29,748	292	29,456	23 27 62
30 Jun-1 Jul	7 Jul	LDLT3	29,631	261	29,370	23 27 63
1-3 Jul	8 Jul	LDLT3	29,707	262	29,445	23 28 03
3-6 Jul	9 Jul	LDLT3	28,765	254	28,511	23 28 05
		Subtotals	382,594	13,282	369,312	
Second Powerhouse Turbine-17 releases						
9-10 Jun	18 Jun	RDLX1	29,882	1,480	28,402	23 28 09
11-12 Jun	19 Jun	RDLX1	29,807	1,477	28,330	23 28 10
12-16 Jun	20 Jun	RDLX1	29,827	1,477	28,350	23 28 12
16-17 Jun	23 Jun	RDLX3	29,743	1,044	28,699	23 28 15
17-19 Jun	24 Jun	RDLX3	30,527	1,071	29,456	23 28 17
19-22 Jun	25 Jun	RDLX3	29,808	1,046	28,762	23 28 18
22-24 Jun	29 Jun	LDLX1	29,721	340	29,381	23 28 20
24-25 Jun	30 Jun	LDLX1	29,660	340	29,320	23 28 23
25-27 Jun	1 Jul	LDLX1	29,960	343	29,617	23 28 24
27-30 Jun	2 Jul	LDLX1	30,009	344	29,665	23 28 27
30 Jun-1 Jul	7 Jul	LDLX3	29,855	289	29,566	23 28 29
1-3 Jul	8 Jul	LDLX3	29,840	289	29,551	23 28 30
3-6 Jul	9 Jul	LDLX3	29,809	288	29,521	23 28 33
		Subtotals	388,448	9,828	378,620	
First Powerhouse Bypass releases						
9-10 Jun	18 Jun	RDLC1	29,812	580	29,232	23 27 39
11-12 Jun	19 Jun	RDLC1	29,823	580	29,243	23 27 40
12-16 Jun	20 Jun	RDLC1	29,833	580	29,253	23 27 41
16-17 Jun	23 Jun	RDLC3	29,689	2,017	27,672	23 27 42
17-19 Jun	24 Jun	RDLC3	29,702	2,018	27,684	23 27 43
19-22 Jun	25 Jun	RDLC3	29,821	2,026	27,795	23 27 44

Table 1.--Continued.

Marking dates	Release date	Brand[a]	Number released: Total[b]	Untagged[c]	Tagged[d]	Wire tag code (AG D1 D2)[e]
22-24 Jun	29 Jun	LDLC1	29,690	339	29,351	23 27 45
24-25 Jun	30 Jun	LDLC1	29,576	338	29,238	23 27 46
25-27 Jun	1 Jul	LDLC1	30,171	345	29,826	23 27 47
27-30 Jun	2 Jul	LDLC1	29,738	340	29,398	23 27 48
30 Jun-1 Jul	7 Jul	LDLC3	29,796	447	29,349	23 27 49
1-3 Jul	8 Jul	LDLC3	30,207	454	29,753	23 27 50
3-6 Jul	9 Jul	LDLC3	28,844	433	28,411	23 27 51
		Subtotals	386,702	10,497	376,205	
Downstream releases						
9-10 Jun	18 Jun	RDLU1	29,831	2,034	27,797	23 28 36
11-12 Jun	19 Jun	RDLU1	29,832	2,034	27,798	23 28 39
12-16 Jun	20 Jun	RDLU1	29,819	2,033	27,786	23 28 40
16-17 Jun	23 Jun	RDLU3	29,811	693	29,118	23 28 43
17-19 Jun	24 Jun	RDLU3	29,676	690	28,986	23 28 45
19-22 Jun	25 Jun	RDLU3	29,749	692	29,057	23 28 46
22-24 Jun	29 Jun	LDLU1	29,686	443	29,243	23 28 48
24-25 Jun	30 Jun	LDLU1	29,679	443	29,236	23 28 51
25-27 Jun	1 Jul	LDLU1	27,941	417	27,524	23 28 53
27-30 Jun	2 Jul	LDLU1	29,758	444	29,314	23 28 54
30 Jun-1 Jul	7 Jul	LDLU3	29,751	181	29,570	23 28 57
1-3 Jul	8 Jul	LDLU3	29,763	181	29,582	23 28 58
3-6 Jul	9 Jul	LDLU3	27,823	170	27,653	23 28 60
		Subtotals	383,119	10,455	372,664	
		Totals	1,540,863	44,062	1,496,801	

[a] Brand position (RD = right dorsal, LD = left dorsal), brand used (two-letter combination), and brand rotation (1 or 3).

[b] Total fish marked; branded, tagged, and adipose fin clipped.

[c] Estimated number of fish released without coded-wire tags. See Appendix Table A1 for tag loss sample data.

[d] Estimated number of fish released with coded-wire tags.

[e] AG D1 D2 = Agency, Data 1, Data 2.

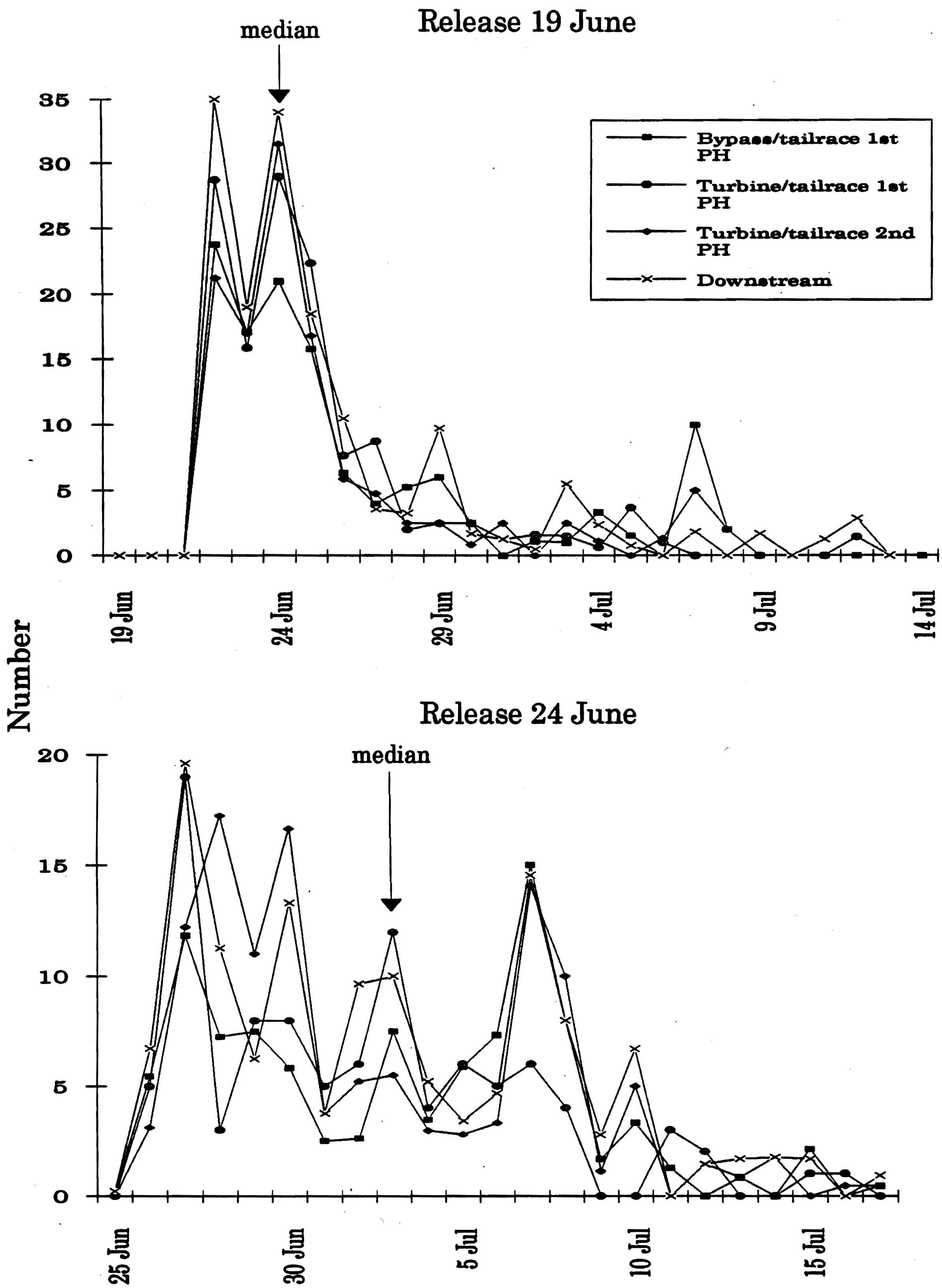


Figure 6.--Daily recoveries of test fish by treatment (standardized for effort) at Jones Beach, 1992. Data shown are from the first two release series.

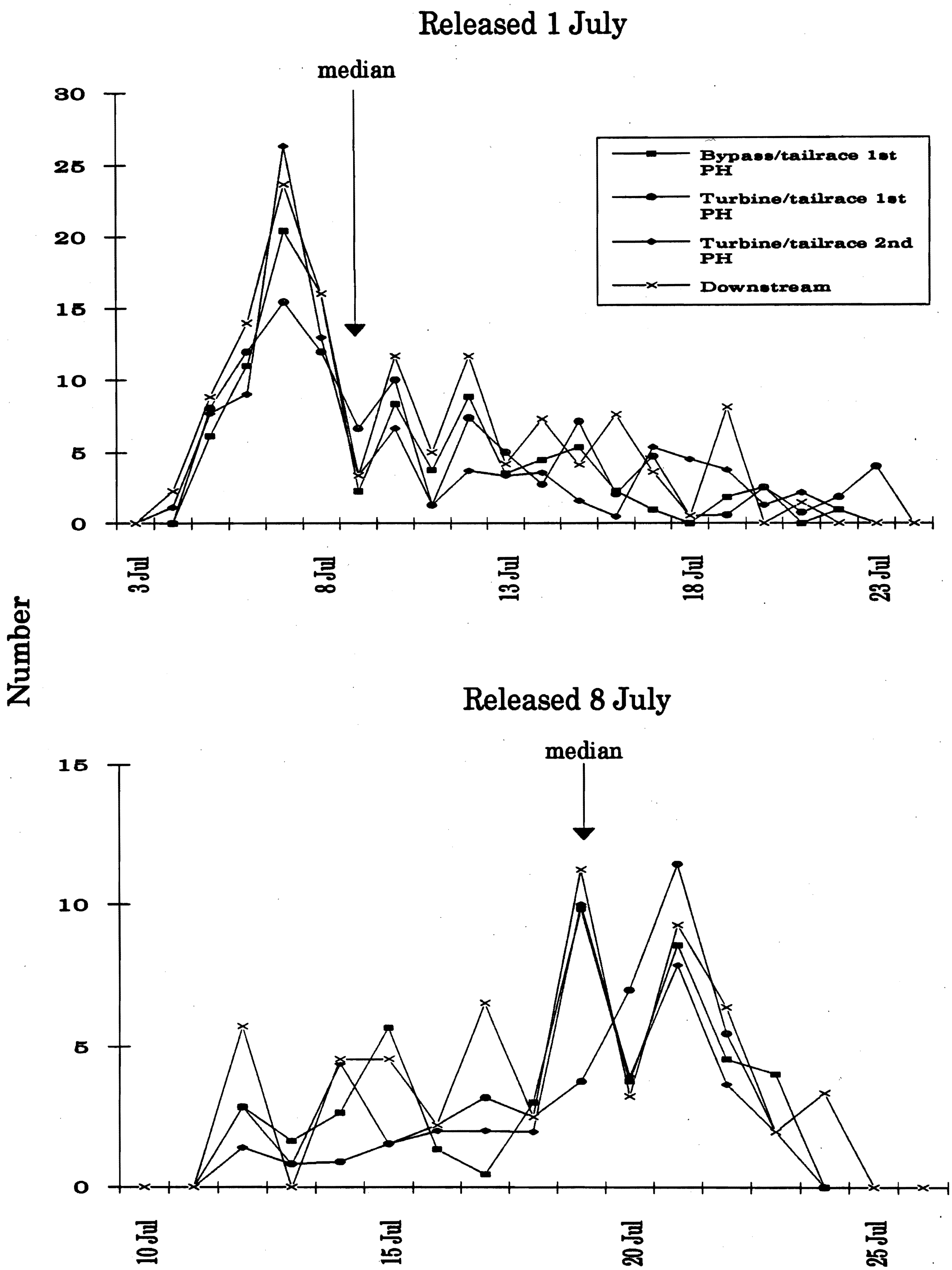


Figure 7.--Daily recoveries of test fish by treatment (standardized for effort) at Jones Beach, 1992. Data shown are from the second two release series.

Table 2.--Movement rates from Bonneville Dam to Jones Beach for marked groups of subyearling chinook salmon, Bonneville Dam survival study, 1992.

Release date[b]	Movement rate (km/day)[a]				Flow
	Bypass First PH	Turbine First PH	Turbine Second PH	Downstream	(k•ft^3/second)[c]
18 June	26.2	26.2	22.2	26.2	198
19 June	31.4	31.4	31.4	31.4	198
20 June	39.3	31.4	31.4	31.4	198
23 June	26.2	26.2	31.4	26.2	165
24 June	19.6	17.4	26.2	19.6	131
25 June	17.4	19.6	17.4	19.6	125
29 June	19.6	19.6	19.6	19.6	119
30 June	19.6	22.4	22.4	22.4	119
1 July	22.4	19.6	22.4	19.6	122
2 July	26.2	19.6	26.2	17.4	122
7 July	13.1	13.1	12.1	13.1	142
8 July	14.3	13.1	14.3	14.3	142
9 July	15.7	15.7	15.7	15.7	142

[a] Purse seine plus beach seine recoveries standardized to a constant daily effort (Appendix Table A4). Movement rate = distance from the downstream release site (RKm 232) to recovery site (RKm 75) ÷ travel time in days from release to median fish recovery.

[b] Fish released during early morning darkness.

[c] Average flow through Bonneville Dam within 4 days of the date that the median fish was captured; by convention, English units were used for river flow volumes (k•ft^3/second = 1,000 ft^3/second = 28.3 m^3/second); flow data courtesy Sonja Dodge, COE, Water Management Division, Portland, OR.

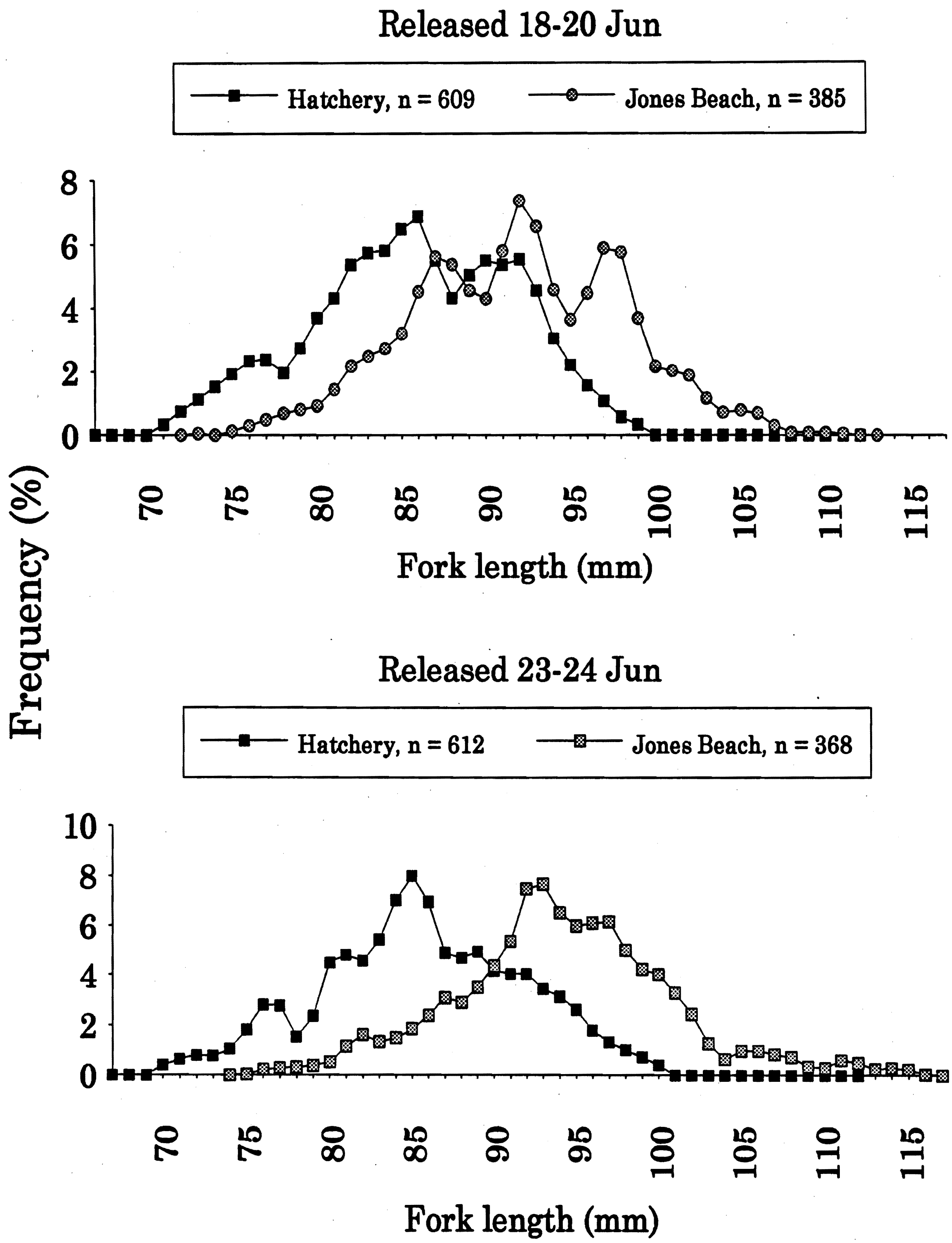


Figure 8.--Fork length distributions (2 point moving average) of fish at release and after recovery in the estuary, first two release series, 1992.

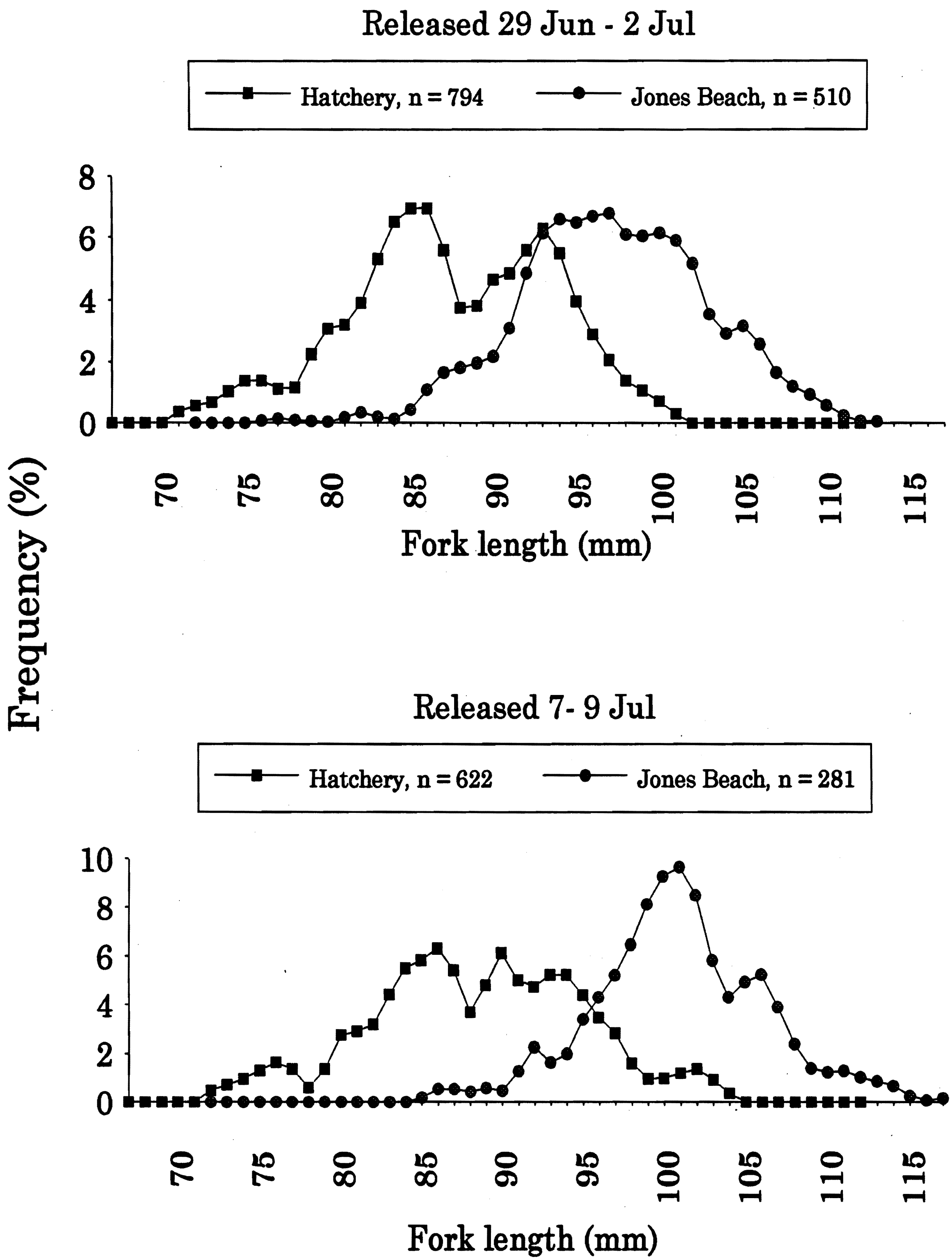
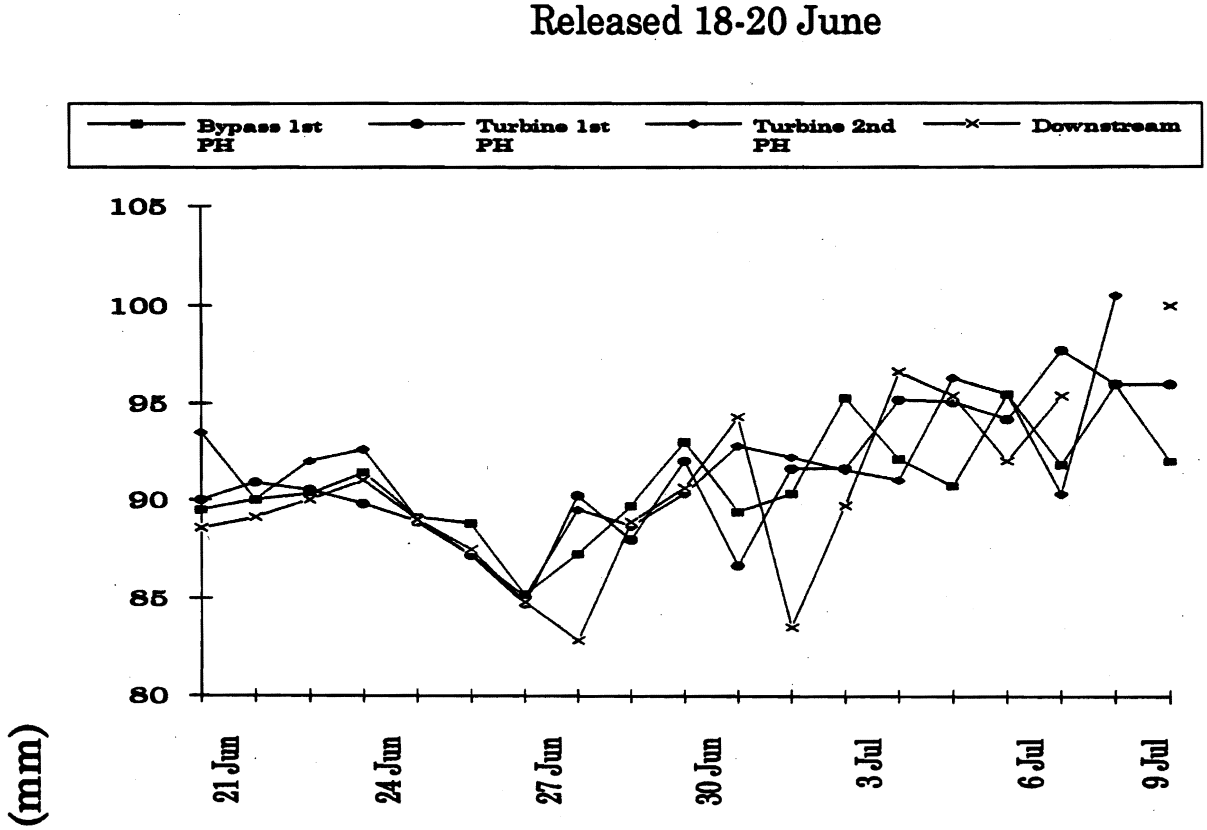


Figure 9.--Fork length distributions (2 point moving average) of fish at release and after recovery in the estuary, second two release series, 1992.



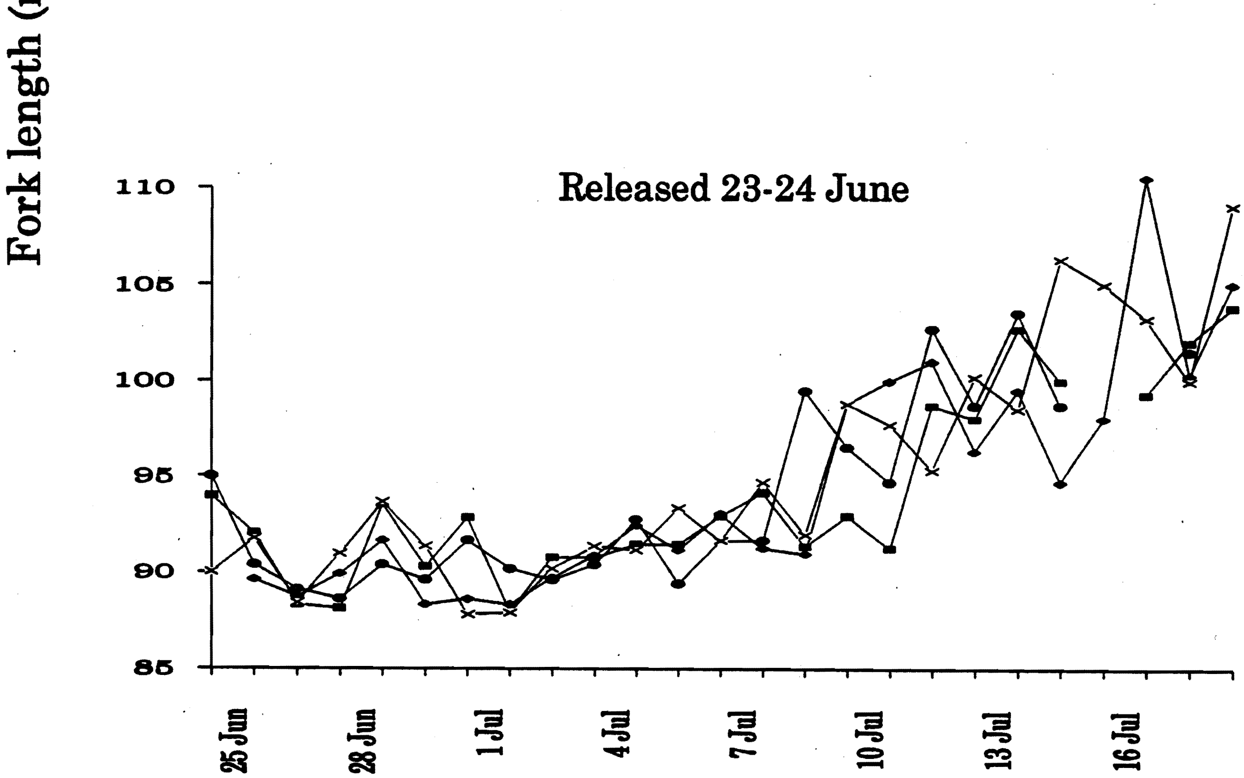


Figure 10.--Daily mean fork lengths of subyearling chinook salmon recovered at Jones Beach, comparing treatments from the first two release series, 1992.

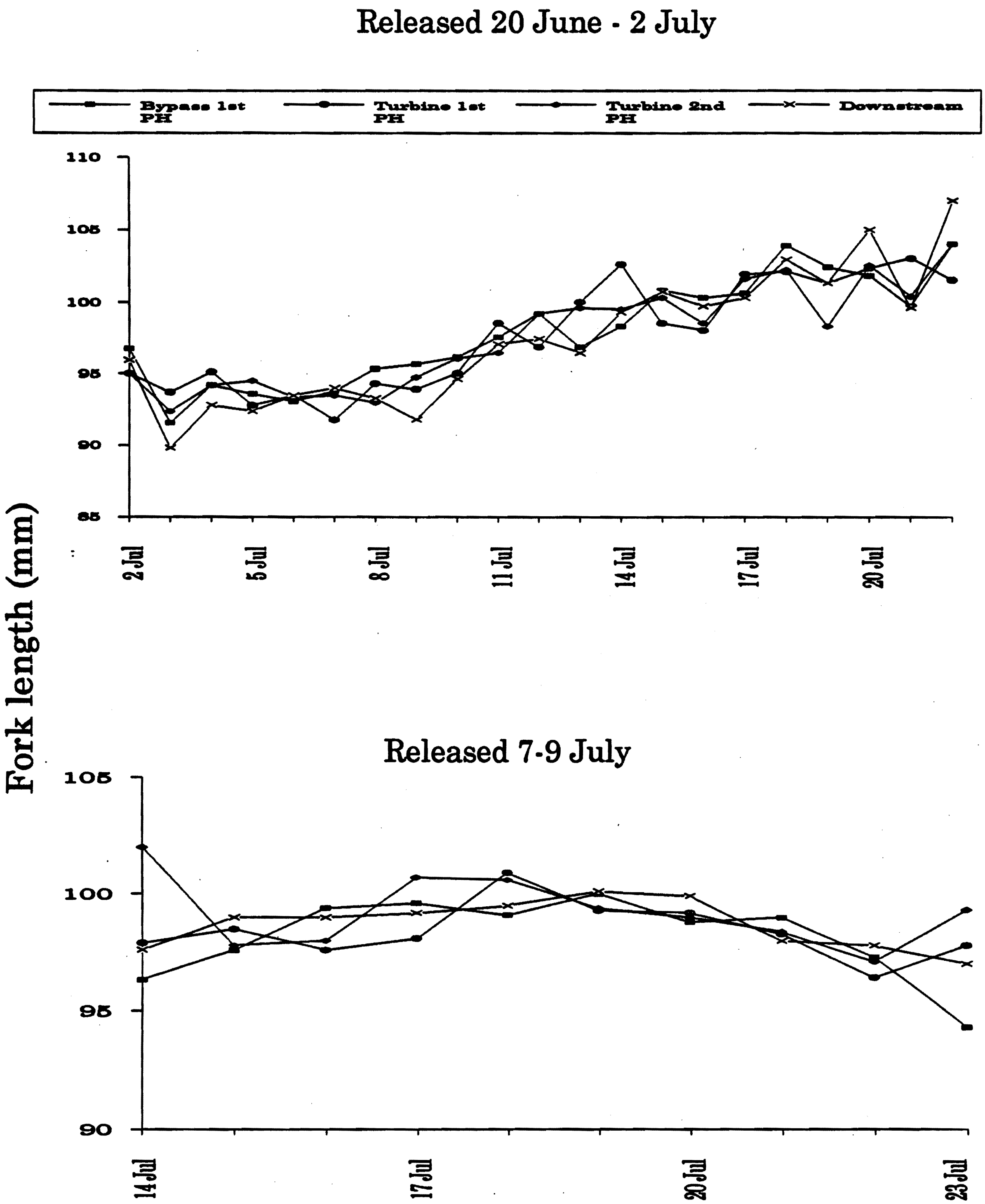


Figure 11.--Daily mean fork lengths of subyearling chinook salmon recovered at Jones Beach, comparing treatments from the second two release series, 1992.

River at Jones Beach increased from 17 to 22°C through the recovery period, substantially higher than in previous years (Fig. 12). During the final release series, we speculated that elevated Columbia River water temperatures shocked study fish, or slowed their movement rate, and increased mortality of fish among all treatment groups.

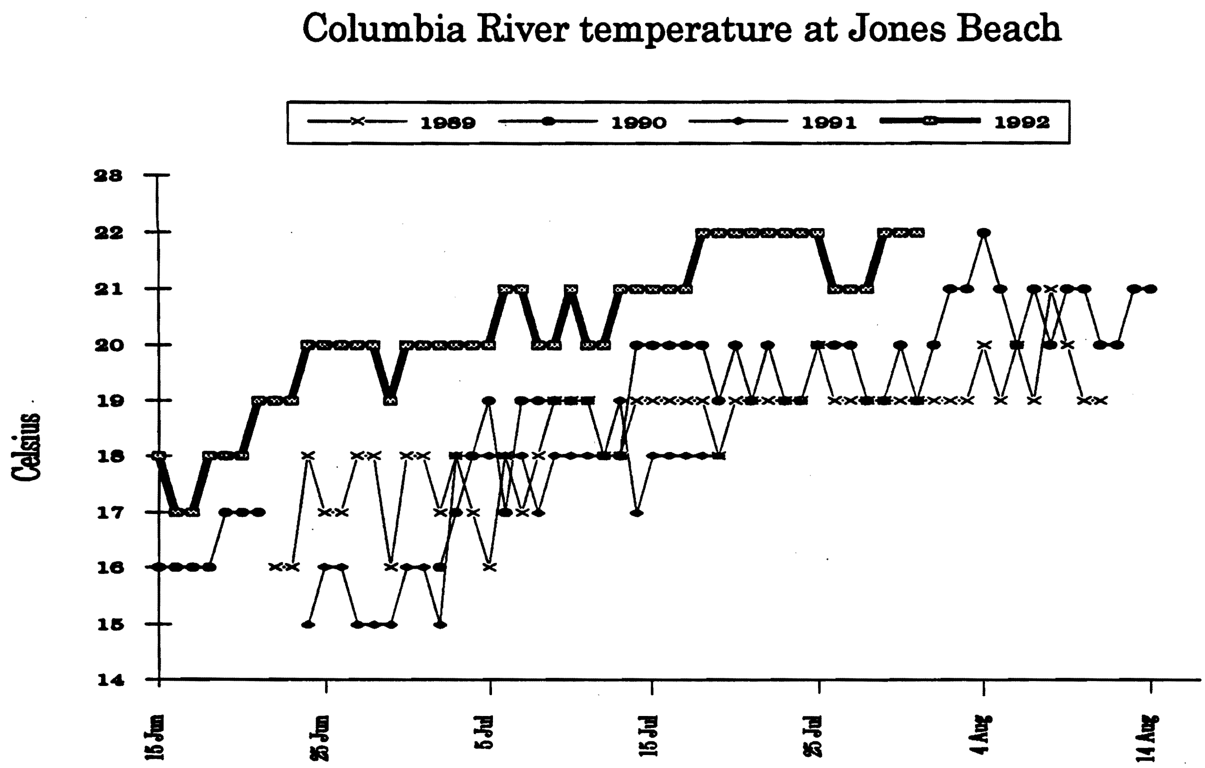
Diel Recovery Patterns

During the diel sampling period, about 12,000 and 10,000 subyearling chinook salmon (primarily non-study fish) were captured in the beach seine and in purse seines, respectively (Appendix Table A5). In the purse seines, catches were highest at sunrise, generally decreased during the day, increased again at dusk, and were lowest at night (Fig. 13). In the beach seine, catches peaked about 3 hours after sunrise, declined during the afternoon, increased again in late afternoon, and were also lowest at night. The pattern of very low catches during darkness for both gear types is similar to patterns observed in previous years at Jones Beach (Ledgerwood et al. 1991a, b).

During the diel sampling period, a total of 429 branded upriver bright stock and 502 branded tule stock subyearling chinook salmon were captured in beach and purse seines (Appendix Table A6). There were no apparent differences between stocks in purse seine or beach seine diel catch patterns (Fig. 14). Catch patterns of both stocks followed the general pattern exhibited by unmarked subyearling chinook salmon except for the vagaries associated with small sample size.

Smoltification

During the migration to Jones Beach, tule stock and upriver bright stock both exhibited significant ($P < 0.05$) increases in smoltification indicators (gill Na^+-K^+ ATPase activity, reflectance, and guanine) (Table 3). Upriver bright stock had significantly higher



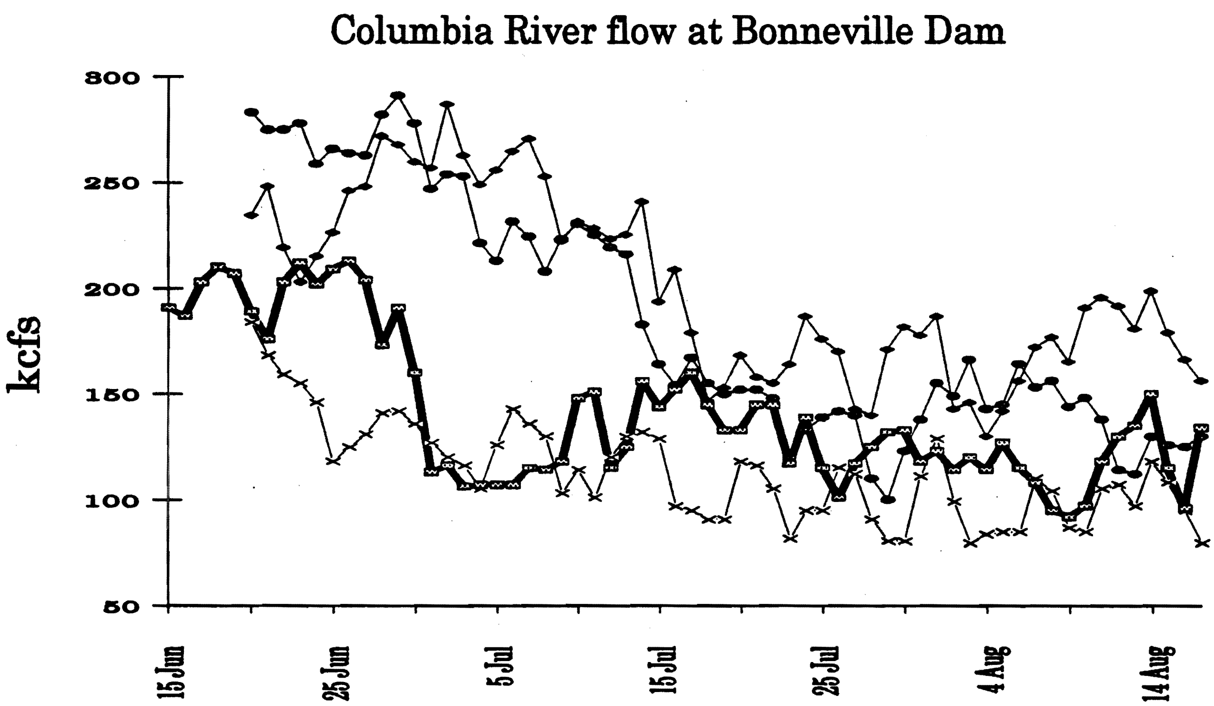


Figure 12.-- Temperature of the Columbia River at Jones Beach and total flow of Columbia River at Bonneville Dam, 1989-1992. By convention, English units were used for river flow volumes (kcfs = 1,000 ft^3/second = 28.3 m^3/second).

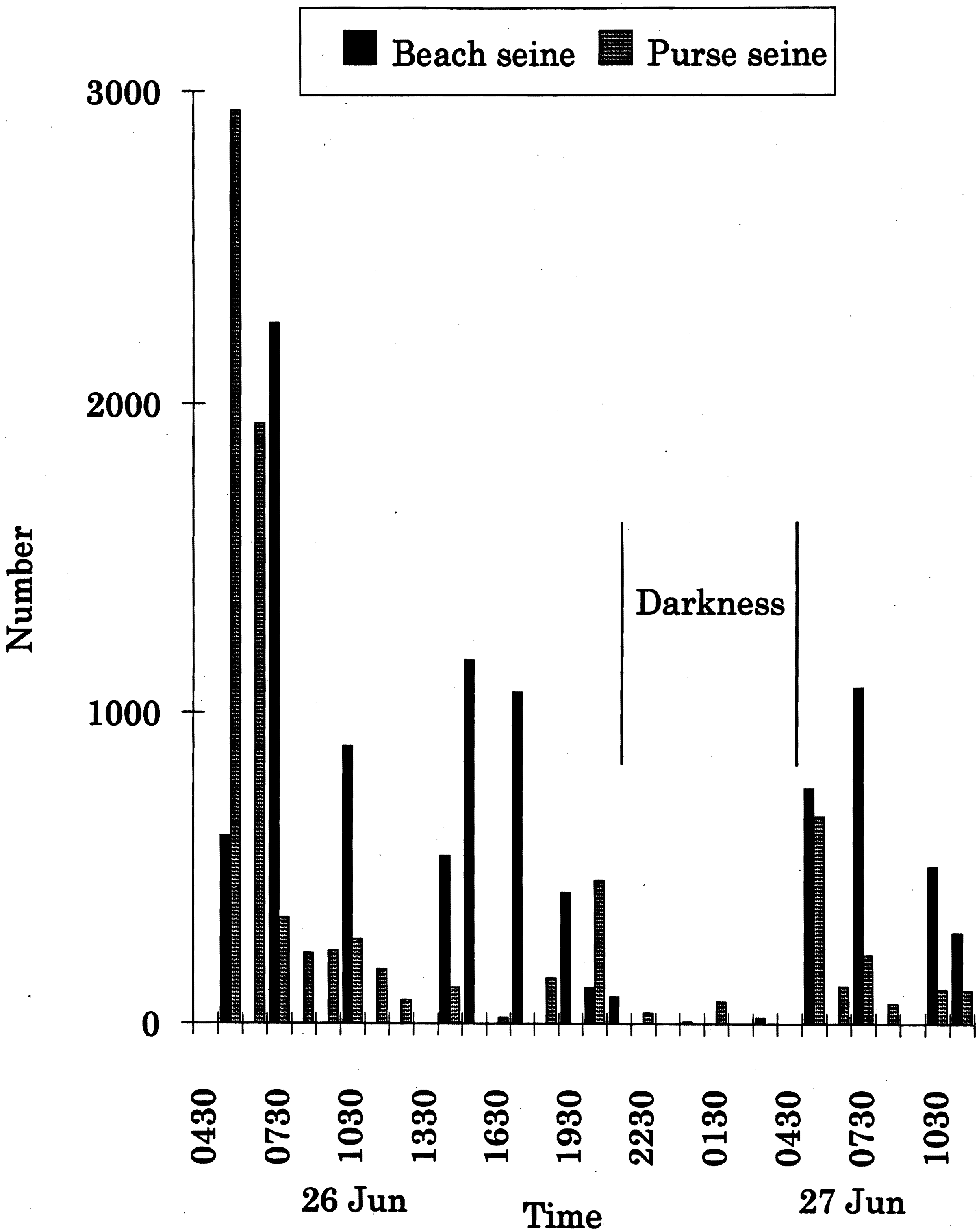


Figure 13.--Diel catch patterns for unmarked subyearling chinook salmon captured in beach and purse seines at Jones Beach, 1992.

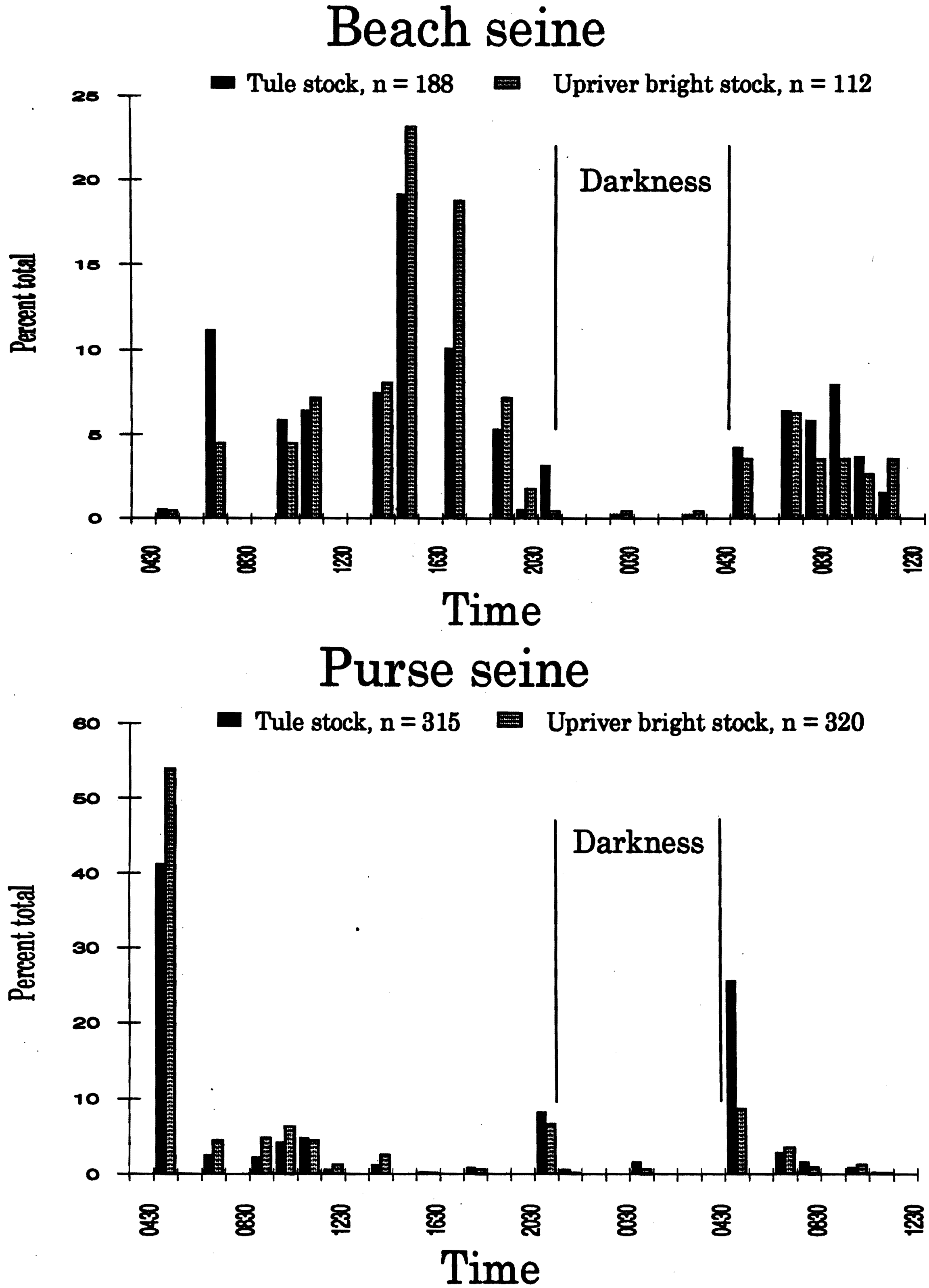


Figure 14.--Diel catch patterns of tule stock and upriver bright stock subyearling chinook salmon captured in beach and purse seines at Jones Beach, 26-27 June 1992.

Table 3.--Smoltification parameters measured for tule stock (Little White Salmon National Fish Hatchery) and upriver bright stock (Bonneville Hatchery) subyearling chinook salmon prior to release at the hatcheries and after migration to Jones Beach; mean values ± SE, n = 27-30 fish per sample.

Stock	Site	Reflectance (units)[a]	ATPase (μmoles $P_i \cdot$mg prot$^{-1} \cdot$hr^{-1})	Guanine (mg GN$\cdot$cm^2 skin^{-1})
Tule	Bonneville Hatchery	2.23 ± 0.10	8.76 ± 0.48	1.28 ± 0.03
Tule	Jones Beach	5.26 ± 0.16	23.91 ± 1.44	1.58 ± 0.08
Upriver bright	Little White Salmon Hatchery NFH	2.43 ± 0.12	11.36 ± 0.64	1.44 ± 0.06
Upriver bright	Jones Beach	5.52 ± 0.17	30.40 ± 2.03	1.70 ± 0.10

[a] Reflectance is measured on a shade of gray ranging from 0 to 10.

ATPase and guanine values both prior to release and after migration to Jones Beach than did tule stock ($P < 0.05$); differences in reflectance between the two stocks were insignificant. Efforts to establish a relationship between measurements of skin reflectance and other measures of smoltification are ongoing (Philip Haner, NBS, Columbia Field Station, Cook, WA. Pers. commun.).

Stomach Fullness and Diet Composition

Based on examination of stomach fullness of subsamples of marked fish, study fish were feeding by the time they arrived at Jones Beach. Stomachs were generally about half full in fish collected during daylight hours. Upriver bright stock had slightly higher fullness values than tule stock sampled concurrently (mean fullness 4.0 and 4.5, respectively; Fig. 15). During the diel sampling period, mean weights of stomach contents in upriver bright stock were generally higher than for tule stock (Fig. 16). In both stocks, mean weights of stomach contents increased during the morning hours, declined somewhat during the afternoon, and were lowest at night, similar to observations made in 1989 and 1990 (Ledgerwood et al. 1990, 1991a).

Analysis of stomach contents showed that crustaceans and insects were the dominant prey items in the diet of both upriver bright and tule stock fall chinook salmon (Fig. 17; Appendix Table A7). Small cladocerans were numerically dominant, although larger crustaceans (amphipods and mysids) and two orders of insects (Psocoptera and Diptera) were important dietary components based on their larger size. These principal dietary components for subyearling chinook salmon were similar to previous years (Ledgerwood et al. 1990, 1991a; Kirn et al. 1986a). Although numbers of prey items fluctuated considerably, there were no apparent diel differences in diet composition and, except for a greater number of cladocerans in beach-seine captured fish, there were no

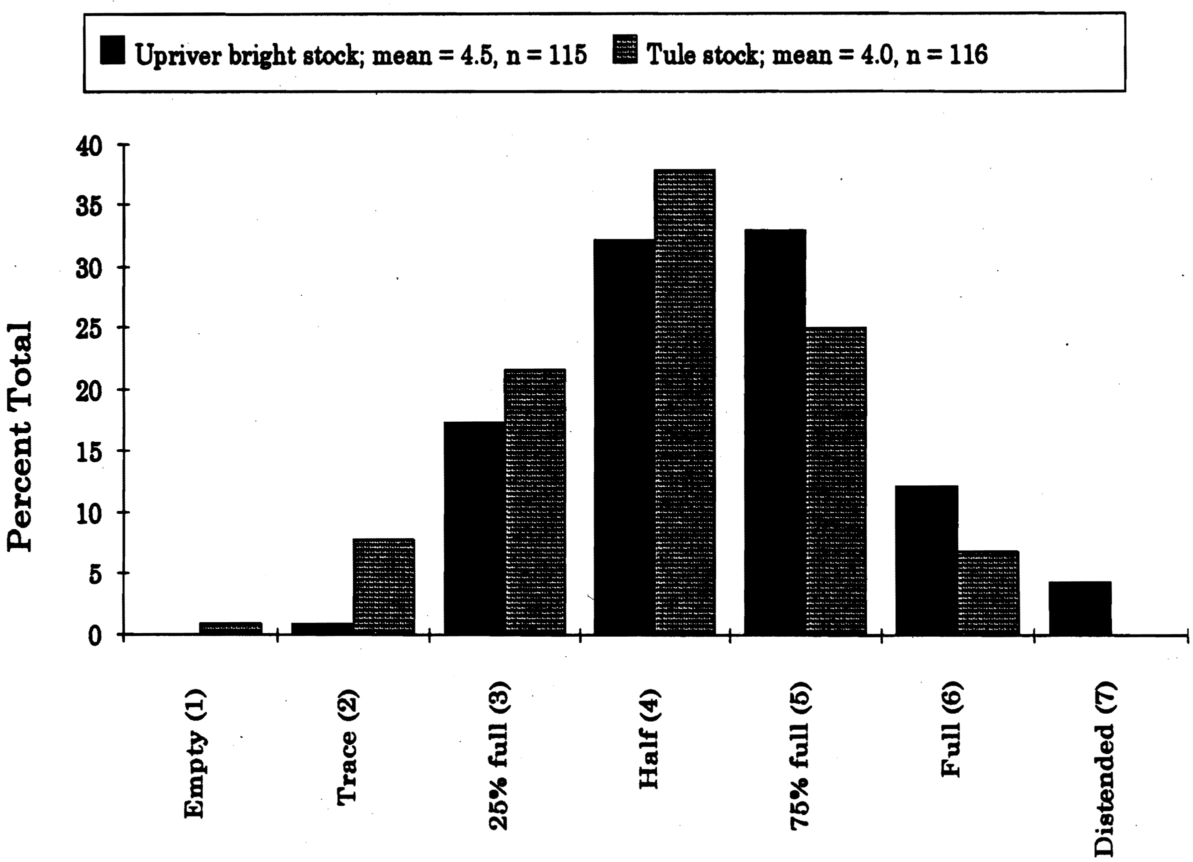


Figure 15.--Relative stomach fullness for upriver bright stock and tule stock subyearling chinook salmon captured at Jones Beach, 1992.

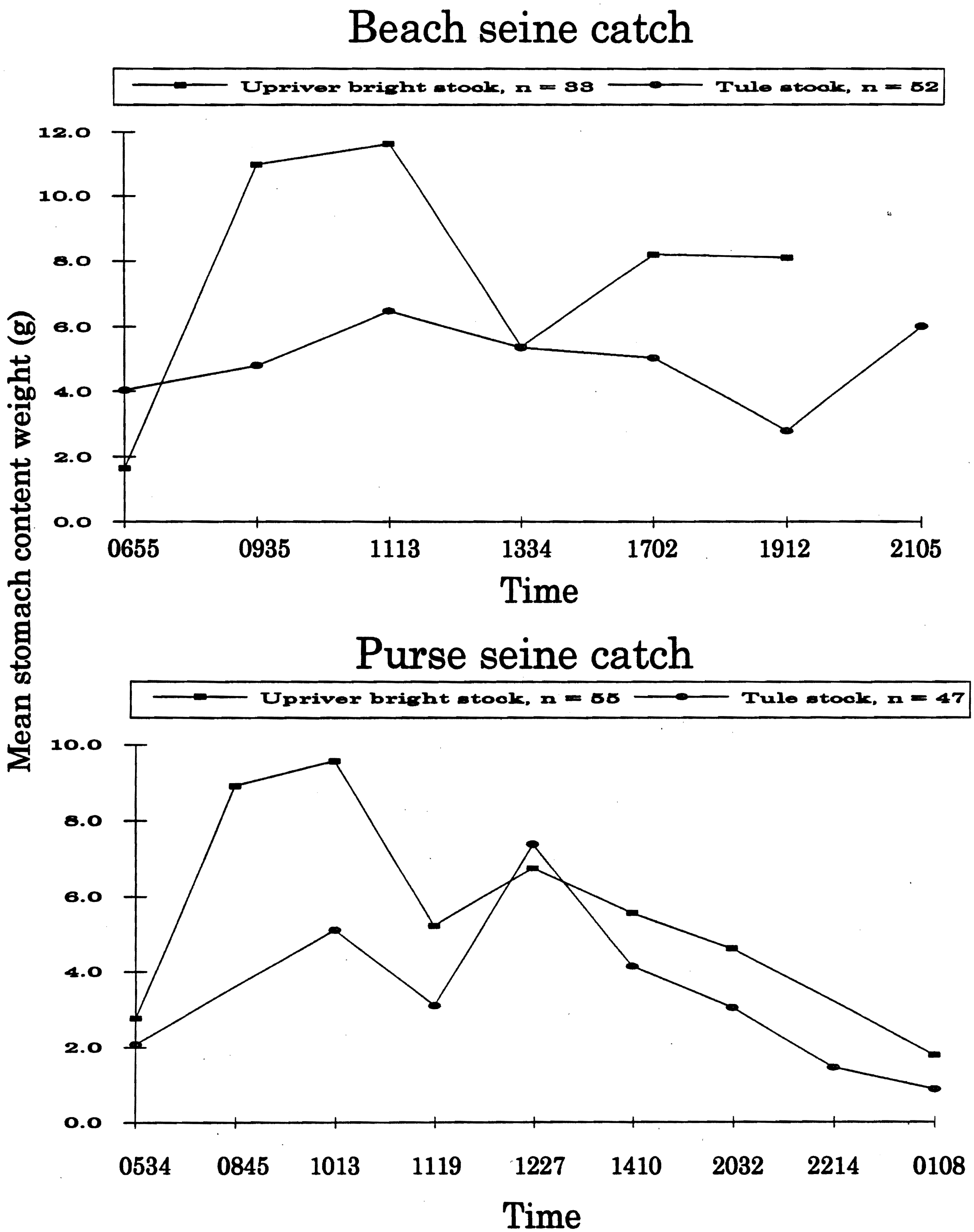


Figure 16.--Mean weight of stomach contents (g) of tule stock and upriver bright stock subyearling chinook salmon captured in beach and purse seines at Jones Beach, 26-27 June 1992.

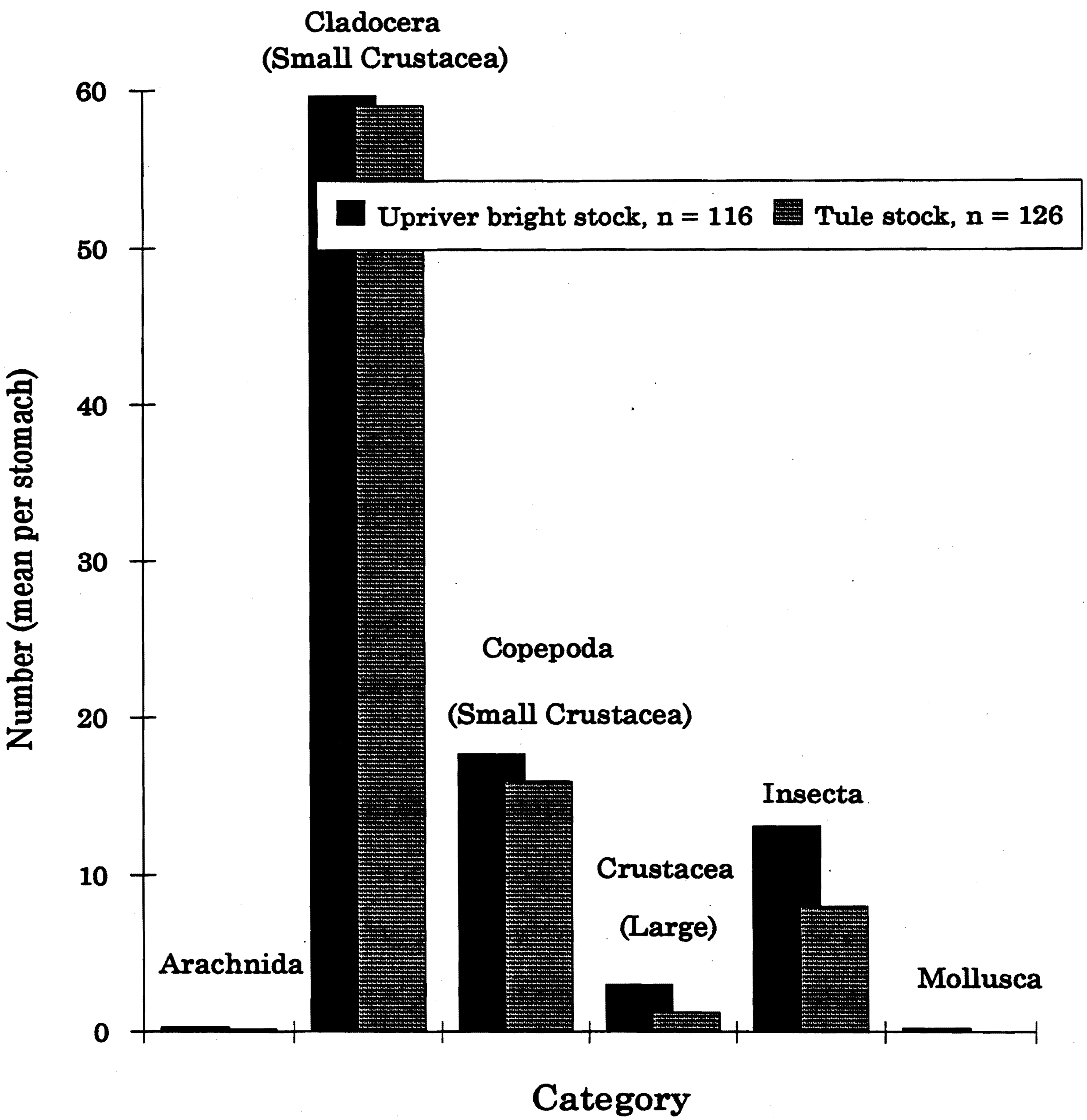


Figure 17.-- Primary dietary components of tule stock and upriver bright stock subyearling chinook salmon captured at Jones Beach, 1992.

apparent dietary differences between fish captured along the shoreline (beach seine) and in midstream (purse seine).

Juvenile Recovery Differences

Estuarine recovery percentages of the 30,000-fish treatment groups released daily at each site ranged from a high of 0.5000 to a low of 0.1590 (Table 4). Recovery percentages decreased over time, but proportional differences among treatments were fairly consistent through the period of testing and provided statistically significant estimates of relative differences for passage survival. Statistical analysis of migrational timing differences for treatment groups released on the same day showed no significant difference among any of the 13 release blocks ($\alpha = 0.05$), and no difference when blocks were pooled ($P = 0.8228$; Appendix B). Thus, there is no evidence to suggest non-homogeneity between treatment recovery distributions.

Statistical analyses of CWT-fish recoveries at Jones Beach (Appendix B) indicated that there were significant differences ($\alpha = 0.05$) in mean recovery percentages among the various treatment groups (Table 4). Rank order (from lowest to highest) was as follows: First Powerhouse bypass and tailrace, Second Powerhouse turbine and tailrace, First Powerhouse turbine and tailrace, and downstream, with mean recovery percentages of 0.31, 0.31, 0.35, and 0.43, respectively. Recovery percentages for the downstream groups were significantly greater than for all other groups, while recovery percentages for the First Powerhouse turbine and tailrace were significantly higher than for the Second Powerhouse turbine and tailrace and the First Powerhouse bypass and tailrace. Recovery difference between the Second Powerhouse turbine and tailrace and the First Powerhouse bypass and tailrace was not significant. Conclusions regarding differences among mean

Table 4.--Recovery percentages of tagged subyearling juvenile fall chinook salmon at Jones Beach, Bonneville Dam survival study, 1992.

Release date[a]	Treatments: Bypass 1st PH	Turbine 1st PH	Turbine 2nd PH	Downstream
18 Jun	0.3729	0.3597	0.3204	0.3921
19 Jun	0.3420	0.4187	0.3706	0.5000
20 Jun	0.3760	0.4503	0.4903	0.4715
23 Jun	0.3433	0.3269	0.3728	0.4190
24 Jun	0.3504	0.3839	0.3666	0.4554
25 Jun	0.3310	0.3852	0.3303	0.4646
29 Jun	0.3646	0.4587	0.3880	0.5984
30 Jun	0.2941	0.3418	0.3240	0.4583
1 Jul	0.3252	0.3368	0.2870	0.4541
2 Jul	0.2585	0.2852	0.2360	0.3684
7 Jul	0.2283	0.3098	0.1725	0.3280
8 Jul	0.1714	0.1766	0.1590	0.2569
9 Jul	0.2217	0.2701	0.2439	0.3869
Mean (%)[b]	0.3061	0.3464	0.3124	0.4272
SE	0.0183	0.0215	0.0256	0.0234
Total released[c]	376,205	369,312	378,620	372,664
Total recovered[d]	1,112	1,257	1,147	1,547
Percent difference[e]	-28.2	-18.8	-25.9	--

[a] Fish were released in early morning darkness.
[b] Weighted equally by block (i.e., by release day).
[c] Adjusted for tag loss.
[d] Observed catch, purse seine plus beach seine.
[e] Compared to downstream release =
(Treatment % - Downstream % ÷ Downstream %) * 100.

recovery percentages derived from the standardized data were similar to those reached with the non-standardized data (Fig. 18.)

Throughout the study, the rank-order of recovery percentages for the various treatment groups was generally consistent among treatments and between blocks (days of release) (Table 4). This general consistency contributed to improved overall statistical power (differences >7.6% were detectable) despite the rather disappointing recovery percentages of study fish (grand mean = 0.35% recovery) and the forced elimination of 1 of the 14 proposed release blocks. For example, recovery percentages of downstream-released groups ranked highest in 12 of 13 release blocks and recovery percentages of bypass-released groups ranked lowest or next to lowest in 12 of the 13 release blocks. Based on variability observed in juvenile recovery data from 1988 to 1990, 14 release blocks of 30,000 fish/treatment would be needed to detect about an 8.5% annual difference and about a 4.3% difference for 4 years combined data at $\alpha = 0.05$, $\beta = 0.2$.

DISCUSSION

The 1992 study was conducted under conditions of regional drought, and the resulting low flows and elevated water temperatures may have affected the comparisons by severely stressing test fish and contributing to increased predation by northern squawfish in the tailrace areas of both powerhouses. The overall recovery percentage of 1992 test fish at Jones Beach (mean 0.35%) was lower than the average recovery percentage from 1987 through 1990 (0.6%).

During the first week of the study (20 June release), another study that used upriver bright stock was conducted coincidentally near Bonneville Dam. Results from this study allowed direct comparisons of migration behavior and biological/physiological

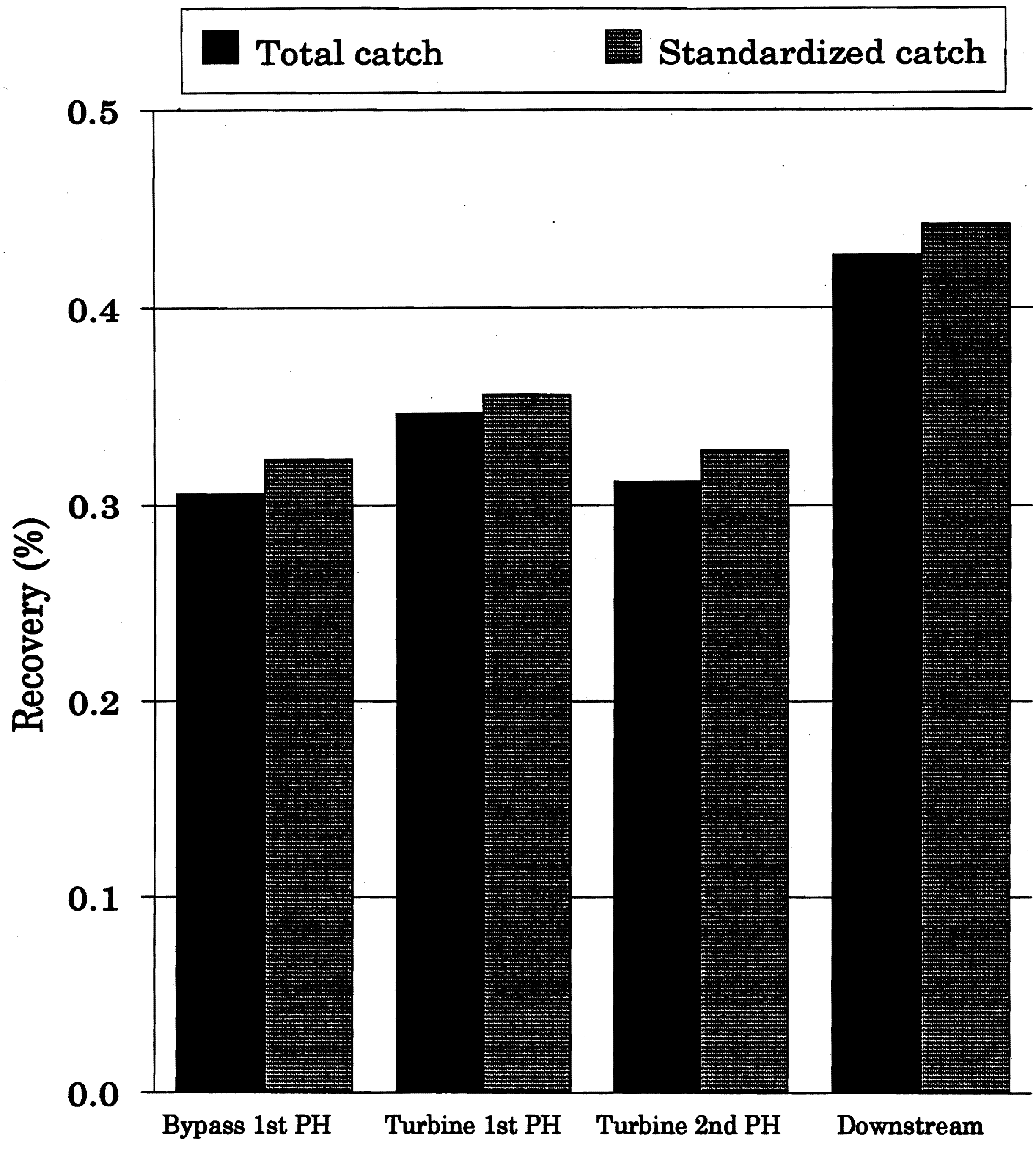


Figure 18.--Mean recovery percentages for treatment groups of tagged subyearling chinook salmon, 1992; total catch and total catch standardized for sampling effort.

parameters between tule stock and upriver bright stock. During this period, tule stock were similar in size to upriver bright stock (mean fork lengths at release 83.8 vs. 85.0 mm, respectively) but had lower recovery rates (0.47 vs. 0.60%, resectively). Although tule stock and upriver bright stock had similar diets (Fig. 17), tule stock had lower food consumption rates (Figs. 15-16) and were less smolted (Table 3) than the upriver bright stock. These differences may be indicative of a generally lower survival rate for tule stock relative to upriver bright stock. Aberrant, drought-related conditions of high water temperature (ca. 21°C) and low flows (<150 kcfs) seemed particularly important for test fish (tule stock) during the final release series (fish released 7, 8, and 9 July). These fish had recovery percentages as low as 0.16%, and passed Jones Beach when river temperatures generally exceeded 21°C. We believe the low rearing-water temperature of 10°C, coupled with the elevated river water temperatures during the migration period of fish in the last release series, severely shocked test fish and increased mortality and susceptibility to predation among all treatment groups. As a consequence, we anticipate poor adult recovery percentages for fish from the final release series.

While we speculated that mortalities of test fish related to different routes of passage at Bonneville Dam were fully expressed in survival differences among marked groups of juveniles sampled at Jones Beach, we question whether the adult recoveries of tule stock will provide sufficient data for the supplemental evaluation. However, the cold-water rearing with reduced rations successfully produced test fish of appropriate size to simulate the normal summer migrants. We feel that size is the single most important factor affecting differences in passage survival of test fish at Bonneville Dam. Fish size is directly related to incidence of physical contact by structures during passage through the bypass system or turbines and predation rates in the tailrace. These survival differences should be fully expressed in mark-recovery differences among release groups after their 157-km migration to Jones Beach.

Effects of River Flow and Powerhouse Discharge

Passage route survival for juvenile salmonids at Bonneville Dam may vary due to alterations of flow distribution among the two powerhouses and spillway and annual variations of river flow. Water-flow management at Bonneville Dam is complicated by the required operation of one turbine at the First Powerhouse (for station services) which results in a necessity for additional turbine operation to provide protection flow at the bypass outlet and attraction flow for the fishway entrances. Thus, water flow redistribution to include use of the Second Powerhouse requires a minimum three-turbine operation at the First Powerhouse. The experimental design with about half of each powerhouse in operation is a fairly realistic water distribution probability for summertime use of the Second Powerhouse. However, to include variations of river flow volumes into the variables being tested, multiple years of testing would be required.

In previous tests at the Second Powerhouse, annual variations in passage survival were related to differences of river flow. During the multiyear study at the Second Powerhouse, survival of fish through the bypass increased with increased tailwater surface elevation (Ledgerwood et al. 1991a). The mechanisms affecting survival difference were thought to be water velocity in the bypass conduit and shear forces at the outlet of the bypass pipe. Similarly, survival through the bypass system at the First Powerhouse may be dependent on tailwater surface elevation which is directly correlated to river flow. Drought conditions in 1992 may have produced a worst-case survival scenario for summer migrants passing through the bypass system of the First Powerhouse by creating conditions of low tailwater surface elevation, increased predation, and greater stress on the fish.

We assume that survival through the turbines at the Second Powerhouse in 1992 was similar to that of previous years (97.0-98.5%) and that the increased difference in recovery percentage between turbine and downstream releases (from the 9% average difference in previous years to about 26% difference in 1992) was due to increased predation in the tailrace. In previous years, flows through the Second Powerhouse were intermittent, generally occurring at night and usually beginning 1 day prior to tests with no operation between test periods, while flows through the First Powerhouse were continuous. In 1992, equalized continuous flows may have attracted additional predators to the Second Powerhouse tailrace. Another factor contributing to the increased difference in recovery percentages may have been increased susceptibility of tule stock test fish to predation due to high stress resulting from low rearing-water temperature and elevated river-water temperatures during the test period.

Impacts from Northern Squawfish

Increased abundance of northern squawfish in the lower Columbia River during recent years (Kirn et al. 1986b) may be severely impacting juvenile salmonids, especially near Bonneville Dam (Petersen et al. 1990). These impacts were documented by the NBS during the survival study releases made on 19 June, 25 June, 1 July, and 8 July. On these dates, beginning about 1 hour after releases of study fish, electrofishing efforts in the tailrace areas of both the First and Second Powerhouses produced 649 northern squawfish (Poe et al. 1993).

Of the juvenile salmonids found in the stomachs of these northern squawfish, 441 were CWT fish from the survival study releases (251, 74, and 116 CWTs each, for fish released into the First Powerhouse bypass, First Powerhouse turbine, and Second Powerhouse turbine, respectively). These observations of northern squawfish stomach contents were similar to those made in 1990, when CWT fish released into the bypass at the Second Powerhouse were more numerous in the stomachs of northern squawfish collected in the tailrace than turbine- or egress[5]-released fish (Ledgerwood et al. 1991a). In both years, stomach content analysis supported speculation that predation by northern squawfish contributed to the apparent lower survival of bypass-released fish compared to turbine-released fish.

CONCLUSIONS

The following conclusions are based on 1 year of study. Special operating conditions of equalized flow through both powerhouses were implemented at Bonneville Dam for this study to 1) attract predators equally to the two tailrace areas, 2) provide an unbiased comparison of survival among the various routes of juvenile fish passage as well as to minimize tailrace eddies, 3) provide high flows past the juvenile bypass outlet, and 4) allow adequate attraction flows to the various fishway entrances for upstream migrant adult salmonids. The regional drought that severely reduced river flow during 1992 may have created a worst-case scenario for salmonid survival due to heavy predation of test fish in the tailrace areas. It is important to consider a wide range of test conditions before formulating conclusions regarding the safest routes for juvenile salmon passing Bonneville Dam during the summer.

---

[5] The egress-released fish were expelled through a hose into the bypass discharge plume. These releases were designed to introduce fish into the tailrace at the location of the bypass exit, but without having passed through the bypass system.

Several tentative conclusions include:

1) Under the drought conditions of 1992, recoveries of marked subyearling chinook salmon in the estuary indicated significantly reduced survival of fish released into the bypass system at the First Powerhouse compared to fish released into the First Powerhouse turbines or fish released downstream from the tailrace.

2) Fish passing through the Second Powerhouse turbines and tailrace had significantly reduced survival compared to fish passing through the First Powerhouse turbines and tailrace.

3) The downstream-released fish had significantly higher survival than all other release groups.

4) Tule stock subyearling chinook salmon used in this study were subjected to cold-water rearing and reduced rations to maintain a size range at release similar to normal summer migrants (upriver bright stock). However, test fish, particularly those from the final week of test releases, may have suffered extreme stress due to elevated Columbia River water temperatures resulting from the regional drought. While the immediate impacts of dam passage are thought to be fully expressed in mark-recovery differences among juvenile fish recovered at Jones Beach, the overall survival of test fish may have been reduced by temperature stress. This potential overall lower survival of test fish may affect comparisons among treatment groups using CWT data from adult contributions to the various ocean and river fisheries and returns to the lower river hatcheries.

5) Because 75 to 90% of the summer migrating juvenile salmon encountering the powerhouses at Bonneville Dam pass through turbines instead of bypass systems, and because of the significant difference between turbine plus tailrace passage survivals at

the First and Second Powerhouses, it is extremely important to identify the safest passage route over a wide range of river flows.

RECOMMENDATIONS

1) Tag recovery of adults should be compiled through 1997 to assess passage survival differences adequately.
2) The study should be repeated for 3 additional years to bracket a wide range of river flow and other physical conditions before making final conclusions regarding the relative survival of summer migrating subyearling chinook salmon through the various passage routes at Bonneville Dam.

ACKNOWLEDGMENTS

We wish to thank Jack Bodle, Hatchery Manager, and James Rockowski, Assistant Hatchery Manager, at Little White Salmon National Fish Hatchery for assistance during rearing, marking, loading, and transporting test fish for this study.

REFERENCES

Allis-Chalmers Corp. 1978. Bonneville Second Powerhouse model test report. U.S. Army Corps of Engineers, Portland, OR. 400 p.

Beeman, J. W., D. W. Rondorf, J. C. Faler, M. E. Free, and P. V. Haner. 1990. Assessment of smolt condition for travel time analysis. Report to Bonneville Power Administration, 103 p. (Available from U. S. Fish and Wildlife Service, MP 5.48L Cook-Underwood Rd, Cook, WA 98605-9701.)

Bergman, P. K., K. B. Jefferts, H. F. Fiscus, and R. C. Hager. 1968. A preliminary evaluation of an implanted coded wire fish tag. Wash. Dep. Fish., Fish. Res. Pap. 3(1):63-84.

Cramer, F. K. 1965. Fish passage through hydraulic turbines. U.S. Army Corps of Engineers, Walla Walla Dist., Walla Walla, Washington 99362-9265.

Dawley, E. M., L. G. Gilbreath, and R. D. Ledgerwood. 1988. Evaluation of juvenile salmonid survival through the Second Powerhouse turbines and downstream migrant bypass system at Bonneville Dam, 1987. Report to U.S. Army Corps of Engineers, Contract DACW57-87-F-0323, 36 p. plus Appendix. (Available from Northwest Fisheries Science Center, 2725 Montlake Blvd. E., Seattle, WA 98112-2097.)

Dawley, E. M., L. G. Gilbreath, R. D. Ledgerwood, P. J. Bentley, B. P. Sandford, and M. H. Schiewe. 1989. Survival of subyearling chinook salmon which have passed through the turbines, bypass system, and tailrace basin of Bonneville Dam Second Powerhouse, 1988. Report to U.S. Army Corps of Engineers, Contract DACW57-87-F-0323, 78 p. (Available from Northwest Fisheries Science Center, 2725 Montlake Blvd. E., Seattle, WA 98112-2097.)

Dawley, E. M., R. D. Ledgerwood, and A. L. Jensen. 1985. 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. of Commer., NOAA Tech. Memo. NMFS N/NWC-74:1-260.

Fisher, R. A. 1944. Statistical methods for research workers. Ninth edition. Oliver and Boyd Ltd., London 350 p.

Gessel, M. H., D. A. Brege, B. H. Monk, and J. G. Williams. 1990. Continued studies to evaluate the juvenile bypass system at Bonneville Dam--1989. Report to U.S. Army Corps of Engineers, Contract E8689-95, 20 p. plus Appendix. (Available from Northwest Fisheries Science Center, 2725 Montlake Blvd. E., Seattle, WA 98112-2097.)

Gessel, M. H., B. H. Monk, D. A. Brege, and J. G. Williams. 1989. Fish guidance efficiency study at Bonneville Dam First and Second Powerhouses--1988. Report to U.S. Army Corps of Engineers, Contract DACW57-87-F-0322, 36 p. (Available from Northwest Fisheries Science Center, 2725 Montlake Blvd. E., Seattle, WA 98112-2097.)

Gilbreath, L. G., E. M. Dawley, R. D. Ledgerwood, P. J. Bentley, and S. J. Grabowski. 1993. Relative survival of subyearling chinook salmon that have passed Bonneville Dam via the spillway or the Second Powerhouse turbines or bypass system: adult recoveries through 1991. Report to U.S. Army Corps of Engineers, Contract E96910013, 25 p. (Available from Northwest Fisheries Science Center, 2725 Montlake Blvd. E., Seattle, WA 98112-2097.)

Groves, A. B. 1972. Effects of hydraulic shearing action on juvenile salmon. Unpubl. manuscr. 7 p. Northwest Fisheries Science Center, 2725 Montlake Blvd. E., Seattle, WA 98112-2097.

Holmes, H. B. 1952. Loss of salmon fingerlings in passing Bonneville Dam as determined by marking experiments. Unpubl. manuscr. 62 p. U.S. Fish and Wildlife Service, Portland, Oregon.

Kirn, R. A., R. D. Ledgerwood, and A. L. Jensen. 1986a. Diet of subyearling chinook salmon (*Oncorhynchus tshawytscha*) in the Columbia River estuary and changes effected by the 1980 eruption of Mount St. Helens. Northwest Science 60:191-196.

Kirn, R. A., R. D. Ledgerwood, and R. A. Nelson. 1986b. Increased abundance and food consumption of northern squawfish (*Ptychocheilus oregonensis*) at River Kilometer 75 in the Columbia River. Northwest Science 60:197-200.

Ledgerwood, R. D., E. M. Dawley, L. G. Gilbreath, P. J. Bentley, B. P. Sandford, and M. H. Schiewe. 1990. Relative survival of subyearling chinook salmon which have passed Bonneville Dam via the spillway or the Second Powerhouse turbines or bypass system in 1989, with comparisons to 1987 and 1988. Report to U.S. Army Corps of Engineers, Contract E85890024/E86890097, 64 p. plus Appendixes. (Available from Northwest Fisheries Science Center, 2725 Montlake Blvd. E., Seattle, WA 98112-2097.)

Ledgerwood, R. D., E. M. Dawley, L. G. Gilbreath, P. J. Bentley, B. P. Sandford, and M. H. Schiewe. 1991a. Relative survival of subyearling chinook salmon that have passed through the turbines or bypass system of Bonneville Dam Second Powerhouse, 1990. Report to U.S. Army Corps of Engineers, Contract E86900104, 90 p. (Available from Northwest Fisheries Science Center, 2725 Montlake Blvd. E., Seattle, WA 98112-2097.)

Ledgerwood R. D., E. M. Dawley, L. G. Gilbreath, L. T. Parker, T. P. Poe, and H. L. Hansen. In prep. Effectiveness of predator removal for protecting juvenile fall chinook salmon released from Bonneville Hatchery, 1992. In C. F. Willis and A. A. Nigro (editors), Development of a system-wide predator control program: stepwise implementation of a predator index, predator control fisheries, and evaluation plan in the Columbia River Basin. Report to Bonneville Power Administration, Contract DE-BI79-90BP07084.

Ledgerwood, R. D., F. P. Thrower, and E. M. Dawley. 1991b. Diel sampling of migratory juvenile salmonids in the Columbia River Estuary. Fishery Bulletin, 89:69-78.

Mighell, J. H. 1969. Rapid cold-branding of salmon and trout with liquid nitrogen. J. Fish. Res. Board Can. 26:2765-2769.

Oligher, R. C., and I. J. Donaldson. 1966. Fish passage through turbines: tests at Big Cliff hydroelectric plant. U. S. Army Corps of Engineers Walla Walla Dist., Walla Walla, Washington, Progress Report 6, 15 p.

Petersen, J. H., D. B. Jepsen, R. D. Nelle, R. S. Shively, R. A. Tabor, and T. P. Poe. 1990. System-wide significance of predation on juvenile salmonids in Columbia and Snake River reservoirs. Report to Bonneville Power Administration, Project 90-078, 53 p.

Petersen, R. G. 1985. Design and analysis of experiments. Marcel Dekker. New York, NY, 429 p.

Poe, T. P., M. G. Mesa, P. S. Shively, and R. D. Peters. In press. Development of biological criteria for siting and operation of juvenile fish bypass systems: implications for protecting juvenile salmonids from predation. U.S. Fish and Wildlife Service, Columbia River Field Station, MP 5.48L Cook-Underwood Road, Cook, WA. Proceedings American Fishery Society symposium in Portland, Oregon in September 1993.

Ruggles, P. C. 1985. Can injury be minimized through turbine design? Hydro Review, Winter:70-76.

Schoeneman, D. E., R. T. Pressey, and C. O. Junge. 1961. Mortalities of downstream migrant salmon at McNary Dam. Trans. Am. Fish. Soc. 90:58-72.

Sokal, R. R., and F. J. Rohlf. 1981. Biometry, 2nd. Edition. W. H. Freeman. San Francisco, CA, 776 p.

Terry, C. 1977. Stomach analysis methodology: still lots of questions, p. 87-92. In C. A. Simenstad and S. J. Lipovsky (editors), Fish food habits studies: First Pacific Northwest Technical Workshop, Proceedings, 13-15 October 1976, University of Washington, Div. Mar. Resources, Wash. Sea Grant, WSG-WO 77-2.

Vreeland, R. R. 1990. Random-sampling design to estimate hatchery contributions to fisheries. Am. Fish. Soc. Symposium 7:691-707.

Willis, C. F., and A. A. Nigro (editors). 1993. Development of a system-wide predator control program: stepwise implementation of a predation index, predator control fisheries, and evaluation plan in the Columbia River Basin. Report to Bonneville Power Administration, Contract DE-BI79-90BP07084, 599 p. (Available from Oregon Department of Fish and Wildlife, 2501 SW First Ave. Portland, OR 97207.)

Zar, J. H. 1974. Biostatistical analysis. Prentice-Hall. Englewood Cliffs, NJ, 620 p.

APPENDIXES

Appendix A
Marking, Release, and Recovery Information

Appendix Table A1.--Tag loss estimates among branded groups of subyearling chinook salmon after a 30-day holding period; Bonneville Dam Survival Study, 1992.

Release dates	Brand[b]	CWT[a] AGD1D2	AGD1D2	AGD1D2	AGD1D2	NCWT[c]	Sample[d]
Turbine 1st Powerhouse							
18-20 Jun	RDLT1	232753	232754	232755	--	13	417
23-25 Jun	RDLT3	232756	232757	232758	--	32	332
29 Jun-2 Jul	LDLT1	232759	232760	232761	232762	5	509
7-9 Jul	LDLT3	232763	232803	232805	--	3	340
Turbine 2nd Powerhouse							
18-20 Jun	RDLX1	232809	232810	232812	--	16	323
23-25 Jun	RDLX3	232815	232817	232818	--	14	399
29 Jun-2 Jul	LDLX1	232820	232823	232824	232827	6	524
7-9 Jul	LDLX3	232829	232830	232833	--	3	310
Bypass 1st Powerhouse							
18-20 Jun	RDLC1	232739	232740	232741	--	7	360
23-25 Jun	RDLC3	232742	232743	232744	--	25	368
29 Jun-2 Jul	LDLC1	232745	232746	232747	232748	6	525
7-9 Jul	LDLC3	232749	232750	232751	--	5	333
Downstream							
18-20 Jun	RDLU1	232836	232839	232840	--	24	352
23-25 Jun	RDLU3	232843	232845	232846	--	11	473
29 Jun-2 Jul	LDLU1	232848	232851	232853	232854	8	536
7-9 Jul	LDLU3	232857	232858	232860	--	2	328

[a] CWT = coded wire tag; where AG = agency code, D1 = data 1, D2 = data 2.
[b] Brand position RD (right dorsal) or LD (left dorsal) followed by the two-letter brand symbol; the numbers 1 or 3 indicate brand rotation.
[c] NCWT = Number of branded fish in the sample with no coded-wire tag.
[d] Number of branded fish checked for the presence of coded-wire tags.

Appendix Table A2.--Flow data[a], operating conditions, and water temperature at times of release on the 13 release dates of the Bonneville Dam survival study, 1992.

	First Powerhouse			Turbine 9							Bypass First Powerhouse		
Date of release	Forebay elev. (ft)	Tailwater elev. (ft)	Flow[b] (kcfs)	Flow[c] (kcfs)	Load (MW)	Head (ft)	Wicket gate (%)	Blade angle (°)	Plant sigma[d] (σ)	Estim. effic. (%)	Collection channel elev. (ft.)	Downwell elev. (ft)	Add-in water (%)
18 Jun	74.5	19.2	54.8	8.7	35.4	53.7	56	20.5	0.88	90.5	70.1	55	23
19 Jun	74.9	18.1	52.7	8.8	37.2	56.8	56	21.0	0.81	90.5	70.2	55	25
20 Jun	74.7	16.7	48.8	7.7	33.0	58.0	56	22.0	0.77	90.5	70.0	55	25
23 Jun	74.9	17.9	50.5	11.2	47.0	57.0	67	26.0	0.81	90.5	70.4	55	25
24 Jun	75.2	18.2	51.2	9.5	40.0	57.2	60	22.0	0.81	90.5	70.5	55	25
25 Jun	75.3	17.7	54.8	9.6	41.0	57.6	61	22.4	0.79	90.5	70.5	55	25
29 Jun	74.3	15.9	46.2	9.2	40.0	57.4	60	22.0	0.76	90.5	69.5	55	25
30 Jun	75.0	14.6	46.0	9.0	40.0	60.4	55	19.5	0.71	91.0	70.0	55	25
1 Jul	75.4	12.2	40.0	9.4	45.0	63.2	55	23.0	0.64	91.0	70.5	55	25
2 Jul	74.4	11.8	50.2	10.9	48.0	62.6	60	26.0	0.64	91.0	70.0	55	25
7 Jul	74.7	12.2	42.3	9.5	46.0	62.5	58	23.0	0.64	91.0	70.2	55	25
8 Jul	75.1	12.2	46.1	10.0	48.0	62.9	57	25.0	0.64	91.0	71.0	55	25
9 Jul	75.2	12.1	45.2	9.5	47.0	63.1	57	22.0	0.64	91.0	70.5	55	25

Appendix Table A2.--Continued

	Second Powerhouse			Turbine 17							Spillway	Total river	
Date of release	Forebay elev. (ft)	Tailwater elev. (ft)	Flow[b] (kcfs)	Flow[c] (kcfs)	Load (MW)	Head (ft)	Wicket gate (%)	Blade angle (°)	Plant sigma[d] (σ)	Estim. effic. (%)	Flow (kcfs)	Flow (kcfs)	Temp (°F)
18 Jun	74.9	19.0	54.8	12.6	54	56.0	61.9	17.1	1.09	92.5	129	247	64
19 Jun	75.2	18.7	54.3	12.4	51	56.5	60.3	16.6	1.08	92.0	104	232	65
20 Jun	74.9	18.1	55.6	13.2	58	56.8	65.8	19.7	1.06	92.5	79	220	65
23 Jun	75.2	18.6	59.7	16.5	73	56.6	74.5	25.4	1.07	92.0	101	221	68
24 Jun	75.5	18.6	55.0	13.8	61	57.0	66.7	20.3	1.07	92.5	106	220	68
25 Jun	75.7	18.4	55.8	14.2	62	57.3	67.4	20.9	1.06	92.5	101	221	68
29 Jun	74.2	16.2	55.8	13.7	62	58.0	66.6	20.7	1.01	93.0	79	191	68
30 Jun	75.0	14.5	55.0	12.6	60	60.5	56.0	16.0	0.94	93.0	48	159	68
1 Jul	75.7	12.4	53.2	13.6	67	63.3	64.0	21.0	0.86	92.5	13	115	68
2 Jul	74.6	12.1	53.9	13.8	68	62.5	65.0	21.0	0.87	92.5	13	125	68
7 Jul	75.1	12.2	53.3	13.4	66	63.1	64.0	21.0	0.86	93.0	22	107	69
8 Jul	75.3	12.1	52.9	13.6	62	63.2	60.0	18.9	0.86	93.0	29	138	69
9 Jul	75.5	11.7	53.4	13.4	67	63.8	62.0	20.3	0.84	93.0	29	140	69

[a] English units are used by convention.
[b] Water flow volumes kcfs = 1,000 ft^3/second.
[c] Data derived from Figure 8-02.1 of Bonneville Dam Second Powerhouse model test report (Allis-Chalmers 1978).
[d] Plant sigma (σ) = {(atmospheric pressure) - (water vapor pressure) - (CL runner elev. - TW elev. pressure differential)} ÷ Head Pressure,
where CL = center line, and TW = tailwater.

Appendix Table A3.--Daily purse seine and beach seine fishing effort, water temperatures, and Secchi disk transparency measurements at Jones Beach, 1992.

Date	Number of sets Purse	Number of sets Beach	Temp. °C	Secchi depth (m)	Date	Number of sets Purse	Number of sets Beach	Temp. °C	Secchi depth (m)
15 Jun	1	2	18	--[a]	9 Jul	9	9	20	1.5
16 Jun	3	6	17	0.9	10 Jul	6	3	21	1.4
17 Jun	4	7	17	1.1	11 Jul	8	9	20	1.2
18 Jun	5	5	18	1.1	12 Jul	7	6	20	1.1
19 Jun[b]	2	4	18	1.1	13 Jul	12	5	21	1.2
20 Jun	7	4	18	1.2	14 Jul	11	6	21	1.2
21 Jun	3	4	19	1.2	15 Jul	10	9	21	1.1
22 Jun	8	2	19	1.4	16 Jul	9	11	21	1.4
23 Jun	9	4	19	1.2	17 Jul	9	11	21	1.4
24 Jun	10	2	20	1.4	18 Jul	4	10	22	1.2
25 Jun	12	0	20	1.2	19 Jul	8	9	22	1.4
26 Jun	16	11	20	1.4	20 Jul	8	7	22	1.2
27 Jun	9	7	20	1.4	21 Jul	14	3	22	1.1
28 Jun	5	4	20	1.5	22 Jul	11	3	22	1.5
29 Jun	8	5	19	1.1	23 Jul	5	2	22	1.8
30 Jun	12	3	20	1.4	24 Jul	3	3	22	1.5
1 Jul	8	4	20	1.1	25 Jul	6	3	22	1.5
2 Jul	9	10	20	1.2	26 Jul	3	3	21	0.9
3 Jul	10	10	20	1.2	27 Jul	3	3	21	1.2
4 Jul	9	8	20	1.4	28 Jul	3	3	21	1.2
5 Jul	13	8	20	1.7	29 Jul	3	2	22	1.2
6 Jul	15	5	21	1.5	30 Jul	2	1	22	1.5
7 Jul	11	1	21	1.4	31 Jul	2	0	22	1.4
8 Jul	5	5	20	1.4					

[a] = data not available.
[b] First recovery of study fish.

Appendix Table A4.--Daily recoveries, recoveries standardized for effort, dates of median fish recovery, and movement rates to Jones Beach of marked subyearling chinook salmon released for the Bonneville Dam survival study, 1992.

	Released 18 June											
	Treatments and tag code (AG D1 D2)[a]											
	Bypass 1st PH 23 27 39						Turbine 1st PH 23 27 53					
Date of recovery	Beach		Purse		Total		Beach		Purse		Total	
	A[b]	S[c]	A	S	A	S	A	S	A	S	A	S
NA	0	0	0	0	0	0	0	0	0	0	0	0
19 Jun	0	0	0	0	0	0	0	0	0	0	0	0
20 Jun	0	0	0	0	0	0	0	0	0	0	0	0
21 Jun	2	3	3	10	5	12	3	4	2	7	5	10
22 Jun	4	10	17	21	21	31	3	8	10	13	13	20
23 Jun	1	1	4	4	5	6	6	8	7	8	13	15
24 Jun	5	13	13	13	18	26[med]	4	10	15	15	19	25[med]
25 Jun	0	7	10	8	10	16	0	7	11	9	11	16
26 Jun	5	2	10	6	15	9	8	4	7	4	15	8
27 Jun	5	4	1	1	6	5	4	3	1	1	5	4
28 Jun	1	1	1	2	2	3	2	3	1	2	3	5
29 Jun	0	0	2	3	2	3	0	0	2	3	2	3
30 Jun	1	2	4	3	5	5	1	2	1	1	2	3
1 Jul	0	0	2	3	2	3	1	1	0	0	1	1
2 Jul	1	1	4	4	5	5	2	1	1	1	3	2
3 Jul	1	1	2	2	3	3	2	1	2	2	4	3
4 Jul	0	0	1	1	1	1	1	1	1	1	2	2
5 Jul	1	1	2	2	3	2	0	0	2	2	2	2
6 Jul	1	1	1	1	2	2	1	1	0	0	1	1
7 Jul	1	5	0	0	1	5	0	0	0	0	0	0
8 Jul	0	0	0	0	0	0	0	0	1	2	1	2
9 Jul	0	0	0	0	0	0	0	0	0	0	0	0
10 Jul	0	0	0	0	0	0	0	0	0	0	0	0
11 Jul	0	0	0	0	0	0	0	0	0	0	0	0
12 Jul	0	0	1	1	1	1	0	0	0	0	0	0
13 Jul	0	0	0	0	0	0	0	0	1	1	1	1
14 Jul	0	0	0	0	0	0	0	0	0	0	0	0
15 Jul	0	0	0	0	0	0	1	1	0	0	1	1
16 Jul	0	0	0	0	0	0	0	0	0	0	0	0
17 Jul	0	0	0	0	0	0	0	0	0	0	0	0
18 Jul	0	0	0	0	0	0	0	0	0	0	0	0
19 Jul	1	1	0	0	1	1	0	0	0	0	0	0
20 Jul	0	0	0	0	0	0	0	0	0	0	0	0
21 Jul	0	0	0	0	0	0	0	0	0	0	0	0
22 Jul	0	0	1	1	1	1	0	0	0	0	0	0
23 Jul	0	0	0	0	0	0	0	0	0	0	0	0
Totals	30	51	79	87	109	137	39	52	65	71	104	122
Recovery %	0.10	0.17	0.27	0.30	0.37	0.47	0.13	0.18	0.22	0.24	0.36	0.42
Mvmt rate[e]						26.2						26.2

Appendix Table A4.--Continued. 2

	Released 18 June											
	Treatments and tag code (AG D1 D2)[a]											
	Turbine 2nd PH 23 28 09						Downstream 23 28 36					
Date of recovery	Beach		Purse		Total		Beach		Purse		Total	
	A[b]	S[c]	A	S	A	S	A	S	A	S	A	S
NA	0	0	0	0	0	0	1	0	0	0	1	0
19 Jun	0	0	0	0	0	0	0	0	0	0	0	0
20 Jun	0	0	0	0	0	0	0	0	0	0	0	0
21 Jun	0	0	0	0	0	0	2	3	4	13	6	16
22 Jun	3	8	10	13	13	20	2	5	14	18	16	23
23 Jun	4	5	12	13	16	18	7	9	5	6	12	14
24 Jun	1	3	13	13	14	16	5	13	13	13	18	26[med]
25 Jun	0	3	11	9	11	12[med]	0	0	11	9	11	9
26 Jun	9	4	9	6	18	10	12	5	4	3	16	8
27 Jun	3	2	1	1	4	3	1	1	1	1	2	2
28 Jun	1	1	0	0	1	1	2	3	0	0	2	3
29 Jun	0	0	2	3	2	3	0	0	0	0	0	0
30 Jun	0	0	1	1	1	1	2	3	4	3	6	7
1 Jul	0	0	2	3	2	3	1	1	0	0	1	1
2 Jul	0	0	1	1	1	1	1	1	0	0	1	1
3 Jul	1	1	0	0	1	1	2	1	3	3	5	4
4 Jul	1	1	0	0	1	1	1	1	0	0	1	1
5 Jul	1	1	1	1	2	1	1	1	2	2	3	2
6 Jul	0	0	2	1	2	1	0	0	4	3	4	3
7 Jul	0	0	1	1	1	1	0	0	1	1	1	1
8 Jul	0	0	0	0	0	0	0	0	0	0	0	0
9 Jul	0	0	0	0	0	0	0	0	0	0	0	0
10 Jul	0	0	1	2	1	2	0	0	1	2	1	2
11 Jul	0	0	0	0	0	0	0	0	0	0	0	0
12 Jul	0	0	0	0	0	0	0	0	0	0	0	0
13 Jul	0	0	0	0	0	0	0	0	0	0	0	0
14 Jul	0	0	0	0	0	0	0	0	0	0	0	0
15 Jul	0	0	0	0	0	0	0	0	0	0	0	0
16 Jul	0	0	0	0	0	0	0	0	0	0	0	0
17 Jul	0	0	0	0	0	0	0	0	1	1	1	1
18 Jul	0	0	0	0	0	0	1	1	0	0	1	1
19 Jul	0	0	0	0	0	0	0	0	0	0	0	0
Totals	24	28	67	66	91	94	41	45	68	76	109	122
Recovery %	0.08	0.10	0.24	0.23	0.32	0.33	0.15	0.16	0.24	0.27	0.39	0.44
Mvmt rate						22.2						26.2

Appendix Table A4.--Continued. 3

Date of recovery	Released 19 June											
	Treatments and tag code (AG D1 D2)[a]											
	Bypass 1st PH 23 27 40						Turbine 1st PH 23 27 54					
	Beach		Purse		Total		Beach		Purse		Total	
	A[b]	S[c]	A	S	A	S	A	S	A	S	A	S
NA	0	0	0	0	0	0	0	0	0	0	0	0
19 Jun	0	0	0	0	0	0	0	0	0	0	0	0
20 Jun	0	0	0	0	0	0	0	0	0	0	0	0
21 Jun	0	0	0	0	0	0	0	0	0	0	0	0
22 Jun	4	10	11	14	15	24	4	10	15	19	19	29
23 Jun	3	4	12	13	15	17	2	3	12	13	14	16
24 Jun	2	5	16	16	18	21[med]	4	10	19	19	23	29[med]
25 Jun	0	4	14	12	14	16	0	8	17	14	17	22
26 Jun	7	3	5	3	12	6	14	6	2	1	16	8
27 Jun	4	3	1	1	5	4	6	4	4	4	10	9
28 Jun	1	1	2	4	3	5	0	0	1	2	1	2
29 Jun	1	1	4	5	5	6	0	0	2	3	2	3
30 Jun	0	0	3	2	3	2	0	0	3	2	3	2
1 Jul	0	0	0	0	0	0	1	1	0	0	1	1
2 Jul	0	0	1	1	1	1	1	1	1	1	2	2
3 Jul	0	0	1	1	1	1	1	1	1	1	2	2
4 Jul	0	0	3	3	3	3	1	1	0	0	1	1
5 Jul	0	0	2	2	2	2	1	1	4	3	5	4
6 Jul	0	0	0	0	0	0	1	1	0	0	1	1
7 Jul	2	10	0	0	2	10	0	0	0	0	0	0
8 Jul	0	0	1	2	1	2	0	0	0	0	0	0
19 Jul	0	0	0	0	0	0	0	0	0	0	0	0
10 Jul	0	0	0	0	0	0	0	0	0	0	0	0
11 Jul	0	0	0	0	0	0	0	0	0	0	0	0
12 Jul	0	0	0	0	0	0	0	0	1	1	1	1
13 Jul	0	0	0	0	0	0	0	0	0	0	0	0
14 Jul	0	0	0	0	0	0	1	1	0	0	1	1
15 Jul	0	0	0	0	0	0	0	0	0	0	0	0
16 Jul	0	0	0	0	0	0	0	0	0	0	0	0
17 Jul	0	0	0	0	0	0	0	0	0	0	0	0
18 Jul	0	0	0	0	0	0	0	0	0	0	0	0
19 Jul	0	0	0	0	0	0	0	0	2	3	2	3
Totals	24	41	76	79	100	121	37	47	84	87	121	134
Recovery %	0.08	0.14	0.26	0.27	0.34	0.41	0.13	0.16	0.29	0.30	0.42	0.46
Mvmt rate						31.4						31.4

Appendix Table A4.--Continued. 4

Date of recovery	Released 19 June											
	Treatments and tag code (AG D1 D2)[a]											
	Turbine 2nd PH 23 28 10						Downstream 23 28 39					
	Beach		Purse		Total		Beach		Purse		Total	
	A[b]	S[c]	A	S	A	S	A	S	A	S	A	S
NA	0	0	0	0	0	0	1	0	0	0	1	0
NA	0	0	0	0	0	0	0	0	0	0	0	0
19 Jun	0	0	0	0	0	0	0	0	0	0	0	0
20 Jun	0	0	0	0	0	0	0	0	0	0	0	0
21 Jun	0	0	0	0	0	0	0	0	0	0	0	0
22 Jun	1	3	15	19	16	21	7	18	14	18	21	35
23 Jun	2	3	13	14	15	17	1	1	16	18	17	19
24 Jun	3	8	24	24	27	32[med]	4	10	24	24	28	34[med]
25 Jun	0	5	14	12	14	17	0	7	14	12	14	18
26 Jun	6	3	5	3	11	6	8	4	11	7	19	11
27 Jun	2	1	3	3	5	5	5	4	0	0	5	4
28 Jun	2	3	0	0	2	3	1	1	1	2	2	3
29 Jun	0	0	2	3	2	3	1	1	7	9	8	10
30 Jun	0	0	1	1	1	1	0	0	2	2	2	2
1 Jul	1	1	1	1	2	3	0	0	1	1	1	1
2 Jul	0	0	0	0	0	0	1	1	0	0	1	1
3 Jul	3	2	1	1	4	3	5	3	3	3	8	6
4 Jul	0	0	1	1	1	1	2	1	1	1	3	2
5 Jul	0	0	0	0	0	0	0	0	1	1	1	1
6 Jul	0	0	2	1	2	1	0	0	0	0	0	0
7 Jul	1	5	0	0	1	5	0	0	2	2	2	2
8 Jul	0	0	1	2	1	2	0	0	0	0	0	0
9 Jul	0	0	0	0	0	0	1	1	1	1	2	2
10 Jul	0	0	0	0	0	0	0	0	0	0	0	0
11 Jul	0	0	0	0	0	0	0	0	1	1	1	1
12 Jul	0	0	0	0	0	0	0	0	2	3	2	3
13 Jul	0	0	0	0	0	0	0	0	0	0	0	0
14 Jul	0	0	0	0	0	0	0	0	0	0	0	0
15 Jul	0	0	0	0	0	0	0	0	1	1	1	1
16 Jul	0	0	0	0	0	0	0	0	0	0	0	0
17 Jul	0	0	0	0	0	0	0	0	0	0	0	0
18 Jul	1	1	0	0	1	1	0	0	1	3	1	3
19 Jul	0	0	0	0	0	0	0	0	0	0	0	0
Totals	22	33	83	85	105	118	36	50	103	107	139	157
Recovery %	0.08	0.11	0.29	0.30	0.37	0.42	0.13	0.18	0.37	0.38	0.50	0.56
Mvmt rate						31.4						31.4

Appendix Table A4.--Continued. 5

Date of recovery	Released 20 June — Treatments and tag code (AG D1 D2)[a] — Bypass 1st PH 23 27 41: Beach A[a]	Beach S[b]	Purse A	Purse S	Total A	Total S	Turbine 1st PH 23 27 55: Beach A	Beach S	Purse A	Purse S	Total A	Total S
NA	0	0	0	0	0	0	0	0	0	0	0	0
19 Jun	0	0	0	0	0	0	0	0	0	0	0	0
20 Jun	0	0	0	0	0	0	0	0	0	0	0	0
21 Jun	0	0	0	0	0	0	0	0	0	0	0	0
22 Jun	0	0	0	0	0	0	0	0	0	0	0	0
23 Jun	1	1	17	19	18	20	0	0	15	17	15	17
24 Jun	1	3	32	32	33	35[med]	2	5	31	31	33	36
25 Jun	0	3	16	13	16	16	0	4	19	16	19	20[med]
26 Jun	8	4	13	8	21	12	6	3	15	9	21	12
27 Jun	2	1	2	2	4	4	2	1	4	4	6	6
28 Jun	1	1	1	2	2	3	1	1	0	0	1	1
29 Jun	0	0	0	0	0	0	0	0	2	3	2	3
30 Jun	3	5	1	1	4	6	0	0	3	2	3	2
1 Jul	0	0	0	0	0	0	1	1	0	0	1	1
2 Jul	0	0	0	0	0	0	0	0	1	1	1	1
3 Jul	0	0	0	0	0	0	2	1	2	2	4	3
4 Jul	0	0	0	0	0	0	1	1	1	1	2	2
5 Jul	0	0	5	4	5	4	1	1	1	1	2	1
6 Jul	0	0	4	3	4	3	1	1	1	1	2	2
7 Jul	0	0	2	2	2	2	0	0	4	4	4	4
8 Jul	0	0	0	0	0	0	0	0	0	0	0	0
9 Jul	0	0	0	0	0	0	0	0	0	0	0	0
10 Jul	0	0	0	0	0	0	0	0	1	2	1	2
11 Jul	0	0	0	0	0	0	0	0	0	0	0	0
12 Jul	0	0	1	1	1	1	0	0	1	1	1	1
13 Jul	0	0	0	0	0	0	0	0	0	0	0	0
14 Jul	0	0	0	0	0	0	0	0	0	0	0	0
15 Jul	0	0	0	0	0	0	0	0	0	0	0	0
Totals	16	18	94	87	110	105	17	19	101	95	118	113
Recovery %	0.05	0.06	0.32	0.30	0.38	0.36	0.06	0.07	0.39	0.36	0.45	0.43
Mvmt rate						39.3						31.4

Appendix Table A4.--Continued. 6

Date of recovery	Released 20 June — Treatments and tag code (AG D1 D2)[a] — Turbine 2nd PH 23 28 12: Beach A[b]	Beach S[c]	Purse A	Purse S	Total A	Total S	Downstream 23 28 40: Beach A	Beach S	Purse A	Purse S	Total A	Total S
NA	0	0	0	0	0	0	0	0	0	0	0	0
19 Jun	0	0	0	0	0	0	0	0	0	0	0	0
20 Jun	0	0	0	0	0	0	0	0	0	0	0	0
21 Jun	0	0	0	0	0	0	0	0	0	0	0	0
22 Jun	0	0	0	0	0	0	0	0	0	0	0	0
23 Jun	1	1	13	14	14	16	2	3	9	10	11	12
24 Jun	0	0	34	34	34	34	2	5	34	34	36	39
25 Jun	0	2	24	20	24	22[med]	0	5	28	23	28	29[med]
26 Jun	10	5	15	9	25	14	13	6	8	5	21	11
27 Jun	5	4	1	1	6	5	4	3	1	1	5	4
28 Jun	0	0	1	2	1	2	2	3	0	0	2	3
29 Jun	2	2	3	4	5	6	1	1	2	3	3	4
30 Jun	2	3	3	2	5	6	0	0	2	2	2	2
1 Jul	0	0	2	3	2	3	0	0	2	3	2	3
2 Jul	1	1	1	1	2	2	1	1	0	0	1	1
3 Jul	1	1	0	0	1	1	3	2	2	2	5	4
4 Jul	2	1	1	1	3	2	2	1	3	3	5	5
5 Jul	3	2	5	4	8	6	0	0	1	1	1	1
6 Jul	2	2	2	1	4	3	0	0	2	1	2	1
7 Jul	1	5	1	1	2	6	2	10	1	1	3	11
8 Jul	0	0	0	0	0	0	0	0	0	0	0	0
9 Jul	0	0	0	0	0	0	0	0	2	2	2	2
10 Jul	0	0	2	3	2	3	0	0	0	0	0	0
11 Jul	1	1	0	0	1	1	0	0	0	0	0	0
12 Jul	0	0	0	0	0	0	0	0	0	0	0	0
13 Jul	0	0	0	0	0	0	0	0	0	0	0	0
14 Jul	0	0	0	0	0	0	0	0	0	0	0	0
15 Jul	0	0	0	0	0	0	1	1	1	1	2	2
16 Jul	0	0	0	0	0	0	0	0	0	0	0	0
Totals	31	29	108	101	139	130	33	39	98	92	131	131
Recovery %	0.11	0.10	0.38	0.36	0.49	0.46	0.12	0.14	0.35	0.33	0.47	0.47
Mvmt rate						31.4						31.4

Appendix Table A4.--Continued. 7

Date of recovery	Released 23 June — Treatments and tag code (AG D1 D2)[a] — Bypass 1st PH 23 27 42 — Beach A[b]	Beach S[c]	Purse A	Purse S	Total A	Total S	Turbine 1st PH 23 27 56 — Beach A	Beach S	Purse A	Purse S	Total A	Total S
NA	0	0	1	0	1	0	0	0	0	0	0	0
24 Jun	0	0	0	0	0	0	0	0	0	0	0	0
25 Jun	0	1	1	1	1	2	0	2	1	1	1	3
26 Jun	4	2	23	14	27	16	8	4	19	12	27	16
27 Jun	1	1	9	10	10	11	3	2	7	8	10	10
28 Jun	1	1	5	10	6	11	2	3	1	2	3	5
29 Jun	0	0	3	4	3	4[med]	2	2	5	6	7	8[med]
30 Jun	0	0	7	6	7	6	1	2	6	5	7	7
1 Jul	0	0	4	5	4	5	0	0	0	0	0	0
2 Jul	8	4	0	0	8	4	2	1	0	0	2	1
3 Jul	4	2	1	1	5	3	5	3	1	1	6	4
4 Jul	0	0	1	1	1	1	1	1	3	3	4	4
5 Jul	1	1	4	3	5	4	1	1	4	3	5	4
6 Jul	1	1	3	2	4	3	0	0	3	2	3	2
7 Jul	0	0	3	3	3	3	1	5	1	1	2	6
8 Jul	0	0	3	6	3	6	1	1	3	6	4	7
9 Jul	1	1	0	0	1	1	0	0	0	0	0	0
10 Jul	1	2	0	0	1	2	0	0	0	0	0	0
11 Jul	1	1	0	0	1	1	1	1	0	0	1	1
12 Jul	0	0	1	1	1	1	0	0	0	0	0	0
13 Jul	0	0	1	1	1	1	1	1	0	0	1	1
14 Jul	0	0	1	1	1	1	0	0	1	1	1	1
15 Jul	0	0	0	0	0	0	0	0	2	2	2	2
16 Jul	0	0	0	0	0	0	1	0	0	0	1	0
17 Jul	0	0	0	0	0	0	0	0	0	0	0	0
18 Jul	1	1	0	0	1	1	0	0	0	0	0	0
19 Jul	0	0	0	0	0	0	0	0	0	0	0	0
20 Jul	0	0	0	0	0	0	0	0	0	0	0	0
21 Jul	0	0	0	0	0	0	0	0	1	1	1	1
22 Jul	0	0	0	0	0	0	0	0	0	0	0	0
Totals	24	16	71	69	95	86	30	27	58	54	88	80
Recovery %	0.09	0.06	0.26	0.25	0.34	0.31	0.11	0.10	0.22	0.20	0.33	0.30
Mvmt rate						26.2						26.2

Appendix Table A4.--Continued. 8

Date of recovery	Released 23 June — Treatments and tag code (AG D1 D2)[a] — Turbine 2nd PH 23 28 15 — Beach A[b]	Beach S[c]	Purse A	Purse S	Total A	Total S	Downstream 23 28 43 — Beach A	Beach S	Purse A	Purse S	Total A	Total S
NA	0	0	0	0	0	0	1	0	0	0	1	0
24 Jun	0	0	0	0	0	0	0	0	0	0	0	0
25 Jun	0	2	0	0	0	2	0	2	1	1	1	3
26 Jun	7	3	25	16	32	19	9	4	22	14	31	18
27 Jun	3	2	5	6	8	8	5	4	13	14	18	18
28 Jun	2	3	5	10	7	13[med]	1	1	7	14	8	15
29 Jun	0	0	3	4	3	4	0	0	8	10	8	10[med]
30 Jun	0	0	5	4	5	4	3	5	1	1	4	6
1 Jul	2	3	2	3	4	5	1	1	2	3	3	4
2 Jul	2	1	3	3	5	4	8	4	0	0	8	4
3 Jul	3	2	2	2	5	4	7	4	1	1	8	5
4 Jul	5	3	1	1	6	4	1	1	2	2	3	3
5 Jul	2	1	6	5	8	6	2	1	6	5	8	6
6 Jul	1	1	10	7	11	8	0	0	8	5	8	5
7 Jul	0	0	1	1	1	1	1	5	1	1	2	6
8 Jul	2	2	2	4	4	6	0	0	1	2	1	2
9 Jul	1	1	1	1	2	2	2	1	0	0	2	1
10 Jul	0	0	0	0	0	0	0	0	0	0	0	0
11 Jul	0	0	0	0	0	0	2	1	0	0	2	1
12 Jul	0	0	2	3	2	3	1	1	1	1	2	2
13 Jul	0	0	0	0	0	0	0	0	1	1	1	1
14 Jul	0	0	0	0	0	0	0	0	0	0	0	0
15 Jul	1	1	2	2	3	3	1	1	1	1	2	2
16 Jul	0	0	0	0	0	0	0	0	0	0	0	0
17 Jul	0	0	0	0	0	0	0	0	0	0	0	0
18 Jul	0	0	0	0	0	0	1	1	0	0	1	1
19 Jul	0	0	0	0	0	0	0	0	0	0	0	0
20 Jul	0	0	0	0	0	0	0	0	0	0	0	0
21 Jul	0	0	0	0	0	0	0	0	0	0	0	0
22 Jul	0	0	1	1	1	1	0	0	0	0	0	0
23 Jul	0	0	0	0	0	0	0	0	0	0	0	0
Totals	31	23	76	71	107	94	46	36	76	76	122	111
Recovery %	0.11	0.08	0.26	0.25	0.37	0.33	0.16	0.12	0.26	0.26	0.42	0.38
Mvmt rate						31.4						26.2

Appendix Table A4.--Continued. 9

Date of recovery	Released 24 June; Treatments and tag code (AG D1 D2)[a]: Bypass 1st PH 23 27 43						Turbine 1st PH 23 27 57					
	Beach		Purse		Total		Beach		Purse		Total	
	A[b]	S[c]	A	S	A	S	A	S	A	S	A	S
NA	1	0	0	0	1	0	0	0	0	0	0	0
22 Jun	0	0	0	0	0	0	0	0	0	0	0	0
23 Jun	0	0	0	0	0	0	0	0	1	1	1	1
24 Jun	0	0	0	0	0	0	0	0	1	1	1	1
25 Jun	0	0	0	0	0	0	0	0	0	0	0	0
26 Jun	1	0	8	5	9	5	0	0	5	3	5	3
27 Jun	1	1	10	11	11	12	2	1	17	19	19	20
28 Jun	1	1	3	6	4	7	0	0	3	6	3	6
29 Jun	0	0	6	8	6	8	1	1	7	9	8	10
30 Jun	0	0	7	6	7	6	1	2	7	6	8	7
1 Jul	0	0	2	3	2	3	3	4	2	3	5	6
2 Jul	3	2	1	1	4	3	4	2	2	2	6	4[med]
3 Jul	7	4	4	4	11	8[med]	9	5	3	3	12	8
4 Jul	2	1	2	2	4	3	2	1	2	2	4	3
5 Jul	2	1	6	5	8	6	0	0	6	5	6	5
6 Jul	2	2	8	5	10	7	1	1	4	3	5	4
7 Jul	3	15	0	0	3	15	4	20	2	2	6	22
8 Jul	0	0	4	8	4	8	1	1	3	6	4	7
9 Jul	3	2	0	0	3	2	0	0	0	0	0	0
10 Jul	1	2	1	2	2	3	0	0	0	0	0	0
11 Jul	0	0	1	1	1	1	3	2	0	0	3	2
12 Jul	0	0	0	0	0	0	0	0	2	3	2	3
13 Jul	0	0	1	1	1	1	0	0	0	0	0	0
14 Jul	0	0	0	0	0	0	0	0	0	0	0	0
15 Jul	2	1	1	1	3	2	0	0	1	1	1	1
16 Jul	0	0	0	0	0	0	1	0	0	0	1	0
17 Jul	1	0	0	0	1	0	0	0	0	0	0	0
18 Jul	0	0	0	0	0	0	2	1	0	0	2	1
19 Jul	1	1	1	1	2	2	0	0	0	0	0	0
20 Jul	0	0	0	0	0	0	0	0	0	0	0	0
21 Jul	0	0	0	0	0	0	0	0	1	1	1	1
22 Jul	0	0	0	0	0	0	0	0	0	0	0	0
Totals	31	33	66	69	97	102	34	41	69	74	103	115
Recovery %	0.11	0.12	0.24	0.25	0.35	0.37	0.13	0.15	0.26	0.28	0.38	0.43
Mvmt rate						19.6						17.4

Appendix Table A4.--Continued. 10

Date of recovery	Released 24 June; Treatments and tag code (AG D1 D2)[a]: Turbine 2nd PH 23 28 16						Downstream 23 28 45					
	Beach		Purse		Total		Beach		Purse		Total	
	A[b]	S[c]	A	S	A	S	A	S	A	S	A	S
NA	0	0	0	0	0	0	0	0	0	0	0	0
26 Jun	0	0	5	3	5	3	1	0	10	6	11	7
27 Jun	0	0	11	12	11	12	1	1	17	19	18	20
28 Jun	1	1	8	16	9	17	1	1	5	10	6	11
29 Jun	1	1	8	10	9	11	0	0	5	6	5	6
30 Jun	5	8	10	8	15	17[med]	2	3	12	10	14	13
1 Jul	2	3	1	1	3	4	3	4	0	0	3	4
2 Jul	6	3	2	2	8	5	6	3	6	7	12	10[med]
3 Jul	3	2	4	4	7	6	6	3	7	7	13	10
4 Jul	3	2	1	1	4	3	3	2	3	3	6	5
5 Jul	2	1	2	2	4	3	3	2	2	2	5	3
6 Jul	0	0	5	3	5	3	0	0	7	5	7	5
7 Jul	1	5	10	9	11	14	2	10	5	5	7	15
8 Jul	0	0	5	10	5	10	0	0	4	8	4	8
9 Jul	2	1	0	0	2	1	1	1	2	2	3	3
10 Jul	0	0	3	5	3	5	0	0	4	7	4	7
11 Jul	0	0	0	0	0	0	0	0	0	0	0	0
12 Jul	0	0	1	1	1	1	0	0	1	1	1	1
13 Jul	0	0	1	1	1	1	0	0	2	2	2	2
14 Jul	1	1	1	1	2	2	1	1	1	1	2	2
15 Jul	0	0	0	0	0	0	3	2	0	0	3	2
16 Jul	1	0	0	0	1	0	0	0	0	0	0	0
17 Jul	1	0	0	0	1	0	2	1	0	0	2	1
18 Jul	1	1	0	0	1	1	1	1	0	0	1	1
19 Jul	0	0	0	0	0	0	0	0	1	1	1	1
20 Jul	0	0	0	0	0	0	0	0	0	0	0	0
21 Jul	0	0	0	0	0	0	0	0	2	1	2	1
22 Jul	0	0	0	0	0	0	0	0	0	0	0	0
23 Jul	0	0	0	0	0	0	0	0	0	0	0	0
Totals	30	29	78	90	108	119	36	34	96	103	132	137
Recovery %	0.10	0.10	0.26	0.31	0.37	0.41	0.12	0.12	0.33	0.35	0.46	0.47
Mvmt rate						26.2						19.6

Appendix Table A4.--Continued. 11

Date of recovery	Released 25 June Treatments and tag code (AG D1 D2)[a] Bypass 1st PH 23 27 44 Beach A[b]	S[c]	Purse A	S	Total A	S	Turbine 1st PH 23 27 58 Beach A	S	Purse A	S	Total A	S
NA	0	0	0	0	0	0	0	0	0	0	0	0
27 Jun	0	0	0	0	0	0	0	0	0	0	0	0
28 Jun	0	0	6	12	6	12	2	3	6	12	8	15
29 Jun	0	0	7	9	7	9	0	0	8	10	8	10
30 Jun	1	2	6	5	7	7	1	2	6	5	7	7
1 Jul	3	4	3	4	6	8	0	0	2	3	2	3
2 Jul	5	3	3	3	8	6	5	3	4	4	9	7
3 Jul	9	5	2	2	11	7	11	6	4	4	15	10[med]
4 Jul	2	1	2	2	4	3[med]	6	4	4	4	10	8
5 Jul	0	0	9	7	9	7	5	3	9	7	14	10
6 Jul	2	2	7	5	9	7	3	3	8	5	11	8
7 Jul	3	15	1	1	4	16	0	0	1	1	1	1
8 Jul	1	1	1	2	2	3	0	0	4	8	4	8
9 Jul	2	1	0	0	2	1	2	1	0	0	2	1
10 Jul	0	0	2	3	2	3	1	2	4	7	5	8
11 Jul	2	1	0	0	2	1	0	0	0	0	0	0
12 Jul	0	0	3	4	3	4	0	0	2	3	2	3
13 Jul	1	1	1	1	2	2	0	0	1	1	1	1
14 Jul	0	0	2	2	2	2	0	0	1	1	1	1
15 Jul	0	0	2	2	2	2	1	1	0	0	1	1
16 Jul	0	0	0	0	0	0	1	0	0	0	1	0
17 Jul	1	0	0	0	1	0	0	0	0	0	0	0
18 Jul	1	1	0	0	1	1	3	2	0	0	3	2
19 Jul	0	0	2	3	2	3	0	0	0	0	0	0
20 Jul	0	0	0	0	0	0	0	0	0	0	0	0
Totals	33	36	59	66	92	102	41	27	64	75	105	102
Recovery %	0.12	0.13	0.21	0.24	0.33	0.37	0.15	0.10	0.23	0.27	0.39	0.37
Mvmt rate						17.4						19.6

Appendix Table A4.--Continued. 12

Date of recovery	Released 25 June Treatments and tag code (AG D1 D2)[a] Turbine 2nd PH 23 28 18 Beach A[b]	S[c]	Purse A	S	Total A	S	Downstream 23 28 46 Beach A	S	Purse A	S	Total A	S
NA	1	0	0	0	1	0	1	0	0	0	1	0
25 Jun	0	0	0	0	0	0	0	0	0	0	0	0
26 Jun	0	0	0	0	0	0	0	0	1	1	1	1
27 Jun	0	0	0	0	0	0	0	0	0	0	0	0
28 Jun	0	0	7	14	7	14	1	1	15	30	16	31
29 Jun	0	0	5	6	5	6	1	1	9	11	10	12
30 Jun	3	5	6	5	9	10	4	7	14	12	18	18
1 Jul	1	1	5	6	6	8	2	3	2	3	4	5
2 Jul	5	3	2	2	7	5	6	3	3	3	9	6
3 Jul	5	3	5	5	10	8	8	4	6	6	14	10[med]
4 Jul	3	2	7	8	10	10[med]	5	3	7	8	12	11
5 Jul	3	2	6	5	9	6	2	1	6	5	8	6
6 Jul	3	3	8	5	11	8	2	2	5	3	7	5
7 Jul	4	20	3	3	7	23	2	10	3	3	5	13
8 Jul	0	0	1	2	1	2	1	1	5	10	6	11
9 Jul	3	2	0	0	3	2	5	3	1	1	6	4
10 Jul	0	0	1	2	1	2	0	0	1	2	1	2
11 Jul	0	0	0	0	0	0	0	0	1	1	1	1
12 Jul	0	0	0	0	0	0	4	3	2	3	6	6
13 Jul	1	1	1	1	2	2	0	0	1	1	1	1
14 Jul	0	0	0	0	0	0	0	0	0	0	0	0
15 Jul	1	1	0	0	1	1	0	0	1	1	1	1
16 Jul	0	0	0	0	0	0	1	0	1	1	2	2
17 Jul	0	0	0	0	0	0	4	2	0	0	4	2
18 Jul	1	1	1	3	2	3	0	0	0	0	0	0
19 Jul	1	1	0	0	1	1	1	1	1	1	2	2
20 Jul	0	0	0	0	0	0	0	0	0	0	0	0
21 Jul	0	0	1	1	1	1	0	0	0	0	0	0
22 Jul	0	0	1	1	1	1	0	0	0	0	0	0
23 Jul	0	0	0	0	0	0	0	0	0	0	0	0
Totals	35	42	60	68	95	110	50	45	85	105	135	150
Recovery %	0.12	0.15	0.21	0.24	0.33	0.38	0.17	0.15	0.29	0.36	0.46	0.51
Mvmt rate						17.4						19.6

Appendix Table A4.--Continued. 13

Date of recovery	Released 29 June — Treatments and tag code (AG D1 D2)[a]: Bypass 1st PH 23 27 45 — Beach A[b]	Beach S[c]	Purse A	Purse S	Total A	Total S	Turbine 1st PH 23 27 59 — Beach A	Beach S	Purse A	Purse S	Total A	Total S
NA	0	0	0	0	0	0	1	0	0	0	1	0
1 Jul	0	0	0	0	0	0	0	0	0	0	0	0
2 Jul	0	0	3	3	3	3	0	0	1	1	1	1
3 Jul	2	1	8	8	10	9	8	4	8	8	16	12
4 Jul	4	3	4	4	8	7	4	3	10	11	14	14
5 Jul	2	1	11	8	13	10	5	3	12	9	17	12
6 Jul	2	2	11	7	13	9	5	5	19	13	24	18
7 Jul	4	20	8	7	12	27[med]	4	20	8	7	12	27[med]
8 Jul	1	1	5	10	6	11	5	5	5	10	10	15
9 Jul	5	3	2	2	7	5	5	3	0	0	5	3
10 Jul	0	0	4	7	4	7	2	3	2	3	4	7
11 Jul	2	1	2	3	4	4	1	1	0	0	1	1
12 Jul	3	2	4	6	7	8	3	2	4	6	7	8
13 Jul	0	0	5	4	5	4	0	0	1	1	1	1
14 Jul	0	0	1	1	1	1	1	1	2	2	3	3
15 Jul	3	2	1	1	4	3	3	2	3	3	6	5
16 Jul	2	1	1	1	3	2	2	1	1	1	3	2
17 Jul	0	0	0	0	0	0	0	0	3	3	3	3
18 Jul	4	2	0	0	4	2	3	2	0	0	3	2
19 Jul	0	0	3	4	3	4	0	0	1	1	1	1
20 Jul	0	0	0	0	0	0	0	0	2	3	2	3
21 Jul	0	0	0	0	0	0	0	0	1	1	1	1
Totals	34	39	73	77	107	116	52	54	83	83	135	137
Recovery %	0.12	0.13	0.25	0.26	0.36	0.39	0.18	0.18	0.28	0.28	0.46	0.46
Mvmt rate						19.6						19.6

Appendix Table A4.--Continued. 14

Date of recovery	Released 29 June — Treatments and tag code (AG D1 D2)[a]: Turbine 2nd PH 23 28 20 — Beach A[b]	Beach S[c]	Purse A	Purse S	Total A	Total S	Downstream 23 28 48 — Beach A	Beach S	Purse A	Purse S	Total A	Total S
NA	2	0	0	0	2	0	0	0	0	0	0	0
28 Jun	0	0	0	0	0	0	0	0	0	0	0	0
29 Jun	0	0	0	0	0	0	0	0	0	0	0	0
30 Jun	0	0	0	0	0	0	0	0	0	0	0	0
1 Jul	0	0	0	0	0	0	0	0	0	0	0	0
2 Jul	0	0	1	1	1	1	0	0	5	6	5	6
3 Jul	4	2	12	12	16	14	7	4	16	16	23	20
4 Jul	5	3	4	4	9	8	10	6	13	14	23	21
5 Jul	5	3	9	7	14	10	7	4	17	13	24	17
6 Jul	3	3	15	10	18	13	3	3	17	11	20	14
7 Jul	4	20	8	7	12	27[med]	9	45	4	4	13	49[med]
8 Jul	2	2	1	2	3	4	8	8	2	4	10	12
9 Jul	3	2	3	3	6	5	9	5	2	2	11	7
10 Jul	0	0	0	0	0	0	2	3	4	7	6	10
11 Jul	2	1	2	3	4	4	3	2	3	4	6	5
12 Jul	1	1	2	3	3	4	1	1	5	7	6	8
13 Jul	1	1	4	3	5	4	1	1	3	2	4	3
14 Jul	2	2	1	1	3	3	1	1	4	4	5	4
15 Jul	1	1	5	5	6	6	1	1	0	0	1	1
16 Jul	0	0	2	2	2	2	5	2	2	2	7	4
17 Jul	3	1	0	0	3	1	1	0	0	0	1	0
18 Jul	3	2	0	0	3	2	4	2	0	0	4	2
19 Jul	1	1	3	4	4	4	0	0	1	1	1	1
20 Jul	0	0	0	0	0	0	0	0	2	3	2	3
21 Jul	0	0	0	0	0	0	0	0	3	2	3	2
22 Jul	0	0	0	0	0	0	0	0	0	0	0	0
Totals	42	44	72	68	114	111	72	88	103	102	175	190
Recovery %	0.14	0.15	0.25	0.23	0.39	0.39	0.25	0.30	0.35	0.35	0.60	0.65
Mvmt rate						19.6						19.6

Appendix Table A4.--Continued. 15

Date of recovery	Released 30 June											
	Treatments and tag code (AG D1 D2)[a]											
	Bypass 1st PH 23 27 46						Turbine 1st PH 23 27 60					
	Beach		Purse		Total		Beach		Purse		Total	
	A[b]	S[c]	A	S	A	S	A	S	A	S	A	S
NA	1	0	0	0	1	0	0	0	0	0	0	0
3 Jul	0	0	0	0	0	0	0	0	0	0	0	0
4 Jul	3	2	1	1	4	3	0	0	8	9	8	9
5 Jul	2	1	10	8	12	9	3	2	16	12	19	14
6 Jul	1	1	8	5	9	6	1	1	17	11	18	12
7 Jul	2	10	11	10	13	20	5	25	5	5	10	30[med]
8 Jul	1	1	10	20	11	21[med]	2	2	6	12	8	14
9 Jul	5	3	2	2	7	5	3	2	3	3	6	5
10 Jul	1	2	3	5	4	7	1	2	4	7	5	8
11 Jul	1	1	3	4	4	4	2	1	3	4	5	5
12 Jul	3	2	3	4	6	7	2	2	2	3	4	5
13 Jul	1	1	3	2	4	3	0	0	2	2	2	2
14 Jul	1	1	1	1	2	2	0	0	0	0	0	0
15 Jul	0	0	2	2	2	2	3	2	2	2	5	4
16 Jul	1	0	2	2	3	3	1	0	2	2	3	3
17 Jul	1	0	0	0	1	0	1	0	0	0	1	0
18 Jul	1	1	1	3	2	3	2	1	0	0	2	1
19 Jul	0	0	0	0	0	0	0	0	0	0	0	0
20 Jul	0	0	1	1	1	1	0	0	1	1	1	1
21 Jul	0	0	0	0	0	0	0	0	0	0	0	0
22 Jul	0	0	0	0	0	0	0	0	1	1	1	1
23 Jul	0	0	0	0	0	0	0	0	0	0	0	0
Totals	25	26	61	71	86	97	26	40	72	74	98	113
Recovery %	0.09	0.09	0.21	0.24	0.29	0.33	0.09	0.14	0.25	0.26	0.34	0.40
Mvmt rate						19.6						22.4

Appendix Table A4.--Continued. 16

Date of recovery	Released 30 June											
	Treatments and tag code (AG D1 D2)[a]											
	Turbine 2nd PH 23 28 23						Downstream 23 28 51					
	Beach		Purse		Total		Beach		Purse		Total	
	A[b]	S[c]	A	S	A	S	A	S	A	S	A	S
NA	1	0	0	0	1	0	0	0	0	0	0	0
3 Jul	0	0	0	0	0	0	0	0	0	0	0	0
4 Jul	3	2	10	11	13	13	4	3	8	9	12	11
5 Jul	3	2	11	8	14	10	5	3	19	15	24	18
6 Jul	1	1	10	7	11	8	3	3	20	13	23	16
7 Jul	4	20	4	4	8	24[med]	4	20	11	10	15	30[med]
8 Jul	3	3	3	6	6	9	1	1	5	10	6	11
9 Jul	3	2	0	0	3	2	3	2	2	2	5	4
10 Jul	2	3	2	3	4	7	1	2	3	5	4	7
11 Jul	1	1	0	0	1	1	1	1	6	8	7	8
12 Jul	1	1	3	4	4	5	4	3	3	4	7	8
13 Jul	2	2	3	2	5	4	1	1	3	2	4	3
14 Jul	0	0	10	9	10	9	2	2	6	5	8	7
15 Jul	2	1	2	2	4	3	2	1	2	2	4	3
16 Jul	2	1	0	0	2	1	3	1	2	2	5	4
17 Jul	0	0	2	2	2	2	0	0	0	0	0	0
18 Jul	0	0	1	3	1	3	2	1	0	0	2	1
19 Jul	0	0	4	5	4	5	1	1	3	4	4	4
20 Jul	0	0	0	0	0	0	1	1	0	0	1	1
21 Jul	0	0	2	1	2	1	1	2	2	1	3	3
22 Jul	0	0	0	0	0	0	0	0	0	0	0	0
Totals	28	38	67	68	95	106	39	46	95	93	134	139
Recovery %	0.10	0.13	0.23	0.23	0.32	0.36	0.13	0.16	0.32	0.32	0.46	0.48
Mvmt rate						22.4						22.4

Appendix Table A4.--Continued. 17

Date of recovery	Bypass 1st PH 23 27 47: Beach A[b]	Beach S[c]	Purse A	Purse S	Total A	Total S	Turbine 1st PH 23 27 61: Beach A	Beach S	Purse A	Purse S	Total A	Total S
Released 1 July — Treatments and tag code (AG D1 D2)[a]												
NA	2	0	0	0	2	0	0	0	0	0	0	0
4 Jul	0	0	0	0	0	0	0	0	0	0	0	0
5 Jul	0	0	8	6	8	6	3	2	8	6	11	8
6 Jul	1	1	15	10	16	11	0	0	18	12	18	12
7 Jul	1	5	17	15	18	20	2	10	6	5	8	15
8 Jul	0	0	8	16	8	16[med]	0	0	6	12	6	12
9 Jul	2	1	1	1	3	2	4	2	4	4	8	7[med]
10 Jul	0	0	5	8	5	8	0	0	6	10	6	10
11 Jul	0	0	3	4	3	4	0	0	1	1	1	1
12 Jul	2	2	5	7	7	9	2	2	4	6	6	7
13 Jul	1	1	3	2	4	3	0	0	6	5	6	5
14 Jul	1	1	4	4	5	4	0	0	3	3	3	3
15 Jul	6	3	2	2	8	5	2	1	6	6	8	7
16 Jul	0	0	2	2	2	2	2	1	1	1	3	2
17 Jul	2	1	0	0	2	1	3	1	3	3	6	5
18 Jul	0	0	0	0	0	0	1	1	0	0	1	1
19 Jul	1	1	1	1	2	2	1	1	0	0	1	1
20 Jul	0	0	2	3	2	3	0	0	2	3	2	3
21 Jul	0	0	0	0	0	0	0	0	1	1	1	1
22 Jul	0	0	1	1	1	1	0	0	2	2	2	2
23 Jul	0	0	0	0	0	0	0	0	2	4	2	4
24 Jul	0	0	0	0	0	0	0	0	0	0	0	0
25 Jul	0	0	0	0	0	0	0	0	0	0	0	0
26 Jul	0	0	1	3	1	3	0	0	0	0	0	0
27 Jul	0	0	0	0	0	0	0	0	0	0	0	0
Totals	19	15	78	86	97	102	20	20	79	84	99	104
Recovery %	0.06	0.05	0.26	0.29	0.33	0.34	0.07	0.07	0.27	0.29	0.34	0.36
Mvmt rate						22.4						19.6

Appendix Table A4.--Continued. 18

Date of recovery	Turbine 2nd PH 23 28 24: Beach A[b]	Beach S[c]	Purse A	Purse S	Total A	Total S	Downstream 23 28 53: Beach A	Beach S	Purse A	Purse S	Total A	Total S
Released 1 July — Treatments and tag code (AG D1 D2)[a]												
NA	0	0	0	0	0	0	2	0	0	0	2	0
3 Jul	0	0	0	0	0	0	0	0	0	0	0	0
4 Jul	0	0	1	1	1	1	0	0	2	2	2	2
5 Jul	0	0	10	8	10	8	1	1	9	7	10	8
6 Jul	1	1	12	8	13	9	1	1	21	14	22	15
7 Jul	4	20	7	6	11	26	2	10	15	14	17	24
8 Jul	3	3	5	10	8	13[med]	0	0	8	16	8	16
9 Jul	2	1	2	2	4	3	2	1	1	1	3	2[med]
10 Jul	2	3	2	3	4	7	0	0	7	12	7	12
11 Jul	0	0	1	1	1	1	2	1	4	5	6	6
12 Jul	1	1	2	3	3	4	2	2	7	10	9	12
13 Jul	0	0	4	3	4	3	0	0	5	4	5	4
14 Jul	1	1	3	3	4	4	0	0	8	7	8	7
15 Jul	1	1	1	1	2	2	2	1	3	3	5	4
16 Jul	1	0	0	0	1	0	1	0	6	7	7	7
17 Jul	2	1	4	4	6	5	2	1	2	2	4	3
18 Jul	4	2	1	3	5	5	1	1	0	0	1	1
19 Jul	0	0	3	4	3	4	1	1	6	8	7	8
20 Jul	0	0	1	1	1	1	0	0	0	0	0	0
21 Jul	0	0	3	2	3	2	0	0	2	1	2	1
22 Jul	0	0	1	1	1	1	0	0	0	0	0	0
23 Jul	0	0	0	0	0	0	0	0	0	0	0	0
Totals	22	34	63	65	85	99	19	19	106	113	125	132
Recovery %	0.07	0.11	0.21	0.22	0.29	0.33	0.07	0.07	0.39	0.41	0.45	0.48
Mvmt rate						22.4						19.6

Appendix Table A4.--Continued. 19

Date of recovery	Released 2 July: Treatments and tag code (AG D1 D2)[a] Bypass 1st PH 23 27 48 Beach A[b]	S[c]	Purse A	S	Total A	S	Turbine 1st PH 23 27 62 Beach A	S	Purse A	S	Total A	S
NA	0	0	0	0	0	0	0	0	0	0	0	0
5 Jul	0	0	0	0	0	0	0	0	0	0	0	0
6 Jul	0	0	9	6	9	6	1	1	11	7	12	8
7 Jul	1	5	13	12	14	17	2	10	9	8	11	18
8 Jul	1	1	10	20	11	21[med]	0	0	2	4	2	4
9 Jul	0	0	0	0	0	0	3	2	6	7	9	8
10 Jul	1	2	4	7	5	8	0	0	6	10	6	10[med]
11 Jul	1	1	3	4	4	4	2	1	4	5	6	6
12 Jul	1	1	2	3	3	4	2	2	2	3	4	5
13 Jul	1	1	3	2	4	3	0	0	4	3	4	3
14 Jul	0	0	5	5	5	5	1	1	7	6	8	7
15 Jul	2	1	3	3	5	4	3	2	2	2	5	4
16 Jul	1	0	2	2	3	3	2	1	2	2	4	3
17 Jul	2	1	1	1	3	2	3	1	1	1	4	2
18 Jul	5	3	0	0	5	3	3	2	0	0	3	2
19 Jul	1	1	2	3	3	3	0	0	2	3	2	3
20 Jul	0	0	1	1	1	1	0	0	1	1	1	1
21 Jul	0	0	0	0	0	0	0	0	1	1	1	1
22 Jul	0	0	1	1	1	1	0	0	2	2	2	2
23 Jul	0	0	0	0	0	0	0	0	0	0	0	0
Totals	17	16	59	69	76	85	22	22	62	65	84	87
Recovery %	0.06	0.05	0.20	0.24	0.26	0.29	0.07	0.07	0.21	0.22	0.29	0.30
Mvmt rate						26.2						19.6

Appendix Table A4.--Continued. 20

Date of recovery	Released 2 July: Treatments and tag code (AG D1 D2)[a] Turbine 2nd PH 23 28 27 Beach A[b]	S[c]	Purse A	S	Total A	S	Downstream 23 28 54 Beach A	S	Purse A	S	Total A	S
NA	0	0	0	0	0	0	0	0	0	0	0	0
5 Jul	0	0	0	0	0	0	0	0	0	0	0	0
6 Jul	0	0	13	9	13	9	1	1	9	6	10	7
7 Jul	5	25	7	6	12	31	2	10	22	20	24	30
8 Jul	0	0	4	8	4	8[med]	0	0	13	26	13	26
9 Jul	1	1	3	3	4	4	1	1	4	4	5	5[med]
10 Jul	0	0	2	3	2	3	0	0	8	13	8	13
11 Jul	0	0	2	3	2	3	1	1	2	3	3	3
12 Jul	1	1	7	10	8	11	0	0	8	11	8	11
13 Jul	1	1	2	2	3	3	0	0	5	4	5	4
14 Jul	2	2	3	3	5	4	1	1	4	4	5	4
15 Jul	0	0	3	3	3	3	4	2	5	5	9	7
16 Jul	0	0	4	4	4	4	2	1	2	2	4	3
17 Jul	1	0	1	1	2	2	2	1	1	1	3	2
18 Jul	2	1	0	0	2	1	2	1	0	0	2	1
19 Jul	1	1	1	1	2	2	1	1	7	9	8	9
20 Jul	0	0	1	1	1	1	0	0	0	0	0	0
21 Jul	0	0	2	1	2	1	0	0	1	1	1	1
22 Jul	0	0	1	1	1	1	0	0	0	0	0	0
23 Jul	0	0	0	0	0	0	0	0	0	0	0	0
Totals	14	31	56	60	70	91	17	19	91	109	108	128
Recovery %	0.05	0.10	0.19	0.20	0.24	0.31	0.06	0.06	0.31	0.37	0.37	0.44
Mvmt rate						26.2						17.4

Appendix Table A4.--Continued. 21

Date of recovery	Released 7 July — Treatments and tag code (AG D1 D2)[a] — Bypass 1st PH 23 27 49						Turbine 1st PH 23 27 63					
	Beach		Purse		Total		Beach		Purse		Total	
	A[b]	S[c]	A	S	A	S	A	S	A	S	A	S
NA	0	0	0	0	0	0	0	0	0	0	0	0
9 Jul	0	0	0	0	0	0	0	0	0	0	0	0
10 Jul	0	0	0	0	0	0	0	0	1	2	1	2
11 Jul	1	1	0	0	1	1	0	0	0	0	0	0
12 Jul	2	2	5	7	7	9	1	1	4	6	5	7
13 Jul	0	0	5	4	5	4	1	1	3	2	4	3
14 Jul	1	1	2	2	3	3	1	1	4	4	5	4
15 Jul	3	2	0	0	3	2	4	2	5	5	9	7
16 Jul	1	0	1	1	2	2	6	3	4	4	10	7
17 Jul	2	1	1	1	3	2	4	2	1	1	5	3
18 Jul	5	3	2	5	7	8	3	2	3	8	6	9
19 Jul	2	1	8	10	10	11[med]	2	1	9	11	11	12[med]
20 Jul	2	1	6	8	8	9	0	0	16	20	16	20
21 Jul	0	0	10	7	10	7	0	0	12	9	12	9
22 Jul	0	0	6	5	6	5	0	0	5	5	5	5
23 Jul	0	0	1	2	1	2	0	0	2	4	2	4
24 Jul	0	0	1	3	1	3	0	0	0	0	0	0
25 Jul	0	0	0	0	0	0	0	0	0	0	0	0
Totals	19	11	48	56	67	67	22	12	69	80	91	92
Recovery %	0.06	0.04	0.16	0.19	0.23	0.23	0.07	0.04	0.23	0.27	0.31	0.31
Mvmt rate						13.1						13.1

Appendix Table A4.--Continued. 22

Date of recovery	Released 7 July — Treatments and tag code (AG D1 D2)[a] — Turbine 2nd PH 23 28 29						Downstream 23 28 57					
	Beach		Purse		Total		Beach		Purse		Total	
	A[b]	S[c]	A	S	A	S	A	S	A	S	A	S
NA	0	0	0	0	0	0	1	0	0	0	1	0
9 Jul	0	0	0	0	0	0	0	0	0	0	0	0
10 Jul	0	0	0	0	0	0	0	0	1	2	1	2
11 Jul	0	0	0	0	0	0	0	0	0	0	0	0
12 Jul	0	0	1	1	1	1	1	1	4	6	5	7
13 Jul	0	0	3	2	3	2	0	0	2	2	2	2
14 Jul	0	0	3	3	3	3	2	1	2	2	4	3
15 Jul	0	0	1	1	1	1	3	2	1	1	4	3
16 Jul	1	0	3	3	4	4	4	2	4	4	8	6
17 Jul	6	3	1	1	7	4	6	3	1	1	7	4
18 Jul	2	1	0	0	2	1	9	5	3	8	12	12
19 Jul	1	1	7	9	8	9	0	0	11	14	11	14[med]
20 Jul	0	0	3	4	3	4[med]	1	1	6	8	7	8
21 Jul	0	0	11	8	11	8	1	2	21	15	22	17
22 Jul	0	0	3	3	3	3	1	2	9	8	10	10
23 Jul	0	0	4	8	4	8	0	0	3	6	3	6
24 Jul	0	0	1	3	1	3	0	0	0	0	0	0
25 Jul	0	0	0	0	0	0	0	0	0	0	0	0
Totals	10	5	41	47	51	51	29	17	68	75	97	93
Recovery %	0.03	0.02	0.14	0.16	0.17	0.17	0.10	0.06	0.23	0.25	0.33	0.30
Mvmt rate						12.1						13.1

Appendix Table A4.--Continued. 23

Date of recovery	Released 8 July											
	Treatments and tag code (AG D1 D2)[a]											
	Bypass 1st PH 23 27 50						Turbine 1st PH 23 28 03					
	Beach		Purse		Total		Beach		Purse		Total	
	A[b]	S[c]	A	S	A	S	A	S	A	S	A	S
NA	0	0	0	0	0	0	0	0	0	0	0	0
11 Jul	0	0	0	0	0	0	0	0	0	0	0	0
12 Jul	0	0	2	3	2	3	0	0	2	3	2	3
13 Jul	0	0	2	2	2	2	0	0	1	1	1	1
14 Jul	1	1	2	2	3	3	0	0	1	1	1	1
15 Jul	3	2	4	4	7	6	1	1	1	1	2	2
16 Jul	3	1	0	0	3	1	0	0	2	2	2	2
17 Jul	1	0	0	0	1	0	7	3	0	0	7	3
18 Jul	1	1	1	3	2	3	5	3	0	0	5	3
19 Jul	2	1	7	9	9	10[med]	0	0	3	4	3	4
20 Jul	0	0	3	4	3	4	1	1	5	6	6	7[med]
21 Jul	0	0	12	9	12	9	0	0	16	11	16	11
22 Jul	0	0	5	5	5	5	0	0	6	5	6	5
23 Jul	0	0	2	4	2	4	0	0	1	2	1	2
24 Jul	0	0	0	0	0	0	0	0	0	0	0	0
Totals	11	6	40	42	51	48	14	7	38	37	52	44
Recovery %	0.04	0.02	0.13	0.14	0.17	0.16	0.05	0.02	0.13	0.12	0.18	0.15
Mvmt rate						14.3						13.1

Appendix Table A4.--Continued. 24

Date of recovery	Released 8 July											
	Treatments and tag code (AG D1 D2)[a]											
	Turbine 2nd PH 23 28 30						Downstream 23 28 58					
	Beach		Purse		Total		Beach		Purse		Total	
	A[b]	S[c]	A	S	A	S	A	S	A	S	A	S
NA	0	0	0	0	0	0	0	0	1	0	1	0
11 Jul	0	0	0	0	0	0	0	0	0	0	0	0
12 Jul	0	0	1	1	1	1	1	1	4	6	5	7
13 Jul	0	0	1	1	1	1	0	0	0	0	0	0
14 Jul	2	2	3	3	5	4	1	1	5	5	6	5
15 Jul	1	1	1	1	2	2	2	1	4	4	6	5
16 Jul	2	1	1	1	3	2	4	2	2	2	6	4
17 Jul	2	1	1	1	3	2	4	2	3	3	7	5
18 Jul	4	2	0	0	4	2	10	5	0	0	10	5
19 Jul	0	0	8	10	8	10[med]	1	1	9	11	10	12[med]
20 Jul	2	1	2	3	4	4	0	0	2	3	2	3
21 Jul	0	0	11	8	11	8	1	2	13	9	14	11
22 Jul	0	0	4	4	4	4	0	0	7	6	7	6
23 Jul	0	0	1	2	1	2	0	0	1	2	1	2
24 Jul	0	0	0	0	0	0	0	0	1	3	1	3
25 Jul	0	0	0	0	0	0	0	0	0	0	0	0
Totals	13	7	34	34	47	42	24	14	52	55	76	68
Recovery %	0.04	0.03	0.12	0.12	0.16	0.14	0.08	0.05	0.18	0.18	0.26	0.23
Mvmt rate						14.3						14.3

Date of recovery	Released 9 July — Treatments and tag code (AG D1 D2)[a] — Bypass 1st PH 23 27 51 — Beach A[b]	Beach S[c]	Purse A	Purse S	Total A	Total S	Turbine 1st PH 23 28 05 — Beach A	Beach S	Purse A	Purse S	Total A	Total S
NA	0	0	0	0	0	0	0	0	0	0	0	0
11 Jul	0	0	0	0	0	0	0	0	0	0	0	0
12 Jul	0	0	1	1	1	1	0	0	2	3	2	3
13 Jul	0	0	6	5	6	5	0	0	2	2	2	2
14 Jul	1	1	1	1	2	2	1	1	1	1	2	2
15 Jul	1	1	0	0	1	1	6	3	3	3	9	6
16 Jul	2	1	1	1	3	2	2	1	2	2	4	3
17 Jul	3	1	1	1	4	2	5	2	2	2	7	4
18 Jul	8	4	2	5	10	9	11	6	1	3	12	8
19 Jul	3	2	9	11	12	13[med]	1	1	5	6	6	7[med]
20 Jul	1	1	4	5	5	6	2	1	4	5	6	6
21 Jul	0	0	12	9	12	9	0	0	19	14	19	14
22 Jul	0	0	7	6	7	6	0	0	6	5	6	5
23 Jul	0	0	0	0	0	0	0	0	1	2	1	2
24 Jul	0	0	0	0	0	0	0	0	0	0	0	0
25 Jul	0	0	0	0	0	0	0	0	0	0	0	0
26 Jul	0	0	0	0	0	0	0	0	0	0	0	0
27 Jul	0	0	0	0	0	0	0	0	0	0	0	0
28 Jul	0	0	0	0	0	0	0	0	0	0	0	0
29 Jul	0	0	0	0	0	0	0	0	0	0	0	0
30 Jul	0	0	0	0	0	0	0	0	0	0	0	0
31 Jul	0	0	0	0	0	0	0	0	1	5	1	5
Totals	19	10	44	46	63	56	28	15	49	53	77	67
Recovery %	0.07	0.04	0.15	0.16	0.22	0.20	0.10	0.05	0.17	0.18	0.27	0.24
Mvmt rate						15.7						15.7

Date of recovery	Released 9 July — Treatments and tag code (AG D1 D2)[a] — Turbine 2nd PH 23 28 33 — Beach A[b]	Beach S[c]	Purse A	Purse S	Total A	Total S	Downstream 23 28 60 — Beach A	Beach S	Purse A	Purse S	Total A	Total S
NA	0	0	1	0	1	0	0	0	0	0	0	0
11 Jul	0	0	0	0	0	0	0	0	0	0	0	0
12 Jul	0	0	1	1	1	1	0	0	4	6	4	6
13 Jul	1	1	1	1	2	2	0	0	1	1	1	1
14 Jul	0	0	3	3	3	3	2	2	9	8	11	10
15 Jul	1	1	1	1	2	2	5	3	2	2	7	5
16 Jul	3	1	4	4	7	6	6	3	3	3	9	4
17 Jul	0	0	1	1	1	1	4	2	2	2	6	4
18 Jul	5	3	0	0	5	3	11	6	2	5	13	11
19 Jul	1	1	14	18	15	18[med]	2	1	17	21	19	22[med]
20 Jul	0	0	12	15	12	15	0	0	9	11	9	11
21 Jul	0	0	15	11	15	11	0	0	25	18	25	18
22 Jul	0	0	7	6	7	6	1	2	1	1	2	3
23 Jul	0	0	1	2	1	2	0	0	0	0	0	0
24 Jul	0	0	0	0	0	0	0	0	0	0	0	0
25 Jul	0	0	0	0	0	0	0	0	0	0	0	0
26 Jul	0	0	0	0	0	0	0	0	1	3	1	3
27 Jul	0	0	0	0	0	0	0	0	0	0	0	0
28 Jul	0	0	0	0	0	0	0	0	0	0	0	0
29 Jul	0	0	0	0	0	0	0	0	0	0	0	0
30 Jul	0	0	0	0	0	0	0	0	0	0	0	0
31 Jul	0	0	0	0	0	0	0	0	0	0	0	0
Totals	11	6	61	63	72	69	31	17	76	82	107	99
Recovery %	0.04	0.02	0.21	0.21	0.24	0.23	0.11	0.06	0.27	0.30	0.39	0.36
Mvmt rate						15.7						15.7

[a] AG D1 D2 = Agency code, Data 1 code, Data 2 code.

[b] A = Actual daily purse seine or beach seine catch. NE = no sampling effort.

[c] S = Standardized daily catch. Purse seine data standardized to a 10 set per day effort; beach seine data standardized to a 5 set per day effort. Due to rounding, totals may not match sum in column.

[d] med = Date that the median fish was captured (total catch, adjusted effort).

[e] Mvmt rate = Movement rate (km/day) = distance traveled (RKm 232, downstream release site minus RKm 75, Jones Beach sampling site) ÷ travel time (in days, from release date to date of median fish recovery at Jones Beach).

Appendix Table A5.--Diel catch results from purse and beach seine sampling at Jones Beach through a 24-hour period, 26-27 June 1992.

Gear--vessel	Date	Set time	Set	Subyearling chinook salmon
Beach	26 Jun	0455	01	606
Beach	26 Jun	0635	02	2,260
Beach	26 Jun	0938	03	957
Beach	26 Jun	1113	04	839
Beach	26 Jun	1334	05	543
Beach	26 Jun	1512	06	1,172
Beach	26 Jun	1702	07	1,067
Beach	26 Jun	1912	08	423
Beach	26 Jun	2005	09	117
Beach	26 Jun	2108	10	87
Beach	26 Jun	2355	11	6
Beach	27 Jun	0300	01	19
Beach	27 Jun	0455	02	763
Beach	27 Jun	0730	03	830
Beach	27 Jun	0810	04	1,333
Beach	27 Jun	0940	05	634
Beach	27 Jun	1030	06	378
Beach	27 Jun	1130	07	293
		Total beach seine	18	12,327
Purse--GW	26 Jun	0520	01	2,940
Purse--GW	26 Jun	0700	02	333
Purse--GW	26 Jun	0829	03	228
Purse--GW	26 Jun	1008	04	300
Purse--GW	26 Jun	1117	05	199
Purse--GW	27 Jun	0506	01	871
Purse--GW	27 Jun	0647	02	223
Purse--GW	27 Jun	0822	03	64
		Subtotal	8	5,158
Purse--Rosa	26 Jun	0534	01	1,937
Purse--Rosa	26 Jun	0723	02	347
Purse--Rosa	26 Jun	0845	03	236
Purse--Rosa	26 Jun	1013	04	243
Purse--Rosa	26 Jun	1119	05	152
Purse--Rosa	26 Jun	1227	06	76
Purse--Rosa	26 Jun	1410	07	116
Purse--Rosa	26 Jun	1545	08	19
Purse--Rosa	26 Jun	1750	09	148
Purse--Rosa	26 Jun	2032	10	463
Purse--Rosa	26 Jun	2214	11	33
Purse--Rosa	27 Jun	0108	01	71
Purse--Rosa	27 Jun	0450	02	468
Purse--Rosa	27 Jun	0620	03	120
Purse--Rosa	27 Jun	0804	04	67
Purse--Rosa	27 Jun	0931	05	111
Purse--Rosa	27 Jun	1056	06	107
		Subtotal	17	4,714
		Total purse seine	25	9,872

Appendix Table A6.--Marked recoveries of tule stock and upriver bright stock subyearling chinook salmon in purse seines and beach seines at Jones Beach during the diel sampling period, 26-27 June 1992.

Time interval[a]	Purse seine				Beach seine			
	Set		Stock		Set		Stock	
	No.	Time	Bright	Tule	No.	Time	Bright	Tule
26 June								
0431-0530	1	0527	173	130	1	0455	0	1
0531-0630	na[b]				na			
0631-0730	2	0711	14	8	2	0635	5	21
0631-0830	na				na			
0831-0930	3	0837	15	7	na			
0931-1030	4	1010	20	13	3	0938	5	11
1031-1130	5	1118	14	15	4	1113	8	12
1131-1230	6	1227	4	2	na			
1231-1330	na				na			
1331-1430	7	1410	8	4	5	1334	9	14
1431-1530	na				6	1512	26	36
1531-1630	8	1545	0	1	na			
1631-1730	na				7	1702	21	19
1731-1830	9	1750	2	3	na			
1831-1930	na				8	1912	8	10
1931-2030	na				9	2005	2	1
2031-2130	10	2032	21	26	10	2108	0	6
2131-2230	11	2214	0	2	na			
2231-2330	na				na			
2331-0030	na				11	2355	0	0
27 June								
0031-0130	1	0108	2	5	na			
0131-0230	na				na			
0231-0330	na				1	0300	0	0
0331-0430	na				na			
0431-0530	2	0458	28	81	2	0455	4	8
0531-0630	na				na			
0631-0730	3	0634	11	9	3	0730	7	12
0731-0830	4	0813	3	5	4	0810	4	11
0831-0930	na				5	0930	4	15
0931-1030	5	0931	4	3	6	1030	3	7
1031-1130	6	1056	0	1	7	1130	4	3
Totals			319	315			110	187

[a] Standardized time intervals used for plotting diel catch curves.
[b] na = data not available (no sampling effort).

Appendix Table A7.--Primary dietary components of subyearling chinook salmon at Jones Beach, 1992.

Upriver bright stock–purse seine

Sample date	22 Jun	23 Jun	23 Jun	24 Jun	24 Jun	26 Jun	26 Jun	26 Jun	26 Jun	26 Jun	26 Jun	26 Jun	27 Jun	Totals	
Set time	0841	0513	0622	0513	0954	0534	0845	1013	1119	1227	1410	2032	0108	No.	%
Insecta (Order)	Number identified in stomachs (pooled by set no.)														
Diptera	9	23	19		1	2	3	27	10	5	45	19	1	164	22.8
Homoptera	7	1	7			1	1				4	1		22	3.1
Hemiptera			1								5	7		13	1.8
Coleoptera			1			1		7	1		6	3		19	2.6
Psocoptera	179	60	75	1		5		21	3	2	121			467	64.8
Thysanoptera			1									1		2	0.3
Hymenoptera	2				1			8	5	1	10	2		29	4.0
Neuroptera						1								1	0.1
Plecoptera								1						1	0.1
Collumbola												1		1	0.1
Lepidoptera												2		2	0.3
Subtotal Insecta														721	
Crustacea (Order)															
Amphipoda		2	9	4	5	17	38	47	12	13	9	32	12	200	7.9
Mysidacea		2		1	1		24	6	2			1		37	1.5
Cladocera	35	26	180		19	47	9		10	1,509	9	79	2	1,925	76.2
Copepoda	15	3	15		1	5	1	1		296	9	18		364	14.4
Subtotal Crustacea														2,526	

Upriver bright stock–beach seine

Sample date	22 Jun	26 Jun	26 Jun	26 Jun	26 Jun	26 Jun	26 Jun	Totals	
Set time	1030	0635	0938	1113	1334	1702	1912	No.	%
Insecta (Order)									
Diptera	6	4		23	22	12	2	69	55.2
Homoptera	2							2	1.6
Hemiptera	1						1	2	1.6
Coleoptera	1			1				2	1.6
Psocoptera	45							45	36.0
Thysanoptera								0	0.0
Hymenoptera				1		2		3	2.4
Neuroptera								0	0.0
Plecoptera			1	1				2	1.6
Collumbola								0	0.0
Lepidoptera								0	0.0
Subtotal Insecta								125	
Crustacea (Order)									
Amphipoda		12	38	33	4	23	2	112	1.6
Mysidacea			3	4		1		8	0.1
Cladocera	2,518	53	24	374	839	1,041	146	4,995	73.3
Copepoda	106	5	111	537	201	352	385	1,697	24.9
Subtotal Crustacea								6,812	

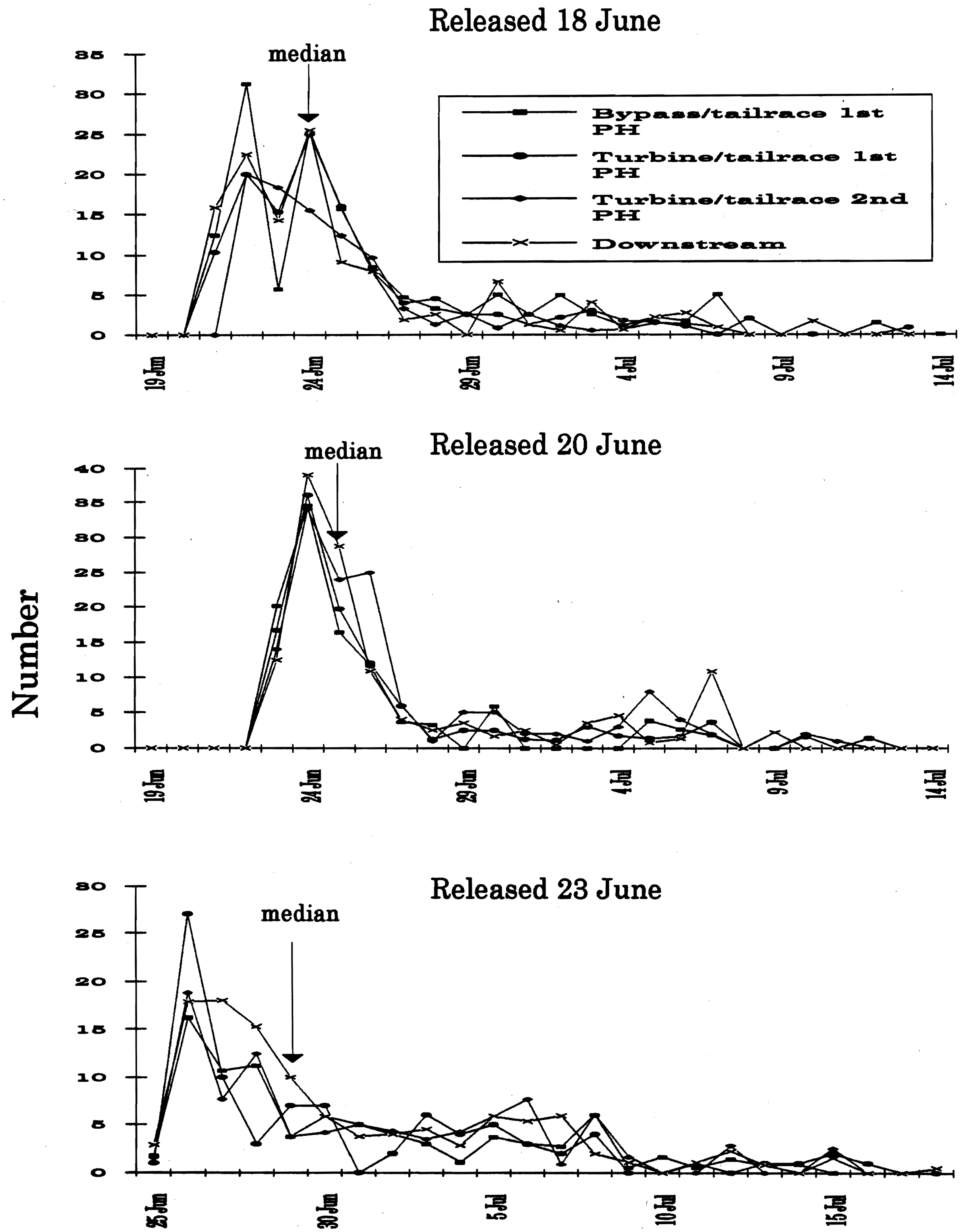
Appendix Table A7.--Continued

Tule stock--purse seine

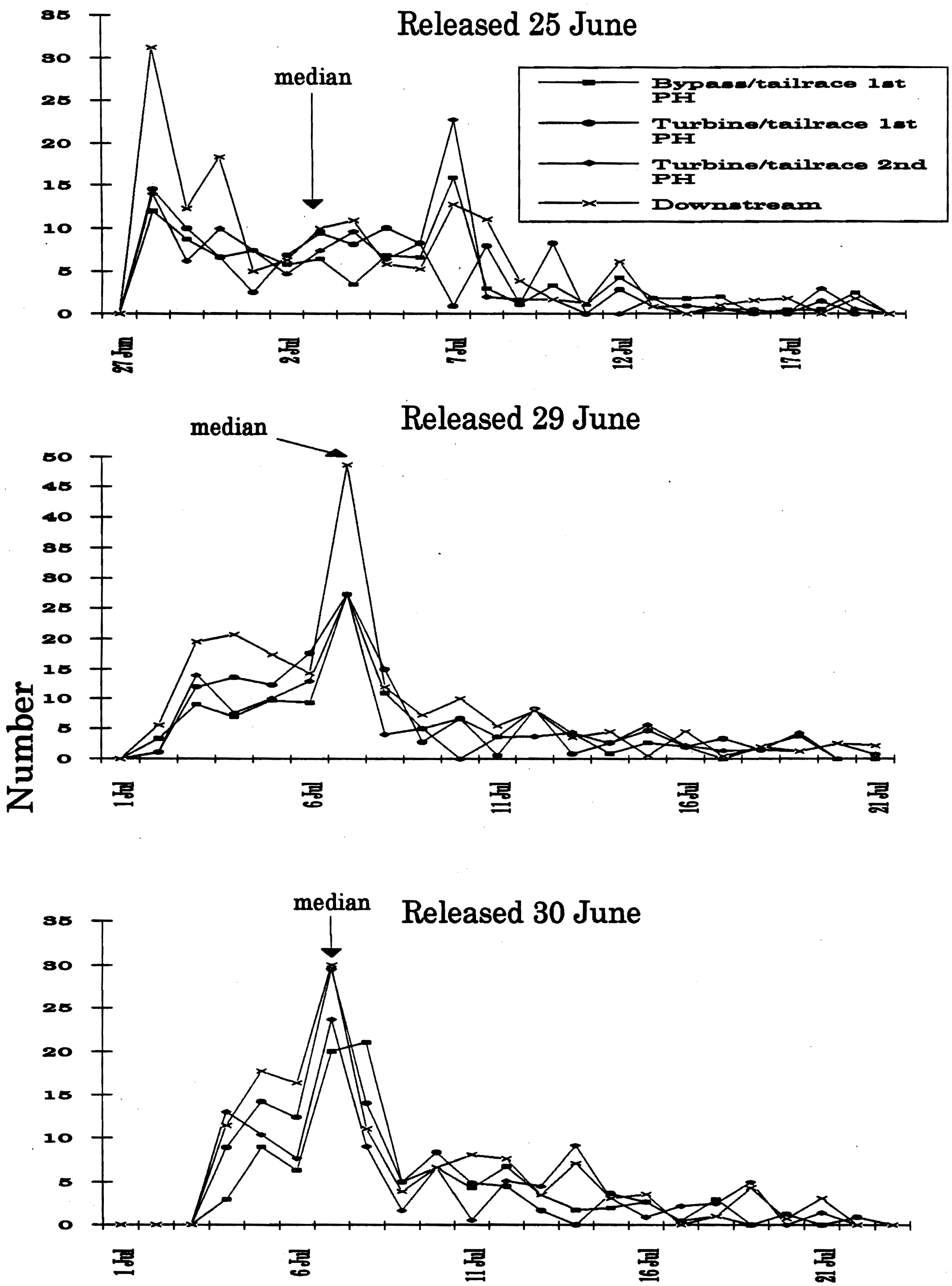
Sample date	22 Jun	23 Jun	23 Jun	24 Jun	24 Jun	26 Jun	26 Jun	26 Jun	26 Jun	26 Jun	26 Jun	26 Jun	27 Jun	Totals	
Set time	0841	0513	0622	0513	0954	0534	1013	1119	1227	1410	2032	2214	0108	No.	%
Insecta (Order)															
Diptera	7	7	3	6	5	11	14	16	13	31	32	2	1	148	30.9
Homoptera	2		6	4	1	1	1			1		1		17	3.6
Hemiptera							1				2			3	0.6
Coleoptera			1	1		1	1	2						6	1.3
Psocoptera	77	12	41	66		6	9			64				275	57.4
Thysanoptera				1					4					5	1.0
Hymenoptera			2	2	1	1	9	1		5	1			22	4.6
Neuroptera									1					1	0.2
Plecoptera														0	0.0
Collumbola			1			1								2	0.4
Lepidoptera														0	0.0
Subtotal Insecta														479	
Crustacea (Order)															
Amphipoda		5	5	6	14	10	11	12	6	7	30	1	2	109	5.5
Mysidacea								1		1				2	0.1
Cladocera	40	15	25	132	30	3	21	2	1,340	4	10			1,622	81.1
Copepda	6	3	2	15	10	2	5	1	218		4			266	13.3
Subtotal Crustacea														1,999	

Tule stock--beach seine

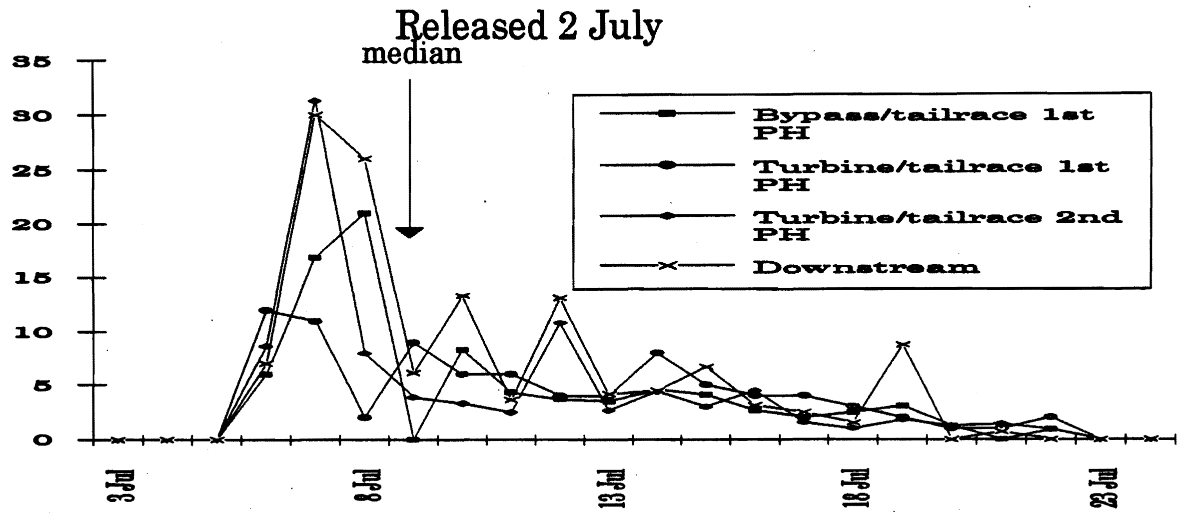
Sample date	22 Jun	26 Jun	26 Jun	23 Jun	26 Jun	26 Jun	26 Jun	26 Jun	Totals	
Set time	1030	0635	0938	1113	1334	1702	1912	2108	No.	%
Insecta (Order)										
Diptera	5	4	3	16	63	2		6	99	56.6
Homoptera	1								1	0.2
Hemiptera								6	6	1.3
Coleoptera			1		4			1	6	1.3
Psocoptera	60								60	12.5
Thysanoptera	1								1	0.2
Hymenoptera				1		1			2	0.4
Neuroptera									0	0.0
Plecoptera									0	0.0
Collumbola									0	0.0
Lepidoptera									0	0.0
Subtotal Insecta									175	
Crustacea (Order)										
Amphipoda	4	1	3	2	17	5	1	4	37	0.5
Mysidacea					2			3	5	0.1
Cladocera	1,724	519	688	496	729	1,302	103	244	5,805	75.9
Copepoda	67	27	372	469	536	90	79	161	1,801	23.6
Subtotal Crustacea									7,648	

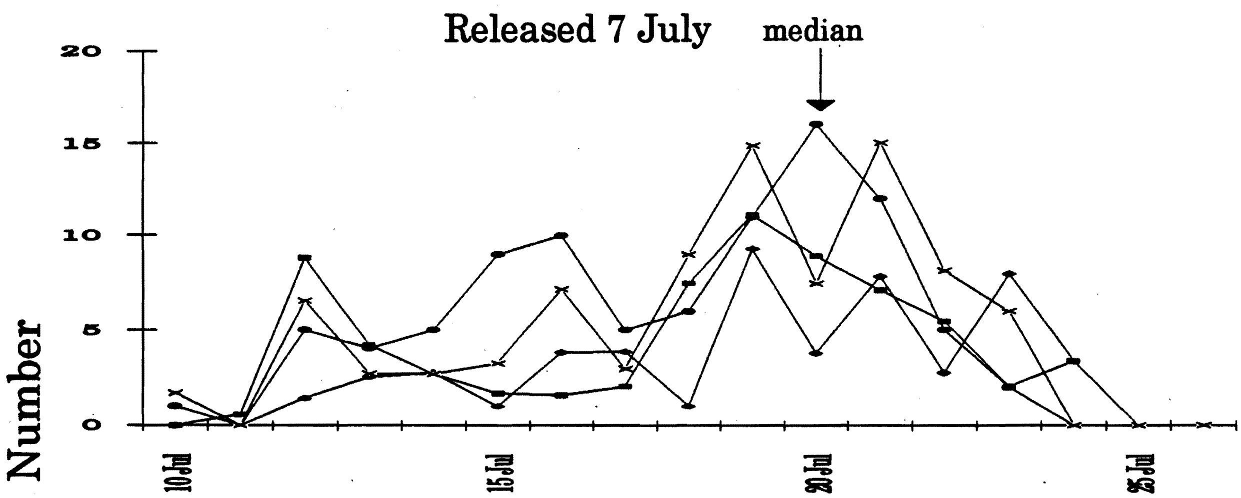


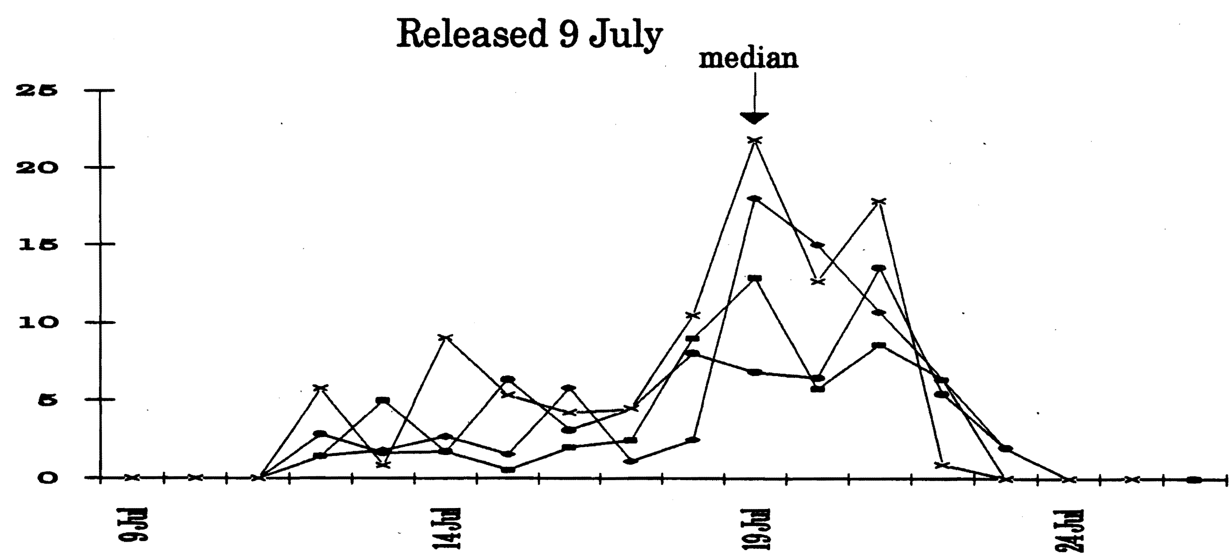
Appendix Figure A1.--Daily recoveries of test fish at Jones Beach (standardized for effort) from releases made on 18, 20, and 23 June 1992.



Appendix Figure A2.--Daily recoveries of test fish at Jones Beach (standardized for effort) from releases made on 25, 29, and 30 June 1992.







Appendix Figure A3.--Daily recoveries of test fish at Jones Beach (standardized for effort) from releases made on 2, 7, and 9 July 1992.

Appendix B

Statistical Analysis of Juvenile Catch Data

APPENDIX B

Statistical Analysis of Juvenile Recovery Data

A. Chi-square goodness of fit analysis was used to evaluate differences among observed recoveries (Appendix Table A4) through time for different treatment groups released on the same day (Sokal and Rohlf 1981). A non-significant result indicated that there was equal probability of capture at Jones Beach for each treatment group (i.e., that the groups were adequately mixed). Results of this analysis are shown below. For additional details of this procedure see Dawley et al. (1989, Appendix D).

H_o: There was homogeneity between recovery distributions of treatments in 1992.

Block	Chi-square	df	P-value
1	25.122	30	0.7191
2	19.233	27	0.8614
3	26.859	27	0.4714
4	29.947	36	0.7511
5	32.000	39	0.7790
6	29.804	39	0.8553
7	28.283	39	0.8978
8	37.940	33	0.2542
9	25.611	33	0.8170
10	33.900	30	0.2848
11	33.692	27	0.1752
12	19.212	21	0.5715
13	34.143	24	0.0822

Appendix B.--Continued.

The 13 tests independently examined the same hypothesis, therefore their results can be combined to obtain an overall test (Fisher 1944). The overall result is:

Block	P-value	-2ln(P)	df
1	0.7191	0.6595	2
2	0.8614	0.2984	2
3	0.4714	1.5041	2
4	0.7511	0.5724	2
5	0.7790	0.4995	2
6	0.8553	0.3126	2
7	0.8978	0.2156	2
8	0.2542	2.7393	2
9	0.8170	0.4042	2
10	0.2848	2.5119	2
11	0.1752	3.4837	2
12	0.5715	1.1190	2
13	0.0822	4.9972	2
Overall Chi-square =		19.3174	26

P-value = 0.8228, non-significant

Conclusion: No evidence to suggest there is non-homogeneity between treatment recovery distributions.

B. Analysis of treatment effects using a randomized block ANOVA design where each day was considered a block (Sokal and Rohlf 1981).

Full data set using all release blocks (see Table 4).

H_o: Mean recovery percents for each treatment are equal.

ANOVA Table

Source	Sum of squares	D.F.	Mean square	F	Significance level
Blocks	0.2725	12	0.0227		
Treatments	0.1209	3	0.0403	36.77	0.0000
Error	0.0394	36	0.0011		
Total	0.4327	51			

Appendix B.--Continued.

The H_o is rejected at $\alpha = 0.05$.

The treatment means are ranked using Fisher's Protected Least Significance Difference (FPLSD) test (Petersen 1985).

FPLSD = $T_{(\alpha = 0.05)(df)}\sqrt{2(MSE)/r} = 0.0263$
where:
T = Student's Tabular T value
MSE = mean square error term in the ANOVA table
r = number of blocks

Any pair of treatment means differing by more than the FPLSD were judged to be significant. The following shows these differences in rank order, where underlined means are not significantly different at $\alpha = 0.05$

Treatment mean (%)

Bypass/tailrace 1st Powerhouse	Turbine/tailrace 2nd Powerhouse	Turbine/tailrace 1st Powerhouse	Downstream
0.3061	0.3124	0.3464	0.4272