ESTUARINE RECOVERY OF PIT-TAGGED JUVENILE SALMONIDS FROM THE LOWER GRANITE DAM TRANSPORTATION STUDY, 1998

by

Richard D. Ledgerwood
Brad A. Ryan
Edward P. Nunnallee
and
John W. Ferguson

Report of Research

Funded by

U.S. Army Corps of Engineers
Walla Walla District
Delivery Order E8960100

and

Fish Ecology Division
Northwest Fisheries Science Center
National Marine Fisheries Service
National Oceanic and Atmospheric Administration
2725 Montlake Boulevard East
Seattle, Washington 98112-2097

December 2000

EXECUTIVE SUMMARY

In 1998, National Marine Fisheries Service researchers continued evaluation of a specialized trawl containing a passive integrated transponder tag (PIT tag) detector for estuarine interception of PIT-tagged juvenile salmonids. The study, which began in 1995, was conducted in the Columbia River estuary off Jones Beach (RKm 75). Principal fish targeted for the research were the nearly 115,000 PIT-tagged juvenile spring/summer chinook salmon released at Lower Granite Dam on the Snake River (RKm 695) or transported and released in the Columbia River 9 km downstream from Bonneville Dam (RKm 234). These fish were released from April through mid-June to compare survival between inriver-migrating and barge-transported fish.

Objectives of the PIT-tag detector/trawl sampling were 1) to provide migration behavior and timing information for comparing fish groups transported and released downstream from Bonneville Dam to those released to migrate in river from Lower Granite Dam or other upstream dams and hatcheries, 2) to provide estuarine passage dates for survival comparisons between adult fish groups that entered the ocean at similar times as juveniles, 3) to provide observations on diel behavior of juvenile salmonids in the estuary, 4) to compare migrational timing between radio-tagged and PIT-tagged juvenile salmonids, 5) to provide unbiased estimates of wild and hatchery smolts by species at the entrance to the estuary for estimating relative vulnerability to predaceous birds nesting in the middle and lower estuary, and 6) to obtain comparative survival estimates for inriver migrating juvenile salmonids to Bonneville Dam.

PIT-tag detector/trawl sampling began on 17 April, increased to daily 16-hour periods between 26 April and 25 May, then decreased to 8-hour days until 5 June. During the 16-hour daily periods we also conducted three diel sampling efforts. The diel sampling allowed comparison of migrational timing between radio-tagged and PIT-tagged fish and provided information on daylight and darkness detection patterns for different fish species.

Descaling and injury rates of fish traversing the detector system were assessed using a sanctuary-bag recovery net periodically attached to the exit of the detector box. We recovered 532 juvenile salmonids with the sanctuary net; 16.8% were descaled, 0.7% had some sort of injury, and mortality was 0.2% of those collected. The descaling rate was higher than that observed for run-of-the-river salmon sampled at John Day (9.5%) and Bonneville Dams (4.7%) during the same period. We believe that the additional handling in the collection net contributed to the descaling increase.

The PIT-tag detector/trawl was deployed and operational a total of 321 hours between 17 April and 5 June. Not counting test tags, duplicate tag records, or records resulting from "bit-shift" phenomena, we detected 4,488 fish with PIT tags. Estuarine detections were recorded for 3,794 chinook salmon, 351 coho salmon, 65 sockeye salmon, and 541 steelhead.

Diel sampling results indicated decreased detection rates for steelhead during darkness (P = 0.01) but not for chinook salmon as in previous years (P = 0.48). For chinook salmon, the average number of detections per hour of detector operation decreased from 7.6 during daylight to 6.0 during darkness; for steelhead the average decrease was from 1.3 to 0.3.

We detected 1,145 spring/summer chinook salmon marked for the transportation study; 297 transported and released downstream from Bonneville Dam and 848 released for inriver migration from Lower Granite Dam. There were significant differences in passage times at Jones Beach between transported and inriver migrant groups. Respective 10th, 50th, and 90th percentile travel times from release site to Jones Beach were 1.5, 2.4, and 3.8 days for transported groups released downstream from Bonneville Dam, and 13.5, 18.7, and 27.6 days for inriver groups released downstream from Lower Granite Dam. The longer, more uniform period of availability in the estuary for inriver migrants released at Lower Granite Dam probably accounted for the higher number of detections of these fish compared to transported fish. During the 154-km migration to Jones Beach, transported fish apparently did not disperse; thus these fish produced a patchy distribution of detections and a detection rate affected by duration and time of daily sampling.

Travel speeds to Jones Beach for PIT-tagged juvenile chinook salmon released from barges just downstream from Bonneville Dam were highly correlated to total river flow (R^2 correlation coefficient range 0.6 to 0.9). When corrected to comparable date ranges, there were no significant differences in travel speed between barged PIT-tagged and barged radio-tagged chinook salmon (P = 0.54) or between PIT-tagged chinook salmon detected at Bonneville Dam and run-of-the-river chinook salmon radio-tagged and released at Bonneville Dam (P = 0.17).[1]

Travel speed to Jones Beach of PIT-tagged chinook salmon detected at Bonneville Dam was significantly higher than that of PIT-tagged fish released from barges during the same date period (98 and 73 km/day respectively, P = 0.001). The average travel speed for inriver migrant steelhead from Bonneville Dam to Jones Beach was 99 km/day. Timing and other information was collected for other groups of PIT-tagged fish released throughout the Columbia River Basin during this study.

The 95% confidence limit for mean survival of inriver migrant steelhead from the tailrace of Lower Granite Dam to the tailrace of Bonneville Dam was 39.2 to 60.7%. For spring/summer chinook salmon, detections from the pair trawl off Jones Beach were insufficient for reliable survival estimates. The data used for these estimates were supplemented using PIT-tag detections obtained from piscivorous Caspian tern (*Sterna caspia*) and double-breasted cormorant (*Phalacrocorax auritus*) colonies downstream from Jones Beach at Rice Island (RKm 35).

[1] Radio-tagging study conducted by the Cooperative Fishery Unit, Oregon State University, Corvallis, Thomas Stahl, project leader.

CONTENTS

INTRODUCTION

In 1998, National Marine Fisheries Service (NMFS) researchers continued deployment of a specialized pair-trawl containing a passive integrated transponder tag (PIT tag) detector for estuarine interception of PIT-tagged juvenile salmonids. The study, which began in 1995, was conducted in the Columbia River estuary off Jones Beach, River Kilometer (RKm) 75 (Ledgerwood et al. 1997). Principal fish targeted for the research were PIT-tagged juvenile spring/summer chinook salmon released from April through early July each year to compare survival between inriver-migrating and barge-transported fish (NMFS transportation study; Marsh et al. 1997, 1998, 2000). Another major PIT-tagging study was conducted during 1998 in several Snake River Basin hatcheries that provided ample target groups of PIT-tagged fish during the same migration period as the transportation study (Berggren and Basham 2000).

Precise estimates of survival to the estuary and subsequent timing of ocean entrance for migrating juvenile salmonids are important to understanding the contribution of various fisheries enhancement projects within the Columbia River Basin. The advent of the PIT tag has provided greater precision and a new dimension to inriver survival and migration comparisons for salmonids in the Columbia and Snake Rivers. PIT tags are decoded remotely through magnetic induction when the fish passes into a suitable magnetic field. Stationary decoding devices have been installed at dams in the Columbia and Snake Rivers to passively monitor passage of PIT-tagged juvenile and adult fish. The use of PIT-tag technology has grown through the years, and a centralized database, the Columbia Basin PIT Tag Information System (PTAGIS; PSFMC 1992), has been established to facilitate regional access to the migration data (Stein 1996).

Beginning in 1966, NMFS researchers evaluated migrational characteristics and relative survival differences of marked groups of juvenile salmonids in the Columbia River estuary and occasionally in the nearshore ocean (Miller et al. 1983, Dawley et al. 1986, Ledgerwood et al. 1990, Ledgerwood et al. 1994, Miller 1992). Purse and beach seines were adopted as the primary sampling gear because they allowed greater catch efficiency and less injury to intercepted salmonids than other sampling equipment tested. Coded-wire tags implanted in juvenile salmonids proved the only useful marking technique for relative survival comparisons because poor mark application or poor retention of fin clips and cold brands resulted in confusion among the many marked groups of fish each year. However, fisheries managers have become increasingly reluctant to authorize evaluations of juvenile migrants using coded-wire tags because tag reading requires sacrificing the fish. Also, because of the large number of recoveries necessary to detect statistically significant differences among treatment groups, it is necessary to sample intensively, intercepting, anesthetizing, and handling as many as 367,000 fish from the juvenile salmon outmigration in order to recover adults from even 5% of those marked (Dawley et al. 1986).

Since 1995, over 500,000 PIT-tagged juvenile salmonids have been released annually into the Columbia River and its tributaries. These large releases of PIT-tagged fish have made feasible the mobile deployment of a PIT-tag detector in the estuary.

Objectives of the PIT-tag detector/trawl sampling were 1) to provide migration behavior and timing information for comparing fish groups transported and released downstream from Bonneville Dam to those released to migrate in river from Lower Granite Dam or other upstream dams and hatcheries, 2) to provide estuarine passage dates for survival comparisons between adult fish groups that entered the ocean at similar times as juveniles, 3) to provide observations on diel behavior of juvenile salmonids in the estuary, 4) to compare migrational timing between radio-tagged and PIT-tagged juvenile salmonids,[2] 5) to provide unbiased estimates by species of the number of wild and hatchery smolts at the entrance to the estuary for evaluating relative vulnerability to birds nesting in the middle and lower estuary,[3] and 6) to obtain comparative survival estimates for inriver migrating juvenile salmonids to the tailrace of Bonneville Dam.

---

[2] Radio-tagging study conducted by Cooperative Fishery Unit, Oregon State University, Corvallis, Thomas Stahl, Project Leader.

[3] Large colonies of Caspian terns (*Sterna caspia*) nest on dredge disposal islands located just downstream from Jones Beach. Researchers from Oregon State Fish Cooperative Unit and Columbia River Intertribal Fish Commission (Roby et al. 1998), are using Jones Beach PIT-tag trawl detection data as a baseline to evaluate relative vulnerability to predation by terns of wild and hatchery salmonids released from transportation barges.

METHODS

Background

In 1995, during the development phase of this research, NMFS and University of Washington (UW) researchers modified nets to allow deployment of specially constructed electronic PIT-tag detection equipment. With these prototypes, sampling procedures were established that produced minimal adverse impacts to test fish, as verified by underwater cameras and SCUBA divers. Initial research with the PIT-tag detector/trawl took place in the current-free and clear waters of Lake Washington. The Lake Washington location was near the NMFS Sand Point electronics lab, where frequent modifications to the various electronic components were facilitated, and near the UW hatchery, where hatchery fish were held and tagged prior to test fish releases.

In early May 1995, inspectors from various agencies observed the PIT-tag detector/trawl system in Lake Washington and granted permission to move the equipment for deployment in the Columbia River. Trawling operations in the Columbia River were conducted adjacent to Jones Beach, a beach- and purse-seining site (Fig. 1). Due to the extended developmental period required for the trawl, we did not begin sampling at Jones Beach until mid-May 1995, after the majority of targeted transportation study fish had passed through the estuary. However, by the end of the migration period, we concluded that the major objectives for successful implementation of the PIT-tag detector/trawl system in the estuary had been achieved. Those objectives were elimination of net debris, rapid passage of fish through the gear, minimal physical harm of fish during passage, and reliable electronics for detection of PIT tags.

In 1996, the PIT-tag detector/trawl was again used at Jones Beach to target PIT-tagged fish released as part of the fish transportation study. The equipment was deployed and operational a total of 193 hours, and we detected 633 PIT-tagged fish having release information in PTAGIS, a regional database (Ledgerwood et al. 1997). Information on diel behavior of chinook salmon and steelhead was obtained, and comparisons between migration behavior of PIT- and radio-tagged fish released from transportation study barges or released to migrate in river were also provided.

The prototype 400-kHz detector designed and used in 1995 and 1996 was difficult to deploy and retrieve and was subject to leaks, which created electronic failures. Perhaps most troubling was the fact that fish resisted passing through the detector, the basic design of which was a cubic plywood box measuring about 110 cm (4 ft) on each side with a total weight of over 295 kg (650 lb). This detector and trawl required about 1.5 hours to deploy and retrieve. These and other factors contributed to lost interrogation time and reduced detection efficiency of the prototype detector and suggested the need for design and operational changes that would improve deployment and detection efficiency.

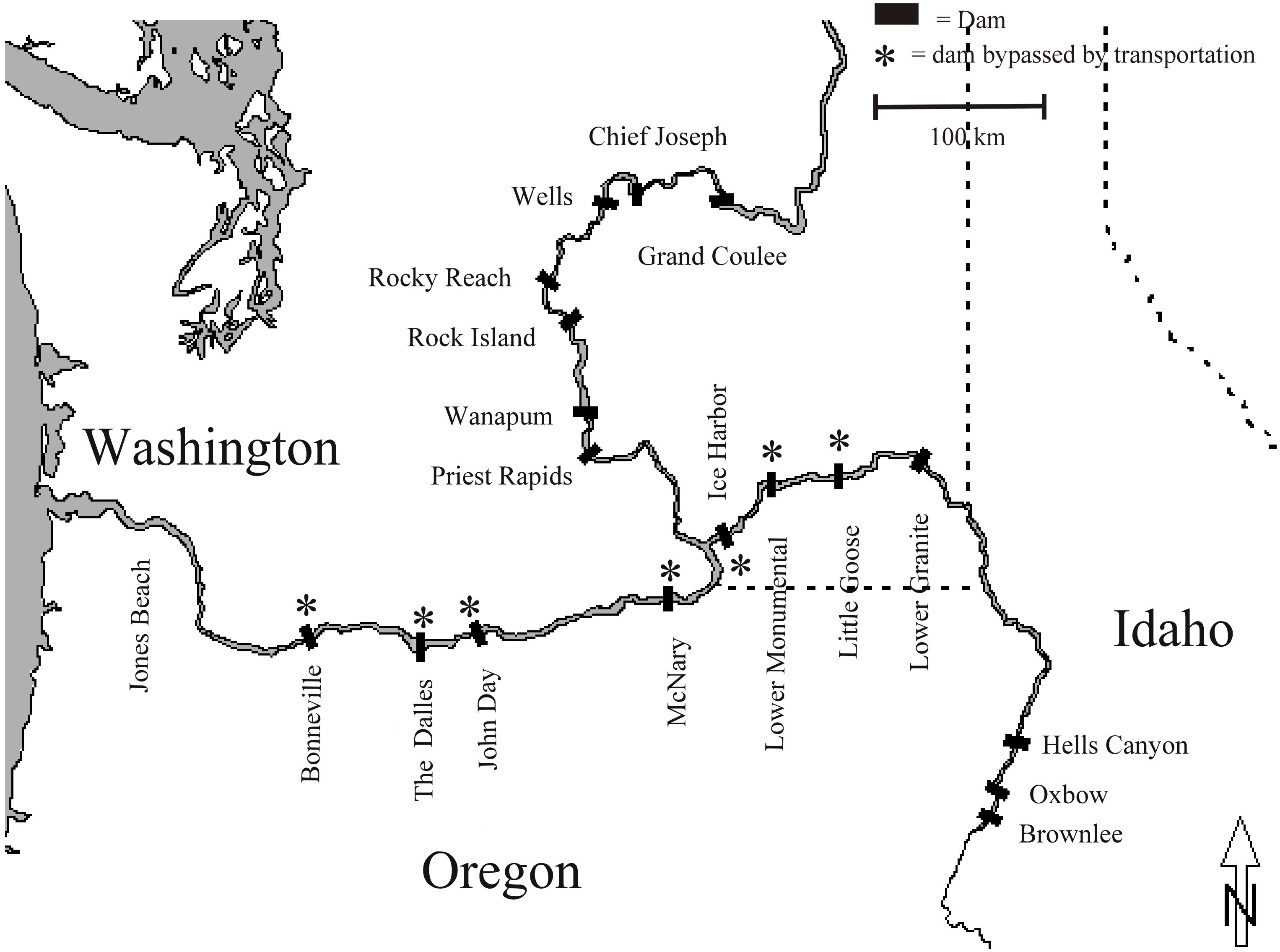


Figure 1. Columbia River and Snake River Basins showing the location of dams bypassed during the Snake River Transportation Study. The Jones Beach pair-trawling location at river kilometer 75 is also shown.

We originally anticipated that 1997 would be a transition year for converting from the 400-kHz PIT tag to the new International Standards Organization (ISO) 134-kHz PIT tag in the Columbia River Basin. Due in part to the expected low number of outmigrant salmonids in 1997, few juvenile fish were scheduled to be PIT tagged during the transition year, and as a result we had no plans for deployment of the 400-kHz PIT-tag detector/trawl equipment after 1996. However, implementation of ISO-tag detector systems at dams on the Columbia and Snake Rivers was delayed until 2000, and PIT-tag research studies using the 400-kHz PIT-tags were scheduled in the Columbia River Basin from 1997 to 1999. Because of the continued release of large numbers of smolts with 400-kHz PIT tags, we made improvements to the 400-kHz PIT-tag detection equipment in 1997 based upon mockup work conducted at Jones Beach (Appendix A). The developmental work in 1997 led to construction of a new 3-pipe, 25-cm-diameter detection antenna which was utilized in the estuary in 1998.

Target Fish

In 1998, the estuarine PIT-trawl sampling effort targeted the nearly 115,000 PIT-tagged juvenile spring/summer chinook salmon released at Lower Granite Dam on the Snake River (RKm 695) or transported and released in the Columbia River 9 km downstream from Bonneville Dam (RKm 234) (Marsh et al. 2000). Fish used for the transportation study were collected daily and comprised about 10% of smolts migrating through the bypass system at Lower Granite Dam. These smolts were a mixture of wild and hatchery reared fish.

In addition to transportation study fish, over 200,000 additional PIT-tagged yearling chinook were released in 1998 for a comparative survival study of hatchery PIT-tagged chinook salmon (Berggren and Basham 2000) and about 64,000 PIT-tagged juvenile yearling salmonids were released for The Dallas Dam survival study (Dawley et al. 2000). Fish from these two studies and others provided additional target groups for estuarine sampling in 1998.

Study Site

The study area is characterized by frequent ship and barge traffic, occasional severe weather, and strong tidal and river currents. The ship channel is about 200 m wide and dredged to about 14 m depth (Fig. 2). In 1996 and 1998, deployment of the PIT-tag detector/trawl in the Columbia River included four drift areas between RKm 83, near Eagle Cliff, and RKm 61, near Clifton Channel (Fig. 3). Tides in the study area are semi-diurnal with about 7 hours of ebb and 4.5 hours of flood. Depending on the time of day and tidal stage during which the net was deployed, the distance that could be traveled downstream with the pair-trawl varied considerably.

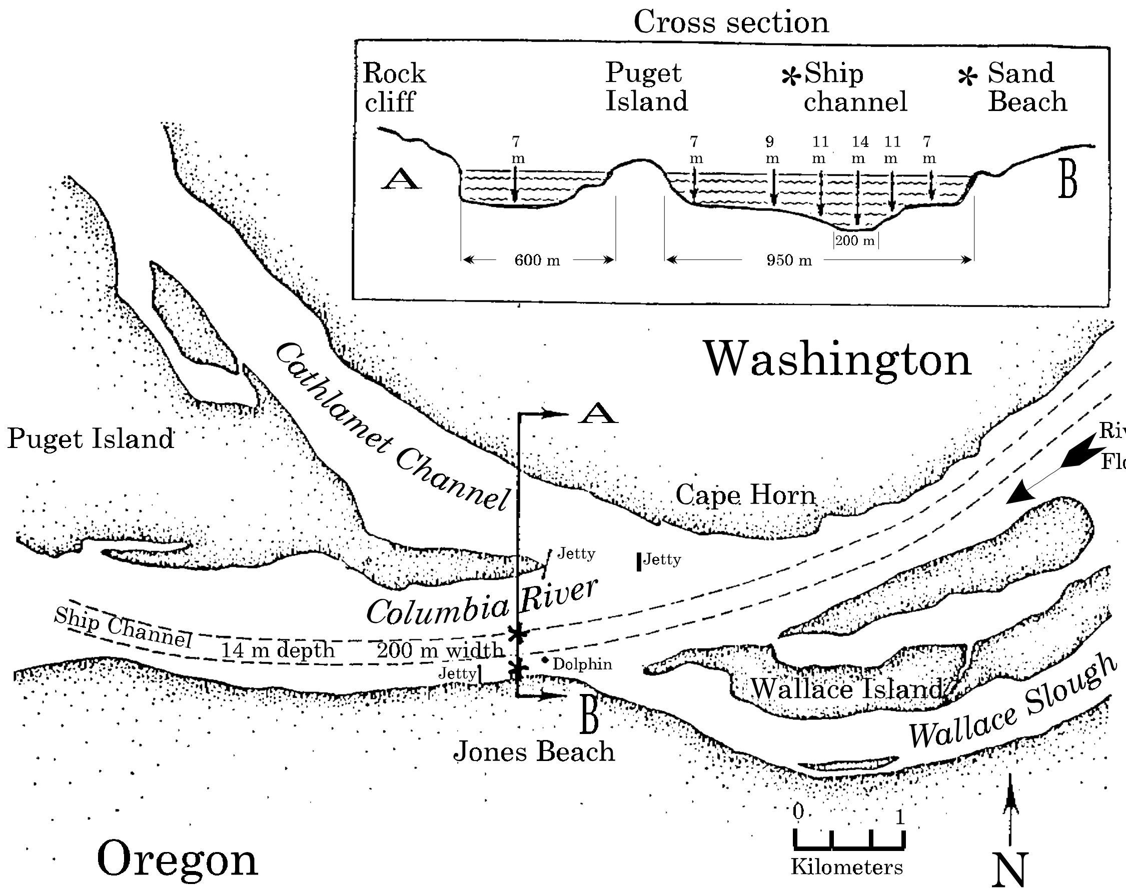


Figure 2. Overview and cross-sectional views of the Columbia River at Jones Beach (river kilometer 75). Historical beach and purse seining areas are denoted by asterisks.

Figure 2. Overview and cross-sectional views of the Columbia River at Jones Beach (river kilometer 75). Historical beach and purse seining areas denoted by asterisks.

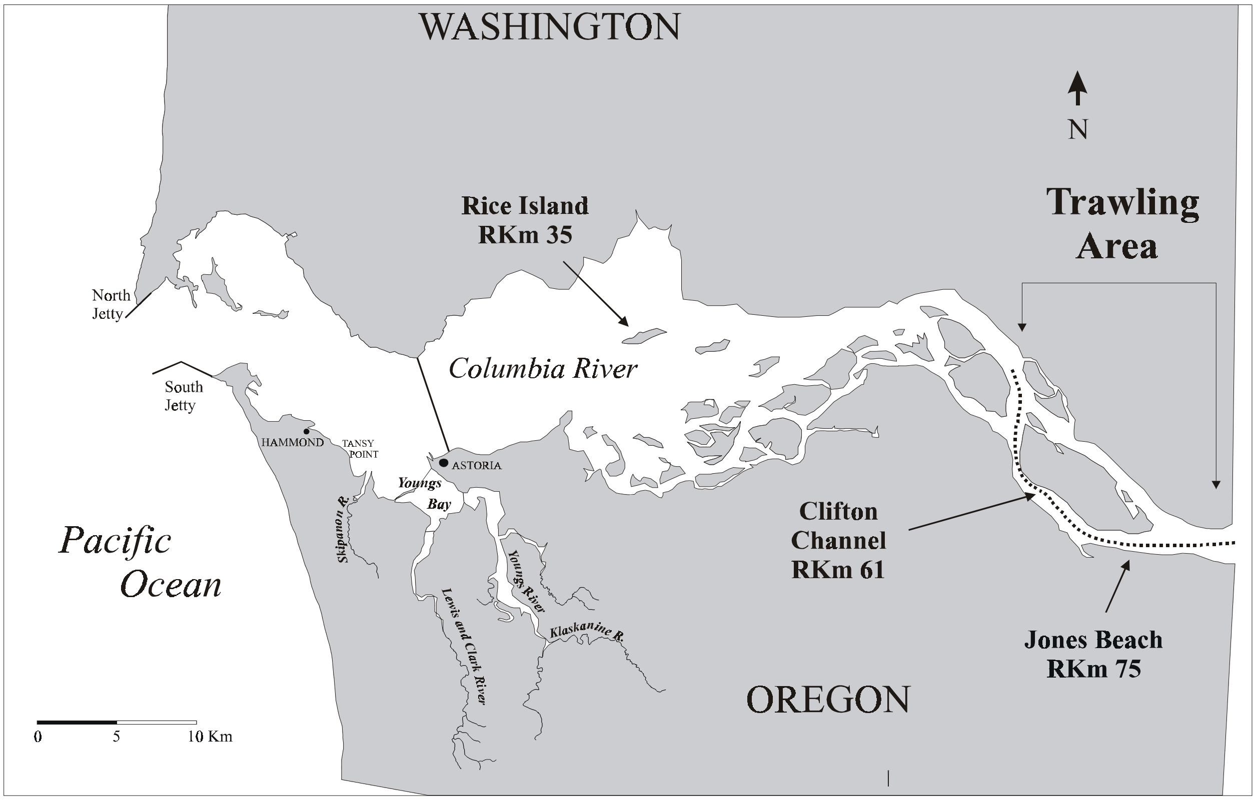


Figure 3. PIT-tag detector/trawl deployment areas between Columbia River kilometer (RKm) 83 (near Eagle Cliff) and RKm 61 (near Clifton Channel), 1998.

During the spring freshet period (April-June), little or no flow reversal occurred at Jones Beach during flood tide, particularly during the high river flows in 1996 and 1998 (Fig. 4). Rarely, and for short periods near peak flood current, were we able to maintain position in the river or actually make upstream headway with the net under tow. Generally, the net and boats moved downstream continuously, with drift velocities often exceeding 1.5 m/s (3 knots). Flooding and high water conditions contributed to the debris load in the river, and at times we were forced to terminate towing operations earlier than desired to clean the net of debris.

Sampling Period

Sampling occurred between 17 April and 5 June, coincident with the passage of PIT-tagged fish from the transportation study. Beginning on 22 April, sampling personnel were increased from a single daily sampling crew to two daily crews. The double crew was maintained until 23 May, when detection rates declined and we returned to a single daily work crew. Generally, one work crew began before daylight and sampled for an 8- to 10-hour period, and a second crew began in late afternoon and sampled until dark. On three occasions during the middle of the season we sampled continuously except for brief periods of net cleaning, net retrieval, and running back upstream to re-deploy the net. During these three diel sampling periods it was necessary to rotate tow vessels out of the operation for refueling.

Trawl Design and Vessel Operations

The pair trawl consisted of a 91.5-m wing attached to each side of the 15.5-m body of the trawl containing the PIT-tag detector, which was located where the cod-end is normally positioned (Fig. 5). Details of trawl construction and vessel operations were similar to those used in 1996 and described by Ledgerwood et al. (1997). Larger (12.5 m), more powerful vessels were available for towing in 1998, and two such vessels were used, with one towing each wing of the trawl, as in 1996. Hydraulic net-reels on these larger vessels allowed for deployment/retrieval over the stern of the trawl rather than over the side as in earlier years, and this adaption increased efficiency.

A 7.9-m pontoon barge bridled to the cork-line near the exit of the trawl was adapted to house the PIT-tag electronics equipment and the detection antenna itself (Fig. 6). In earlier years, the antenna was attached/detached on the towing vessel prior to deployment/retrieval of the trawl, which made deployment cumbersome. The pontoon barge had small winches on the bow allowing for attachment/detachment of the antenna in the water, which also increased deployment efficiency. As in earlier years, a 5.5-m skiff was used to assist in deployment/retrieval operations and to move crew members between vessels as needed.

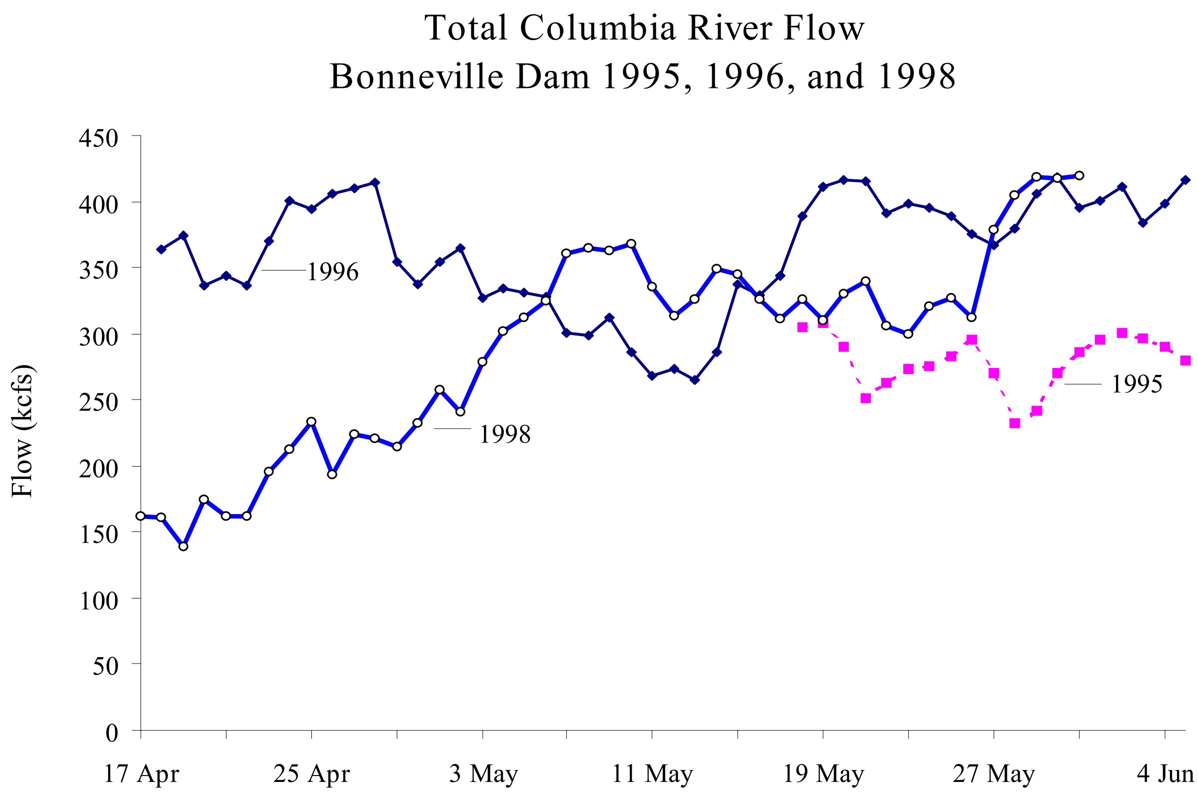


Figure 4. Total flow of the Columbia River at Bonneville Dam during the time periods of PIT-tag detector trawling, 1995, 1996, and 1998.

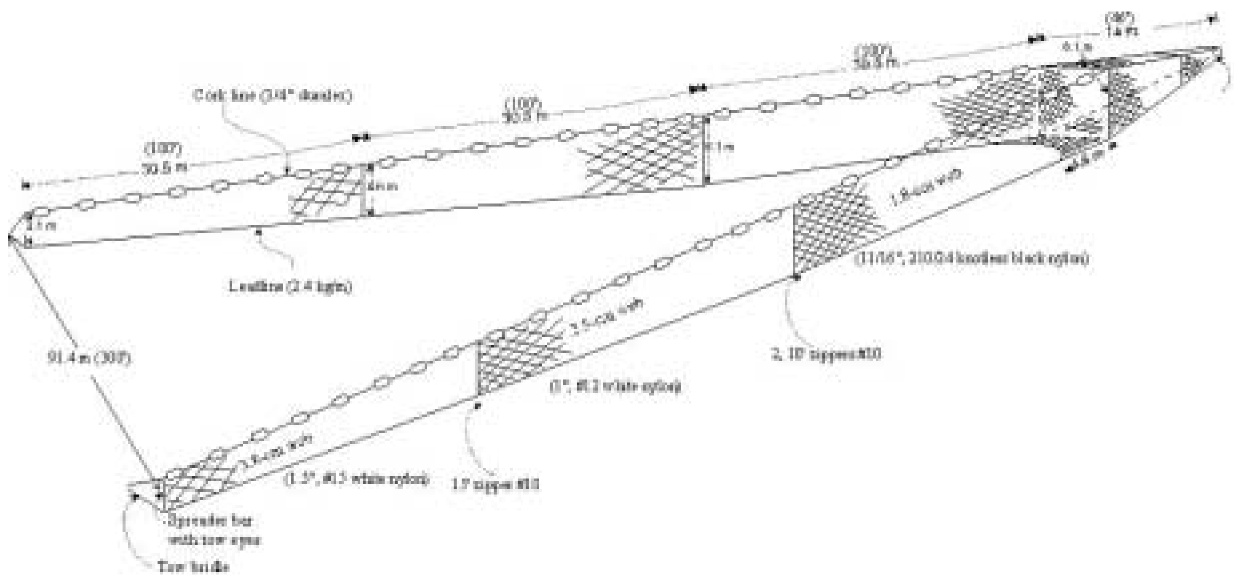


Figure 5. Drawing of the PIT-tag detector pair trawl used at Jones Beach 1996 and 1998.

Figure 6. The 7.9-m pontoon barge, bridled to the pair-trawl cork line near the exit of the trawl, housed the PIT-tag electronics and recording equipment used in 1998. The detection antenna rides between the pontoons about 2 m beneath the surface and cables connect the antenna with other electronics in the cabin of the barge.

Electronic Equipment and Operation

A PIT tag is a sealed glass cylinder, approximately 2.1 mm in diameter and 11 mm long, containing an integrated circuit attached to a multi-turn coil of fine wire (Destron Fearing 1993). First used in the Columbia River Basin in 1985, the PIT tag has a unique number stored in its permanent memory at the time of manufacture (Prentice et al. 1990).[4] The tag is usually inserted into the peritoneal cavity or dorsal sinus cavity of a fish. The integrated circuit and memory stores and transmits the encoded, unique identification number when the tag is placed within range of a detector antenna that generates the proper magnetic field.

Detector Antenna

In 1998, a new design was utilized for the underwater detector antenna (Figs. 7-8). The antenna used in 1995 and 1996 had been heavy (295 kg in air), cumbersome to deploy and retrieve, and unreliable (leaked). The earlier structure consisted of two rectangular tunnels, each containing two antenna coils and appropriate spacers to prevent electronic interference. Improvements to this design were based upon newly available electronics and mockup testing of a new antenna design in 1997 (Appendix A). The new design consisted of a 3-pipe bundle of 27-cm-diameter detection tunnels, each with a single antenna coil. A “multiplex-type” switching device was used to cycle individual coils on and off multiple times per second such that no two detection coils were on at the same time. The cycling between adjacent coils avoided electronic interference, thus spacers were not required between adjacent coils, which resulted in a more compact design. The overall weight of the detection antenna in 1998 was about 45 kg, including the fiberglass housing surrounding the detector.

Cabling and Data Recording

A 6-m-long cable leading to the surface was attached to the tuner box of each antenna coil. A video camera was also mounted on the net in front of the detector housing to observe fish passage and debris accumulation. Unlike 1996, the video cable was not bundled with the PIT-tag detection cables, and this allowed simultaneous operation of video equipment and PIT-tag detection equipment without electronic interference. A 3,500-W gas-powered generator provided power for all electronics. Once the detector was energized, most operations were automatic. A DOS-based computer software program and printer automatically recorded and printed detection data. We also maintained a written log of times and durations when the detector was energized, the total number of detections, and diver observations. A special test circuit installed in each antenna coil could be manually activated by a switch on the barge to print a test-tag record for each coil in the system. This allowed us to verify proper operation of the electronics. We also occasionally tested the system using a PIT tag taped to a stick and passed through the detector by divers or using PIT tags inserted into surrogate fish (oranges, apples, etc.) and thrown forward into the trawl.

[4] The PIT tag is available from Destron Fearing Identification Devices, Inc. Reference to trade names does not imply endorsement by the National Marine Fisheries Service.

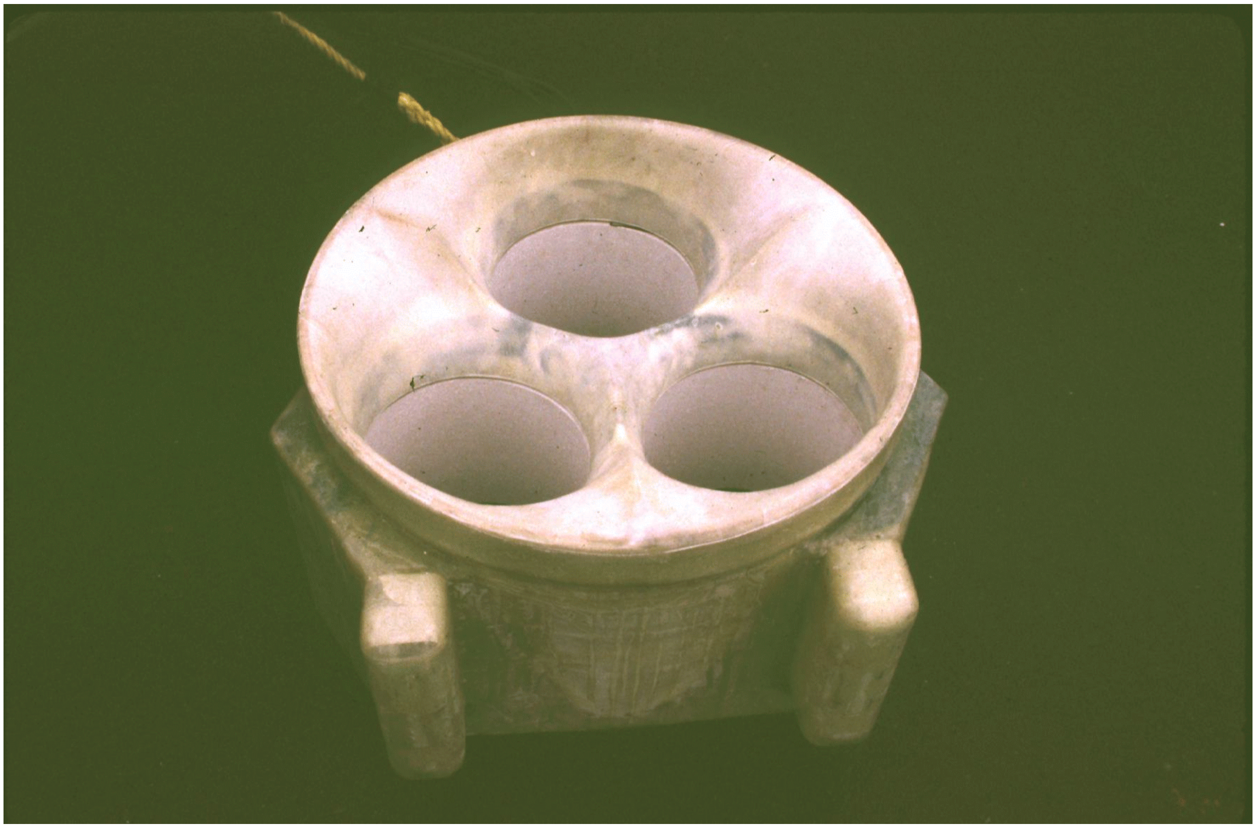
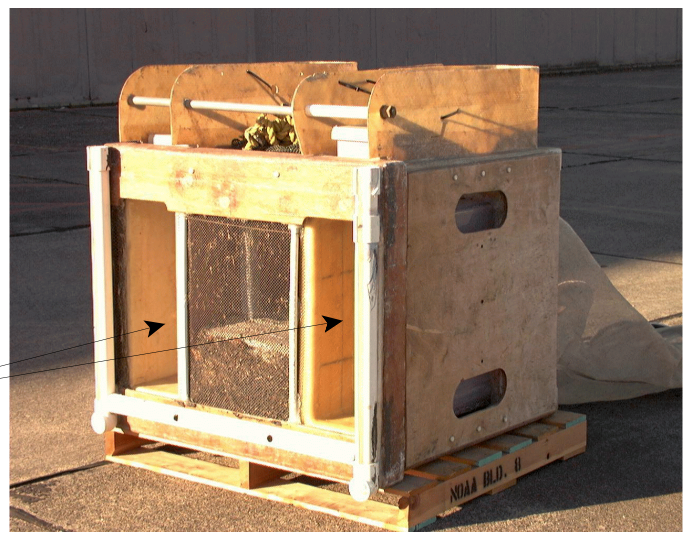


Figure 7. Photos showing the 3-pipe bundle of 27-cm diameter detection tunnels and housing used to attach the antenna to the pair-trawl in 1998. The overall weight of the antenna and housing was about 45 kg in air and each tunnel contained one detection coil.

Front View



Detection Tunnels

Rear View

Figure 8. Photos showing entrance and exit of the PIT-tag detector antenna box used with the pair-trawl at Jones Beach in 1995 and 1996. The box weighs 650 lb and is approximately 4 cubic ft in size.

We recorded Global Position Satellite (GPS) readings of the tow vessel at the beginning and end of each deployment and occasionally during deployment. These position recordings are available for calculations of the approximate location of individual PIT-tagged fish by matching date and time of detection to date and time of GPS positions.

PIT-Tag Information System

The Columbia Basin PIT-tag Information System (PTAGIS) was used as a repository for all interrogation information recorded with the PIT-tag detector/trawl equipment. The unfiltered and unedited interrogation data files required by PTAGIS were uploaded to the database periodically during the sampling season using standard procedures via modem (Destron Fearing 1993, Stein 1996). The interrogation records obtained using the PIT-tag detector/trawl are identified within the database with an interrogation-site code of "TWX" (towed array).

We also maintained an independent database (Microsoft Access) of our interrogation data to facilitate analysis and to couple our estuarine detection data with corresponding release information available through PTAGIS. To more accurately interpret information from detections of barged fish from the transportation study, we modified the PTAGIS release information within our database to reflect the date, time, and location (RKm) where transportation barges were emptied of fish downstream from Bonneville Dam. The PTAGIS release information represented the approximate date, time, and location that fish were placed into the raceways at Lower Granite Dam prior to loading onto transportation study barges. We obtained date, time, and location information for fish released from transport barges from U.S. Army Corps of Engineers (COE) personnel (Michael Halter and David Hurson, COE, Lower Granite Dam, Pers. commun., August 1998).

PIT-tag interrogations (over 38,000 fish) recorded by detectors at Bonneville Dam during our study (1 April-15 June 1998) were also accessed and downloaded from PTAGIS. These data, when compared to individuals subsequently detected in the estuary, were used to evaluate travel time from Bonneville Dam to the estuary and to make a comparative survival estimate for inriver migrants from the transportation study between the Lower Granite Dam release site and Bonneville Dam.

Descaling and Injury Assessments

Fish traversing the detector system were sampled regularly (about once per week) to assess descaling and injury rates using a sanctuary-bag recovery net attached to the back of the detector box. The recovery net apparatus included a PVC framework attached to the outside of the sanctuary net and placed about 0.3 m in front of the terminal vinyl bag liner and about 1.5 m from the back of the detector (Fig. 9). The PVC framework allowed a variable sample volume and helped to avoid overcrowding fish when large numbers entered the sanctuary net.

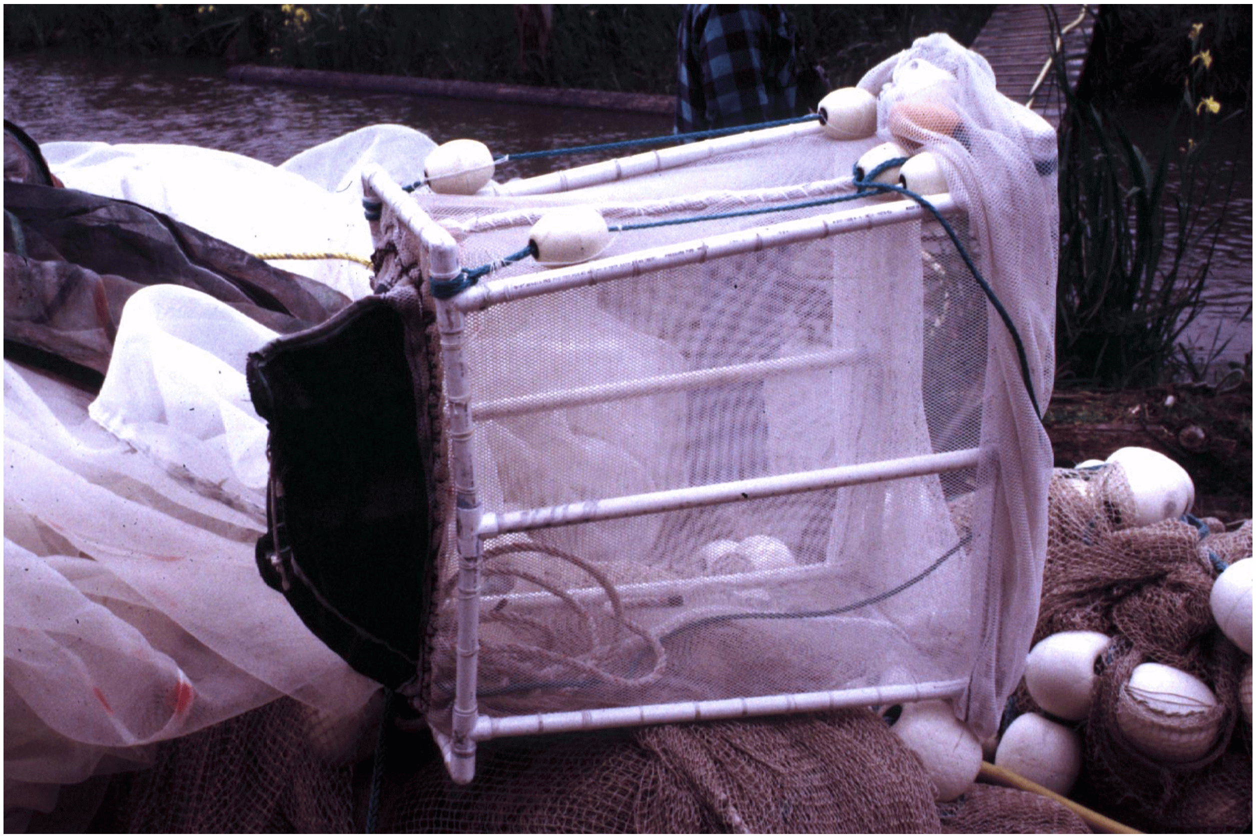


Figure 9. Photo of the sanctuary bag recovery net used to collect a sample of fish exiting the PIT-tag detector/trawl, 1998.

To obtain a sample, the trawl was brought to one-half tow speed, and divers attached the net to the back of the detector. The trawl was then brought back to full tow speed and the video camera and divers were used to determine when sufficient fish had entered the sanctuary (desired sample size was about 100 fish). Divers then removed the sanctuary net, which was retrieved by a drifting skiff. Duration of sampling was generally less than 15 minutes, depending on the density of fish that passed through the detector. Captured fish were transported to processing facilities aboard the barge. Numbers of dead, injured, or descaled salmonids were recorded. All fish were returned to the river immediately after processing and recovery from the anesthetic.

In addition to sampling fish that had traversed the net and detection system, we recorded all observances of fish impinged, gilled, or otherwise entrapped in the netting. Divers also periodically assessed the net and detection system.

Statistical Analysis

Diel patterns (number detected per hour during daylight compared to darkness) for juvenile chinook salmon and steelhead were evaluated by one-way analysis of variance (ANOVA). One-way ANOVA was also used to evaluate differences in detection rates of transportation study fish between rearing history (wild vs. hatchery origin). For this analysis, we pooled data by release dates until we had a minimum of 1,000 fish in each rearing-history category. A two-sample *t*-test was used to test the null hypotheses, that there were no differences in travel times to Jones Beach among PIT-tagged fish released from transportation barges and inriver migrant groups detected at Bonneville Dam.

We used a *z*-test to assess detection percentages for all release groups having greater than 100 detections in the estuary in order to test the hypothesis that detection distribution was normal about the mean detection percentage. We then used a one-way ANOVA for the same data set to test for differences among species in detection percentages.

Williams et al. (in review) presented annual survival estimates for salmonids migrating from the upstream extent of Lower Granite Reservoir to the tailrace of Bonneville Dam. Pair-trawl detections and additional detections obtained from piscivorous bird colonies in the estuary were analyzed in their estimates, and these analyses are presented here to address Objective 6. However, only survival estimates for juvenile steelhead are presented because of insufficient detections of spring/summer chinook salmon in the estuary.

In 1998, they used a modified single-release model (Cormack 1964, Skalski et al. 1998, Muir et al. In press) to obtain survival estimates for daily groups of PIT-tagged steelhead leaving Lower Granite Dam and arriving at McNary Dam. For survival estimates from McNary Dam to Bonneville Dam they used weekly groups leaving McNary Dam. The estimates from McNary Dam to Bonneville Dam utilized PIT-tag detections in the estuary. Williams et al. calculated annual mean survival estimates for the two reaches, and the product of these annual means provided the mean estimate of survival from the tailrace of Lower Granite Dam to the tailrace of Bonneville Dam which is used here.

RESULTS

The PIT-tag detector/trawl was deployed and operational a total of 321 hours between 17 April and 5 June (Fig. 10). During this period, 6,819 PIT-tag detections were recorded. Excluding test tags, duplicate tag codes, and erroneous codes resulting from a weak signal on a detector coil (see "bit-shifting," Ledgerwood et al. 1997), we detected 4,844 fish with PIT tags (Appendix Table B1). Estuarine detections were recorded for 3,803 chinook salmon, 359 coho salmon, 66 sockeye salmon, and 558 steelhead. In addition, 58 detections had no release information in the PTAGIS database.

Bit-Shifting, Duplication of Records, Tow Speeds, and Delay in Passage

Unlike in 1996, when over half of the detections recorded were invalid due to duplicate and erroneous codes (Ledgerwood et al. 1997), there were only 7 erroneous codes and 581 duplicates recorded in 1998. Most duplicate records occurred when the same fish was recorded on more than one detection coil in the antenna at the same time.

We had more powerful tow vessels in 1998 than in 1996, and during the early part of the season we experimented with faster tow speeds in the hope that we would get better volitional passage of fish out of the net and through the detector (Fig. 11). We evaluated towing velocities up to about 0.9 m/s (1.7 knots at 1,550 engine rpm) but concluded that the increased speed did not significantly change the rate that fish passed through the detector. However, the increased towing speed did increase the potential impingement of fish against the webbing, so we elected to drop the towing velocity to about 0.7 m/s (1.4 knots at about 1,300 engine rpm).

As in 1996, we brought the wings of the trawl together about every 15 minutes to "flush" the fish through the detector, and the majority of the detections came during these flushing actions. We believe the increase in detections during these flushes was a result of disturbance in the currents going through the detector and an increase in velocity (to about 0.8 m/s) that occurred when the drag load on the vessels decreased as the net wings were collapsed.

We also assessed delay of fish in the trawl by compiling a list of lapsed times between full deployment of the trawl (electronics energized and trawl at towing velocity) and the first fish detection (Fig. 12). For this assessment we selected only deployments wherein no unexpected delays were encountered. The mean time between full deployment and first fish detection was about 16 minutes. An inanimate object entering the 107-m-long trawl at a towing velocity of about 0.7 m/s would require about 2.5 minutes to reach the detector. To minimize this apparent delay in passage, which was possibly fatiguing to fish, we generally flushed the net about 15 minutes after bringing the net to tow speed. Video observations showed that fish backed their way down through the net and detector.

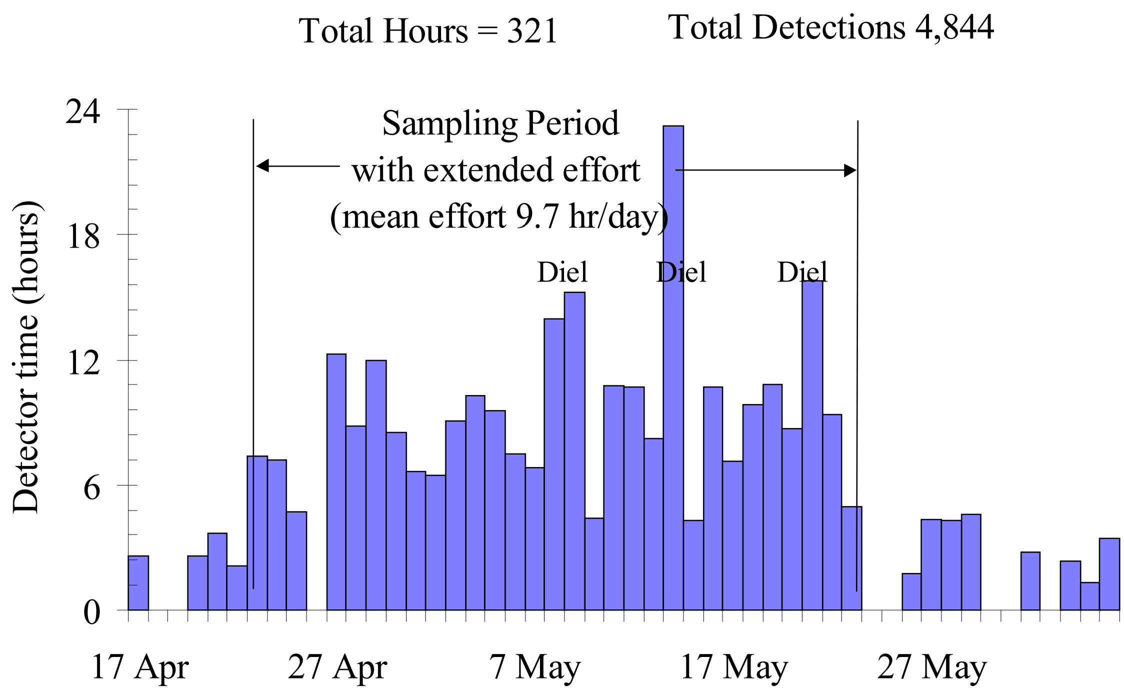


Figure 10. Daily detector on times (hours detector energized) during PIT-tag detector trawl sampling off Jones Beach, RKm 75, 1998.

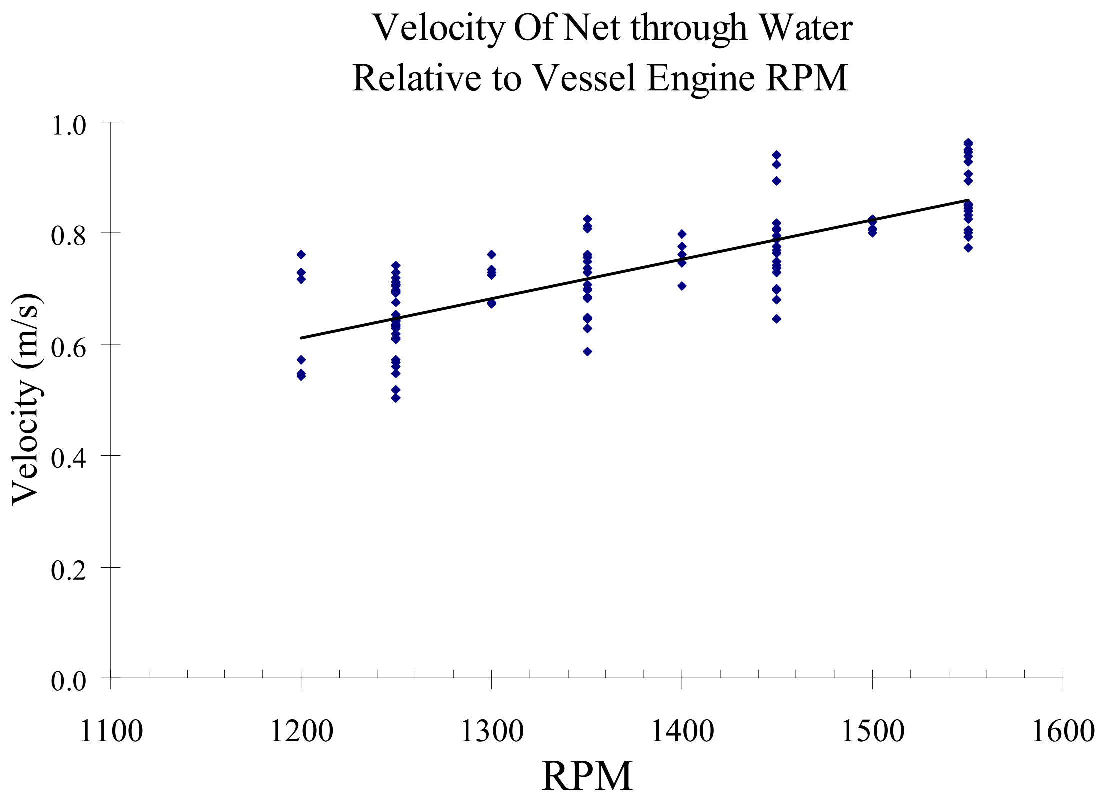


Figure 11. Measurements of water velocity between the pair-trawl wings (1-m depth) relative to towing vessel engine rpm with trawl in the open, sample-collection configuration, 1998.

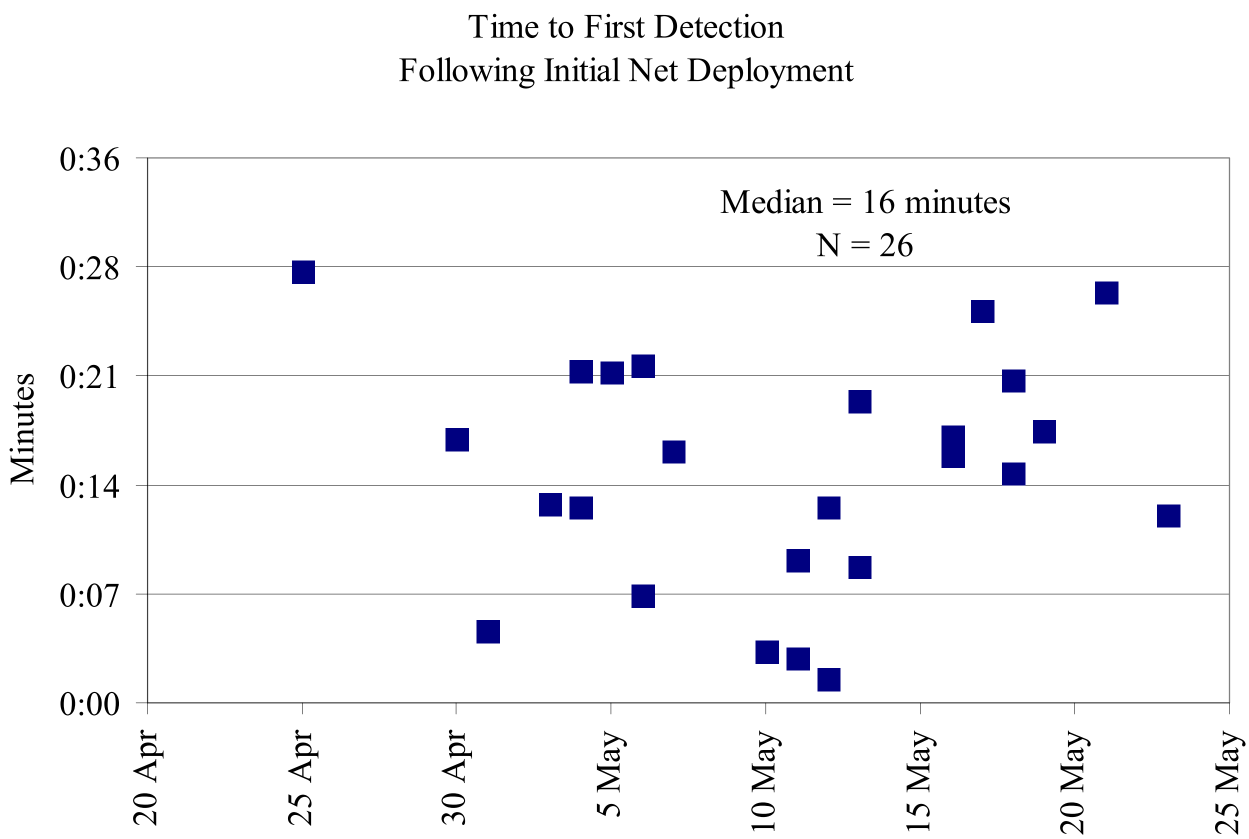


Figure 12. Lapse time to first fish detection after the electronics were energized and the deployed trawl brought to tow speed.

Descaling, Injury, and Mortality

As previously described, descaling and injury rates of fish traversing the detector system were assessed using a sanctuary-bag recovery net, which was attached periodically to the back of the detector box. Of the 532 juvenile salmonids recovered with the sanctuary net, 16.8% were descaled, 0.7% had some sort of injury, and mortality was 0.2% (Table 1). The descaling rate was higher than that observed for run-of-the-river salmon sampled during the same period at John Day (9.5%; Richard Graves, NMFS, Rufus, Oregon, Pers. commun., June 1998) and Bonneville Dams (4.7%; Rick Cowlishaw, NMFS, Bonneville Dam, Pers. commun., June 1998). However, we believe that the additional handling in the sanctuary net contributed to the increase in descaling.

Twenty-eight additional mortalities occurred on the morning of 7 May when we attempted to collect dead fish from the trawl to assess mortality (dead fish were not included in the descaling assessments). We attempted this sample by not flushing live fish through the detector to the sanctuary net. Rather, we left the net open for an extended time to allow weak or dead fish to drift through into the sanctuary net. We discovered that most collected fish were hatchery coho (adipose clip), probably originating from a lower river release. These fish were lethargic and became easily impinged on the net, had no PIT-tags, and were extremely numerous (observed jumping everywhere). We terminated trawling after that, and when we resumed the following morning, May 8, this mass of hatchery fish was no longer present.

Table 1. Number of descaled, injured, and dead juvenile salmonids recovered in a sanctuary bag sample-net attached to the exit of the PIT-tag detector/trawl, Jones Beach, Columbia River Kilometer 75, 1998.[a]

	Spring/summer chinook salmon				Fall chinook salmon				Coho salmon				Steelhead				Sockeye salmon				Generic[b] salmonids				Species breakdown[c] of generic salmonids					Total salmonids			
Date	n	D	M	I	n	D	M	I	n	D	M	I	n	D	M	I	n	D	M	I	n	D	M	I	Ch 1	Ch 0	Co	St	So	n	D	M	I
21 Apr	13	4	0	2	0	0	0	0	0	0	0	0	22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	35	4	0	2
22 Apr	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23 Apr	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	1	0	1	0
24 Apr	38	5	0	0	0	0	0	0	8	0	0	0	56	4	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	102	9	1	1
25 Apr	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
26 Apr	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27 Apr	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11	0	11	0	3	2	3	3	0	11	0	11	0
28 Apr	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	10	0	2	2	3	2	0	10	0	10	0
29 Apr	2	0	2	0	0	0	0	0	0	0	0	0	2	0	2	0	0	0	0	0	15	0	15	0	3	3	4	3	0	19	0	19	0
30 Apr	75	29	0	1	0	0	0	0	10	6	0	0	17	2	0	0	0	0	0	0	11	0	11	0	3	2	3	3	0	113	37	11	0
1 May	28	9	0	0	10	3	0	0	27	1	0	0	56	1	0	0	1	0	0	0	42	0	42	0	10	9	13	10	1	164	14	42	0
2 May	28	3	0	0	3	1	0	0	7	0	0	0	13	1	0	0	0	0	0	0	4	0	4	0	1	1	1	1	0	55	5	4	0
3 May	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	5	0	1	1	2	1	0	6	0	6	0
4 May	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	0	7	0	2	1	2	2	0	7	0	7	0
5 May	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	3	0	1	1	1	1	0	3	0	3	0
6 May	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	5	0	1	1	2	1	0	6	0	6	0
7 May	8	2	6	0	2	0	0	0	31	5	21	0	7	0	1	0	0	0	0	0	300	0	300	0	50	13	194	44	0	300	0	300	0
8 May	7	2	0	0	4	1	0	0	1	0	0	0	3	0	2	0	2	1	0	0	68	0	68	0	16	14	20	16	2	85	4	70	0
9 May	22	0	22	0	0	0	0	0	74	0	74	0	12	0	12	0	18	0	18	0	30	0	30	0	7	6	9	7	1	156	0	156	0
10 May	9	0	9	0	0	0	0	0	14	0	14	0	2	0	2	0	10	0	10	0	0	0	0	0	0	0	0	0	0	35	0	35	0
11 May	24	2	2	0	31	7	10	0	18	1	4	0	42	0	0	0	6	5	0	0	40	0	40	0	9	8	12	9	1	161	15	56	0
12 May	19	0	19	0	0	0	0	0	3	0	3	0	2	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	24	0	24	0
13 May	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	2	0	0	0	1	0	0	2	0	2	0
14 May	10	0	10	0	2	0	2	0	2	0	2	0	0	0	0	0	0	0	0	0	2	0	2	0	0	0	1	0	0	16	0	16	0
15 May	14	0	14	0	0	0	0	0	3	0	3	0	0	0	0	0	0	0	0	0	21	0	21	0	5	4	6	5	1	38	0	38	0
16 May	4	0	4	0	0	0	0	0	9	0	9	0	0	0	0	0	0	0	0	0	14	0	14	0	3	3	4	3	0	27	0	27	0
17 May	0	0	0	0	0	0	0	0	3	0	3	0	0	0	0	0	0	0	0	0	5	0	5	0	1	1	2	1	0	8	0	8	0

Table 1. Continued.

Date	Spring/summer chinook salmon				Fall chinook salmon				Coho salmon				Steelhead				Sockeye salmon				Generic[b] salmonids				Species breakdown[c] of generic salmonids					Total salmonids			
	n	D	M	I	n	D	M	I	n	D	M	I	n	D	M	I	n	D	M	I	n	D	M	I	Ch 1	Ch 0	Co	St	So	n	D	M	I
18 May	11	3	2	19	3	1	0	27	2	0	2	0	22	2	1	0	33	15	0	0	37	0	37	0	9	8	11	9	1	151	23	43	0
19 May	7	0	7	0	0	0	0	0	6	0	6	0	0	0	0	0	1	0	1	0	1	0	1	0	0	0	0	0	0	15	0	15	0
20 May	15	0	15	0	0	0	0	0	4	0	4	0	0	0	0	0	0	0	0	0	8	0	8	0	2	2	2	2	0	27	0	27	0
21 May	7	0	7	0	0	0	0	0	3	0	3	0	0	0	0	0	0	0	0	0	4	0	4	0	1	1	1	1	0	14	0	14	0
22 May	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	7	0	7	0	2	1	2	2	0	8	0	8	0
23 May	4	0	4	0	0	0	0	0	2	0	2	0	0	0	0	0	0	0	0	0	2	0	2	0	0	0	1	0	0	8	0	8	0
24 May	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25 May	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
26 May	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27 May	6	2	1	0	15	3	0	0	34	1	2	0	2	1	0	0	28	8	2	0	0	0	0	0	0	0	0	0	0	85	15	5	0
28 May	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
29 May	1	0	1	0	0	0	0	0	3	0	3	0	0	0	0	0	0	0	0	0	2	0	2	0	0	0	1	0	0	6	0	6	0
30 May	26	0	26	0	18	0	18	0	18	0	18	0	0	0	0	0	0	0	0	0	18	0	18	0	4	4	5	4	1	80	0	80	0
31 May	27	0	27	0	19	0	19	0	19	0	19	0	0	0	0	0	0	0	0	0	19	0	19	0	4	4	6	4	1	84	0	84	0
1 Jun	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	4	0	4	0	1	1	1	1	0	5	0	5	0
2 Jun	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3 Jun	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4 Jun	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5 Jun	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Totals:	**406**	**61**	**171**	**3**	**124**	**18**	**50**	**0**	**329**	**14**	**172**	**0**	**258**	**11**	**20**	**1**	**99**	**29**	**31**	**0**	**694**	**0**	**52**	**0**	**141**	**96**	**312**	**135**	**12**	**1,718**	**95**	**1,138**	**4**

[a] Codes used were n, sample observed; D, number descaled; M, number dead (mortality); I, number injured. Included are daily totals for juvenile salmonids observed entrapped in the detector/trawl by divers or upon retrieval of the detector/trawl.

[b] Fish recovered from the trawl net included all those specimens identified to species plus others that could not be accurately identified due to the observer (divers underwater) or location (entrapped in the net during retrieval). All of the fish so observed were counted as mortalities.

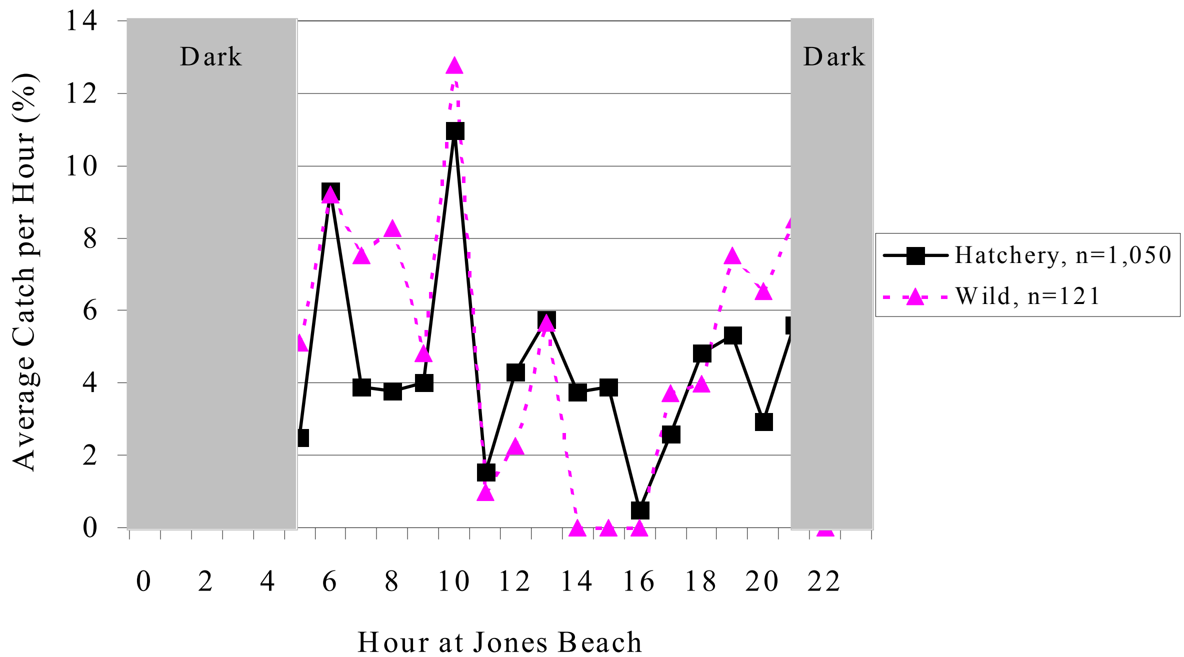
[c] Percentage species breakdown of unidentified salmonids was based on our 1996 observation (Ledgerwood 1997, Table 1) of species composition in our sanctuary bag collection net: 23% spring/summer (yearling) chinook; 21% subyearling fall chinook; 30% coho; 23% steelhead; and 3% sockeye. The exception was on 7 May, when 300 impinged salmonids were broken out using a species ratio obtained that day using the sanctuary bag collection net set to purposefully capture impinged specimens: 16.7% spring/summer chinook salmon; 4.2% fall chinook salmon; 64.6% coho; and 14.6% steelhead; (0% sockeye). The May 7 incident was a result of a large population of lethargic hatchery (adipose clipped) coho salmon passing the area that day; this population was not detected the next day.

In addition to fish collected in the sanctuary-bag recovery net, 1,138 salmonids were recovered from the trawl upon retrieval or observed by divers to be impinged or entrapped in the net underwater (this included the estimated 300 impinged hatchery coho observed on 7 May). In 1998, we developed a regular routine of debris cleaning, and unlike in 1996, we had the ability to pull the cod-end and detector to the surface for debris removal (through the newly installed zippers). During the cleaning routine we recorded any impingement observed in the cod-end as a mortality (these observations were not possible in 1996). Other mortalities and injuries to fish may have occurred but were unobserved due to the net inversion process used to clean debris from the net during retrieval.

Diel Detection Pattern

We continued PIT-tag trawling after nightfall during three periods in May (Appendix Tables B2 and B3). Hourly detection rates for the three periods were pooled to summarize the diel pattern for both juvenile spring/summer chinook salmon and steelhead (Fig. 13). Diel sampling results indicated that as in previous years detection rates for steelhead decreased during dark hours ($P = 0.01$) but those for chinook salmon did not ($P = 0.48$). For chinook salmon, the average number of detections per hour of detector operation decreased from 7.6 during daylight to 6.0 during darkness; for steelhead the average decrease was from 1.3 to 0.3 detections per hour.

Chinook Salmon Diel Catch Pattern



Steelhead Diel Catch Pattern

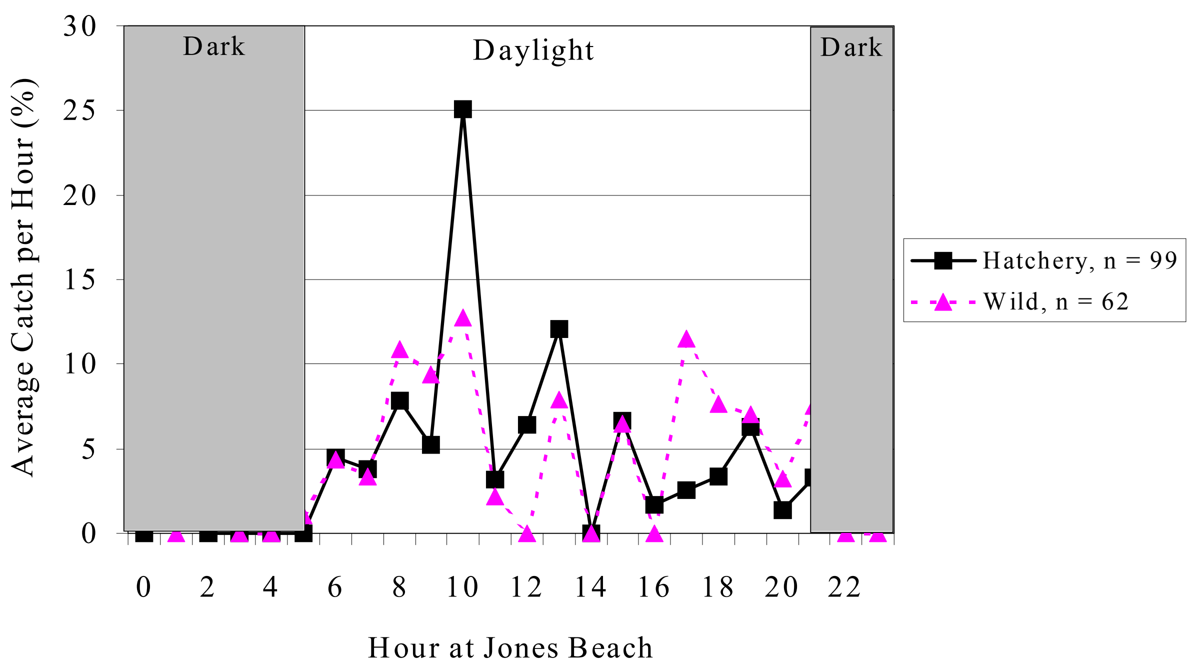


Figure 13. Average diel detection pattern for juvenile yearling chinook salmon and steelhead during three diel sampling periods at Jones Beach, 1998.

Transportation Study Detections

We detected 1,145 spring/summer chinook salmon marked for the transportation study: 297 transported from Lower Granite Dam and released downstream from Bonneville Dam and 848 released for inriver migration from Lower Granite Dam (Fig. 14; Table 2). There were significant differences in arrival timing between transported and inriver-migrating fish groups at Jones Beach (Fig 15). Respective 10th, 50th, and 90th percentile travel times from release site to the Jones Beach site were 1.5, 2.4, and 3.8 days for transports, and 13.5, 18.7, and 27.6 days for inriver migrants (Table 3). The longer, more uniform period of availability for fish released at Lower Granite Dam probably accounted for the increased number of detections for these fish compared to transported fish, and this pattern was similar to observations made in 1996.

During the 154-km migration from the release site below Bonneville Dam to Jones Beach, transported fish apparently did not disperse; thus, these fish produced a patchy distribution of detection rates which was strongly affected by the duration and time of daily sampling. By applying the median arrival time at Jones Beach for barged fish to the daily total of PIT-tagged fish released, we found that about 84% of the barged PIT-tagged fish passed Jones Beach between 5:00 am and 7:00 am (Fig. 16a; Appendix Table B4).

We also calculated a median travel time to Jones Beach for inriver migrant chinook salmon previously detected at Bonneville Dam (median = 1.6 days, n = 255). By adding this median time to the detection times for all 22,155 PIT-tagged chinook salmon detected at Bonneville Dam during our sampling period, we estimated a more uniform daily availability of fish at Jones Beach for the inriver migrants, with a slight peak near noon at about 16% and about 4% during other hours (Fig. 16b). The peak in availability near noon for inriver migrants at Jones Beach corresponds to the peak passage hours at Bonneville Dam near dusk. The rapid travel and lack of dispersal for transported fish relative to inriver fish resulted in an unreliable comparison of detection rates (relative survival comparisons), even for those groups passing the sampling site on the same dates.

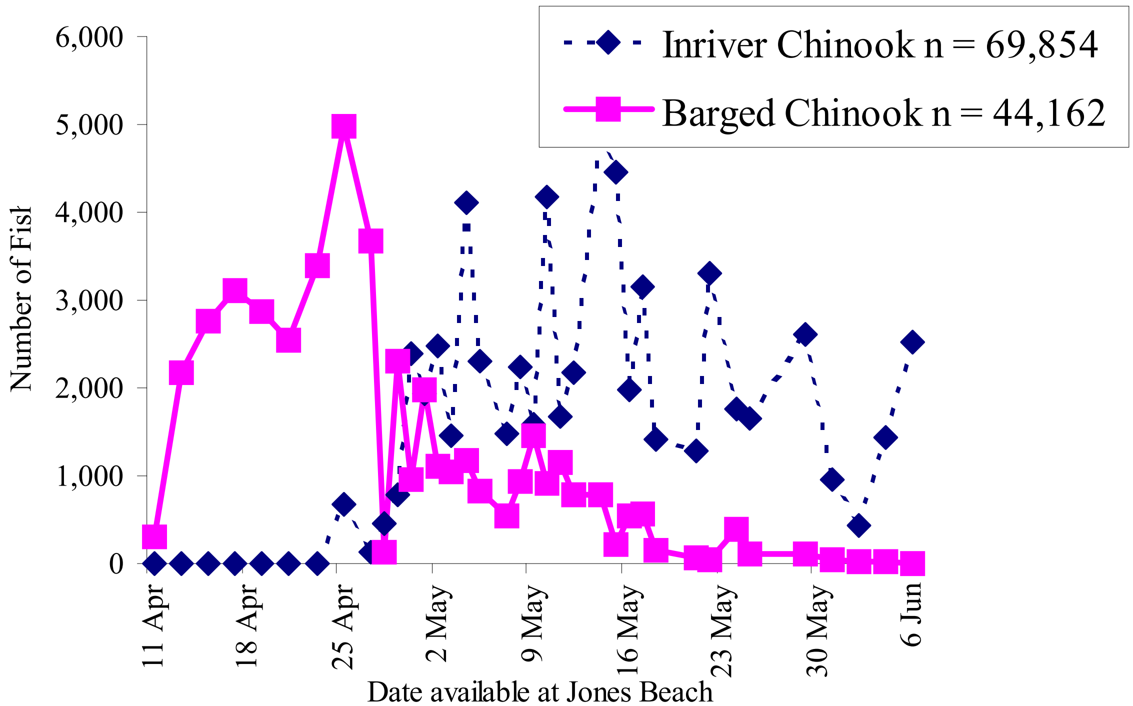


Figure 14. Number of PIT-tagged spring/summer chinook salmon released at Lower Granite Dam or transported by barge to release locations downstream from Bonneville Dam for a study of fish transportation, 1998. Temporal distributions shown are adjusted to reflect estimated timing to Jones Beach.

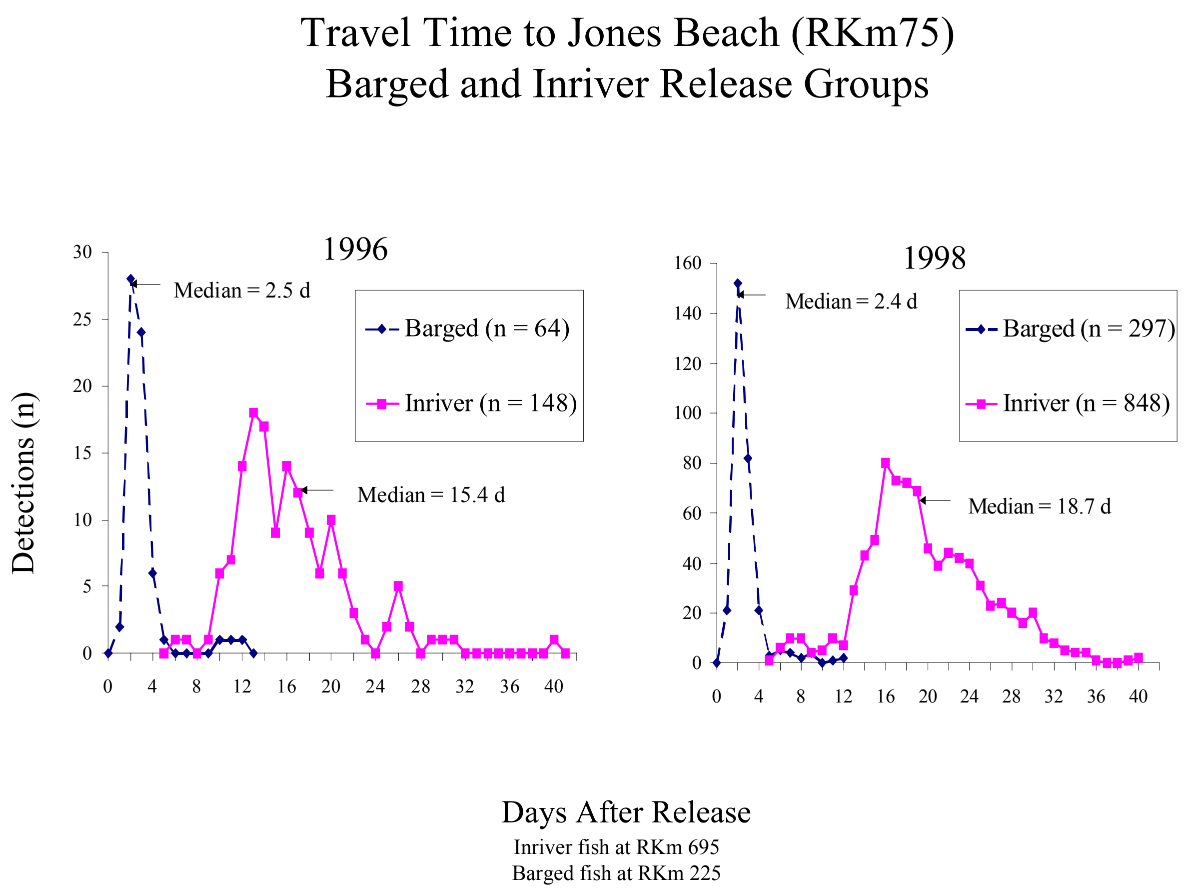


Figure 15. Duration of availability of transportation study fish at Jones Beach based on number of days post-release that fish were detected using the PIT-tag detector/trawl, 1996 and 1998.

Table 2. Estuarine PIT-tag detection data for juvenile spring/summer chinook salmon released for the Snake River transportation study, 1998. Detection data are separated by rearing type history recorded at the time of tagging.

A. Estuarine detection data for PIT-tagged chinook salmon transported and released downstream from Bonneville Dam, 1998.

Release date[ab]	Detection date (mean)	Total	Hatchery	Wild
12 Apr	24 Apr	1	1	
14 Apr	21 Apr	6	1	5
16 Apr	22 Apr	12	8	4
18 Apr	22 Apr	6	5	1
20 Apr	23 Apr	6	5	1
22 Apr	25 Apr	2	1	1
24 Apr	27 Apr	24	19	5
26 Apr	29 Apr	39	28	11
28 Apr	1 May	1	1	
29 Apr	30 Apr	12	10	2
29 Apr	2 May	4	4	
30Apr	2 May	27	23	4
2 May	4 May	26	25	1
2 May	4 May	16	16	
4 May	5 May	18	14	4
6 May	8 May	11	10	1
7 May	9 May	20	19	1
8 May	10 May	13	11	2
10 May	11 May	15	13	2
11 May	12 May	19	19	
11 May	13 May	9	7	2
13 May	17 May	1	1	
15 May	17 May	2	2	
16 May	18 May	3	2	1
17 May	20 May	2	1	1
20 May	22 May	1	1	
24 May	27 May	1		1
	Totals detected:	297	247	50
	Totals released[c]:	43,980	37,971	6,009
	Detection (%)[d]:	0.80	0.76	0.96

Table 2. Continued.

B. Estuarine detection data for PIT-tagged chinook salmon released for inriver migration downstream from Lower Granite Dam, 1998.

Release date	Detection date (mean)	Total	Hatchery	Wild
7 Apr	6 May	10	5	5
8 Apr	7 May	2	2	
9 Apr	9 May	6	5	1
10 Apr	8 May	14	8	6
11 Apr	9 May	43	27	16
12 Apr	7 May	33	24	9
13 Apr	9 May	26	21	5
14 Apr	8 May	20	15	5
15 Apr	9 May	58	47	11
16 Apr	9 May	33	25	8
17 Apr	9 May	11	10	1
18 Apr	9 May	38	31	7
19 Apr	7 May	19	18	1
20 Apr	9 May	61	57	4
21 Apr	8 May	20	18	2
22 Apr	9 May	24	22	2
23 Apr	10 May	80	72	8
24 Apr	10 May	76	69	7
25 Apr	11 May	29	22	7
26 Apr	12 May	47	43	4
27 Apr	13 May	17	16	1
28 Apr	15 May	23	19	4
29 Apr	14 May	30	29	1
30 Apr	13 May	14	14	
1 May	13 May	9	9	
1 May	15 May	5	5	
2 May	15 May	29	27	2
3 May	15 May	10	7	3
5 May	14 May	7	7	
6 May	15 May	16	13	3
7 May	20 May	18	17	1
8 May	21 May	2	2	

Table 2. Continued.

Release date[ef]	Detection date (mean)	Total	Hatchery	Wild
9 May	26 May	3	2	1
10 May	25 May	6	4	2
12 May	27 May	6	5	1
14 May	29 May	2	2	
15 May	29 May	1	1	
	Totals detected:	848	720	128
	Totals released[g]:	68,500	59,259	9,241
	Detection (%):	1.12	1.16	1.19

a. Release dates for only those releases having estuarine PIT-tag detections.

b. For transported fish, release dates\times were adjusted to the time fish were liberated downstream from Bonneville Dam.

c. Total release for transported fish through 24 May, the time period that the released fish would have passed Jones Beach during intensive sampling; see Appendix Table B4 for the total daily releases of transported study fish separated by rearing type history.

d. Mean detection percentages weighted by release day.

e. Release dates for only those releases having estuarine PIT-tag detections.

f. For transported fish, release dates/times were adjusted to the time fish were liberated downstream from Bonneville Dam.

g. Total release for inriver migrants through 15 May, the time period that the released fish would have passed Jones Beach during intensive sampling; see Appendix Table B4 for the total daily releases of transported study fish separated by rearing type history.

Table 3. Mean travel speed (km/day) of PIT- and radio-tagged spring/summer chinook salmon from Bonneville Dam or from barge release sites within approximately 5 km of Bonneville Dam to Jones Beach and correlations with total river flow, 1998.

A. Travel speed data, total and mean values by 5-day intervals.

	Yearling spring/summer chinook salmon										Steelhead	
	Barge release				Inriver migrant[a]						Inriver migrant	
Date interval Bonneville	Transport. study PIT-tag		Radio-tag[b]		Transport. study PIT-tag		All PIT-tag		Radio-tag[b]		All PIT-tag	
Dam	n	Speed	n	Speed	n	Speed	n	Speed	n	Speed	n	Speed
11 - 15 Apr	7	19.1	0	N/A	0	N/A	0	N/A	0	N/A	0	N/A
16 - 20 Apr	24	30.6	0	N/A	0	N/A	0	N/A	0	N/A	0	N/A
21 - 25 Apr	26	51.4	0	N/A	0	N/A	2	37.7	0	N/A	0	N/A
26 - 30 Apr	83	57.3	15	60.2	0	N/A	1	32.1	0	N/A	1	82.6
1 - 5 May	60	83.7	20	61.3	21	95.1	37	91.1	0	N/A	4	94.3
6 - 10 May	59	80.5	30	85.6	32	104.8	78	104.1	0	N/A	15	100.1
11 - 15 May	31	75.0	21	79.2	20	101.9	56	99.1	24	92.1	30	98.0
16 - 20 May	6	73.1	17	77.1	5	94.0	40	97.3	14	94.1	11	97.7
21 - 25 May	1	54.1	41	79.9	0	N/A	9	95.1	30	92.3	3	99.9
26 - 30 May	0	N/A	5	89.4	2	111.4	5	104.9	9	102.3	2	101.9
31 May - 4 Jun	0	N/A	16	91.8	0	N/A	1	106.5	13	103.8	2	122/8
5 - 9 Jun	0	N/A	0	N/A	0	N/A	0	N/A	0	N/A	0	N/A
Totals/mean	297	58.3	165	78.1	80	101.4	229	85.3	90	96.9	68	99.6
Comparable dates[c]	240	70.6	144	73.9			110	99.1	90	96.9	56	98.6

Table 3. Continued.

B. Correlation coefficients of fish travel speeds with river flow.

Total flow at Bonneville Dam		Correlations to flow	Correlation coefficient (R^{2})	Mean travel time (km/day)
Date interval	KCFS			
11-15 Apr	151.8	Barged PIT-tag spring/summer chinook salmon	0.718	70.6
16-20 Apr	155.4	Barged Radio-tag spring/summer chinook salmon	0.912	73.9
21-25 Apr	193.0	Inriver PIT-tag spring/summer chinook salmon (Trans. Study only)	0.635	101.4
26-30 Apr	217.0	Inriver PIT-tag spring/summer chinook salmon (All groups)	0.938	99.1
1-5 May	278.4	Inriver radio-tag spring/summer chinook salmon	0.932	96.9
6-10 May	356.3	Inriver steelhead PIT-tag (Trans. Study only)	98.500	98.6
11-15 May	334.1			
16-20 May	320.6			
21-25 May	318.5			
36-30 May	386.2			
31 May-4 Jun	412.0			
5-9 Jun	358.8			

[a] Inriver migrant PIT-tagged fish detected in the bypass system at Bonneville Dam (not handled at Bonneville); Radio-tagged fish collected from the bypass system at Bonneville Dam, tagged, and released within 24 hours.

[b] Radio-tagging study conducted by the Cooperative Fishery Unit, Oregon State University, Corvallis, OR, Thomas Stahl, project leader.

[c] Totals and mean values using date range having both PIT- and Radio-tagged fish.

Fork Length Comparisons

We plotted fish length by week of tagging vs. detection date at Jones Beach for transported and inriver fish groups (Figs. 17-18). There were no consistent trends between fish length at tagging and travel time to the estuary (e.g., larger fish apparently did not travel downstream faster than smaller fish). This may indicate that when collected from the river and tagged at Lower Granite Dam, all the fish were smolted.

Wild vs. Hatchery Stock Comparisons

There were no significant differences among daily detection percentages based on rearing type (wild or hatchery) for either transported groups ($P = 0.73$) or inriver groups ($P = 0.40$). The daily mean detection percentages for hatchery and wild fish were 0.76 and 0.96% for transported fish and 1.2 and 1.2% for inriver fish, respectively (Table 2).

Radio-Tagged Fish Migration vs. PIT-Tagged Fish Migration

Travel speed to Jones Beach for PIT-tagged and radio-tagged juvenile chinook salmon detected at Bonneville Dam or released from barges just downstream from Bonneville Dam were highly correlated to total river flow (R^2 correlation coefficient range 0.6 to 0.9) (Table 3). When corrected to comparable date ranges, there were no significant differences in travel speed between barged PIT-tagged or barged radio-tagged chinook salmon (means 70.6 and 73.9 km/day, respectively; $P = 0.54$) or between PIT-tagged chinook salmon detected at Bonneville Dam and run-of-the-river chinook salmon radio-tagged and released at Bonneville Dam (means 99.1 and 96.9 km/day, respectively; $P = 0.17$; Figs. 19-20). The average travel speed for PIT-tagged inriver migrant steelhead from Bonneville Dam to Jones Beach was 98.5 km/day.

Travel speed to Jones Beach of PIT-tagged chinook salmon detected at Bonneville Dam was significantly higher than that of PIT-tagged fish released from barges during the same date period (98 and 73 km/day, respectively; $P < 0.01$). The faster migration of inriver migrants was possibly due to a more advanced state of smoltification or other factors related to acclimation during the 2- to 3-weeks of migration after passing Lower Granite Dam. In contrast to this period of inriver acclimation, barged fish were transported and released below Bonneville Dam about 36 hours after arriving at Lower Granite Dam.

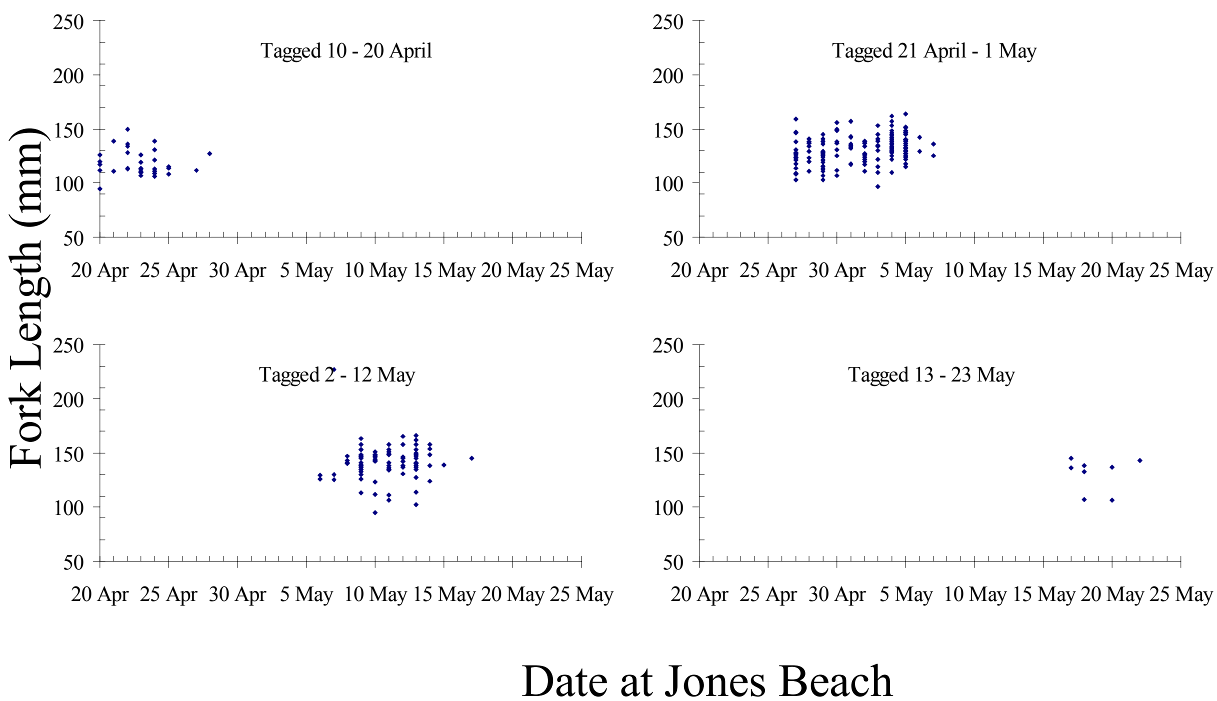


Figure 17. Lengths at time of tagging for transportation study spring/summer chinook salmon released from barges downstream from Bonneville Dam and subsequently detected at Jones Beach, 1998. Data were grouped by week of tagging.

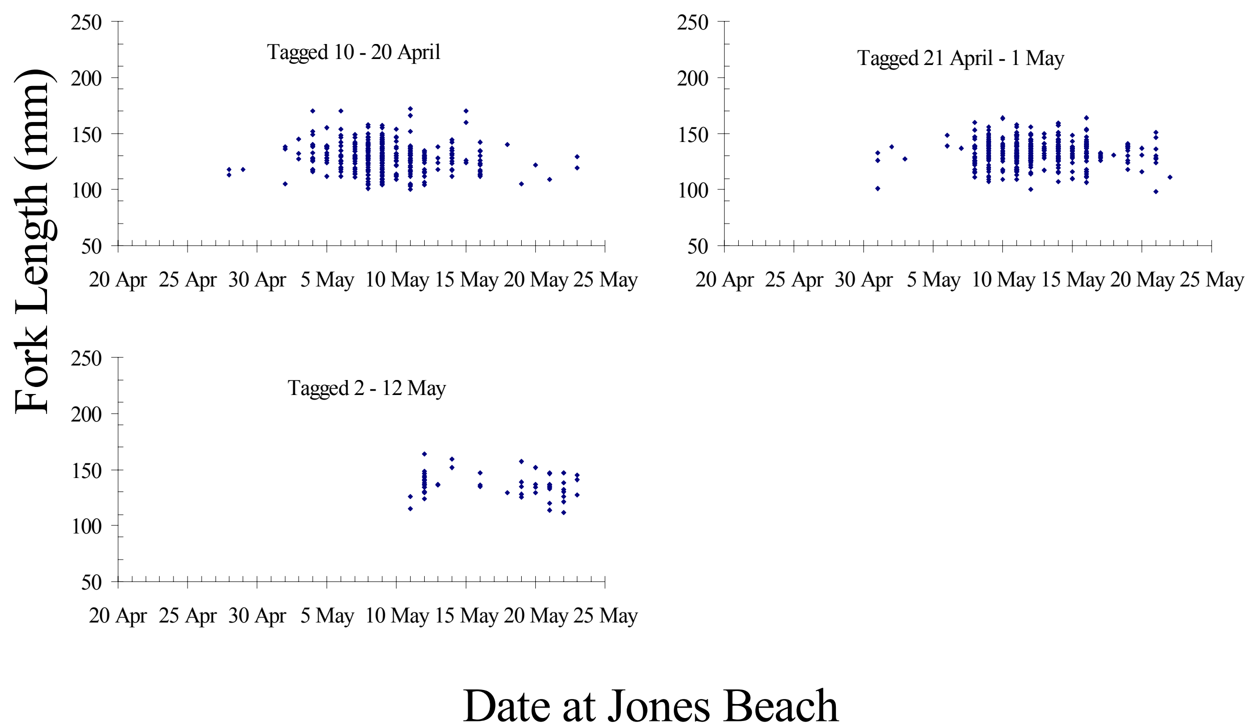


Figure 18. Lengths at time of tagging for transportation study spring/summer chinook salmon released for inriver migration at Lower Granite Dam and subsequently detected at Jones Beach, 1998. Data were grouped by week of tagging.

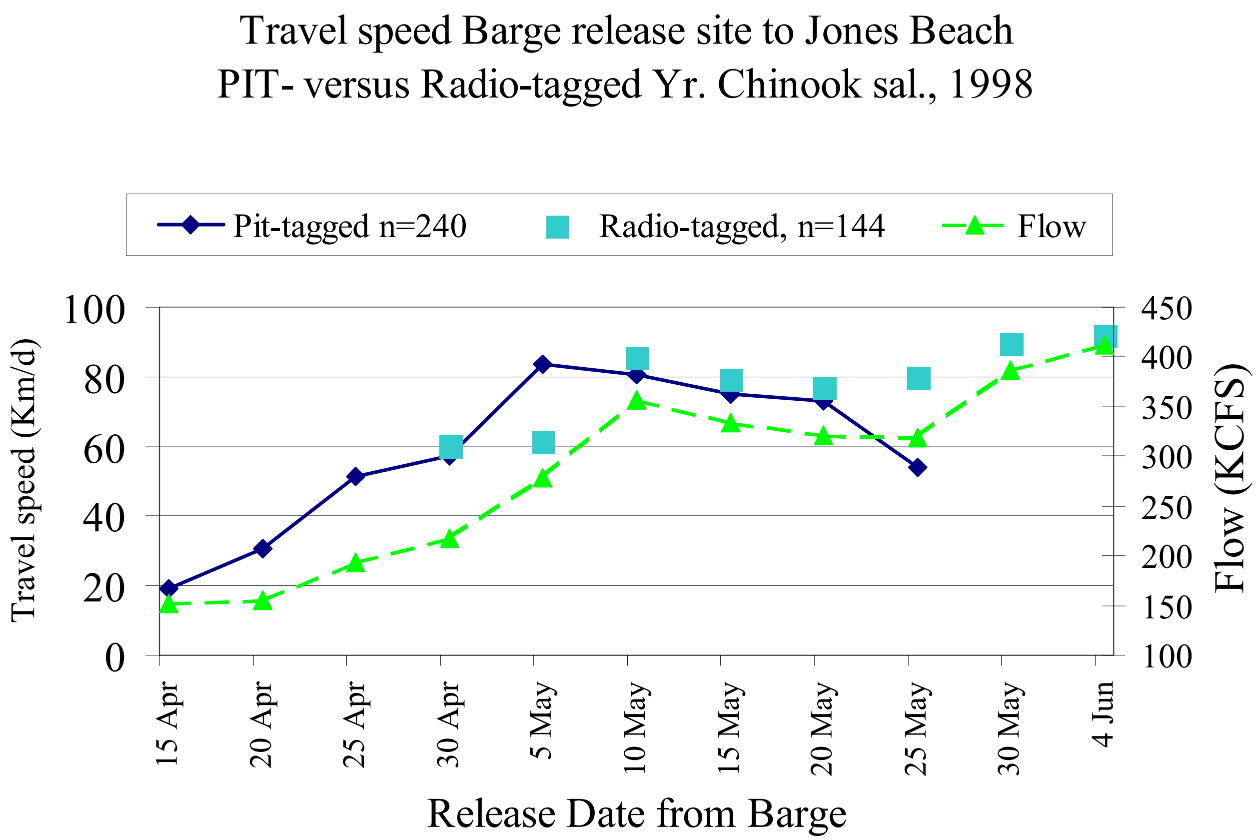


Figure 19. Travel speed to Jones Beach and 5-day average river flow for PIT- and radio-tagged chinook salmon released from transportation barges, 1998.

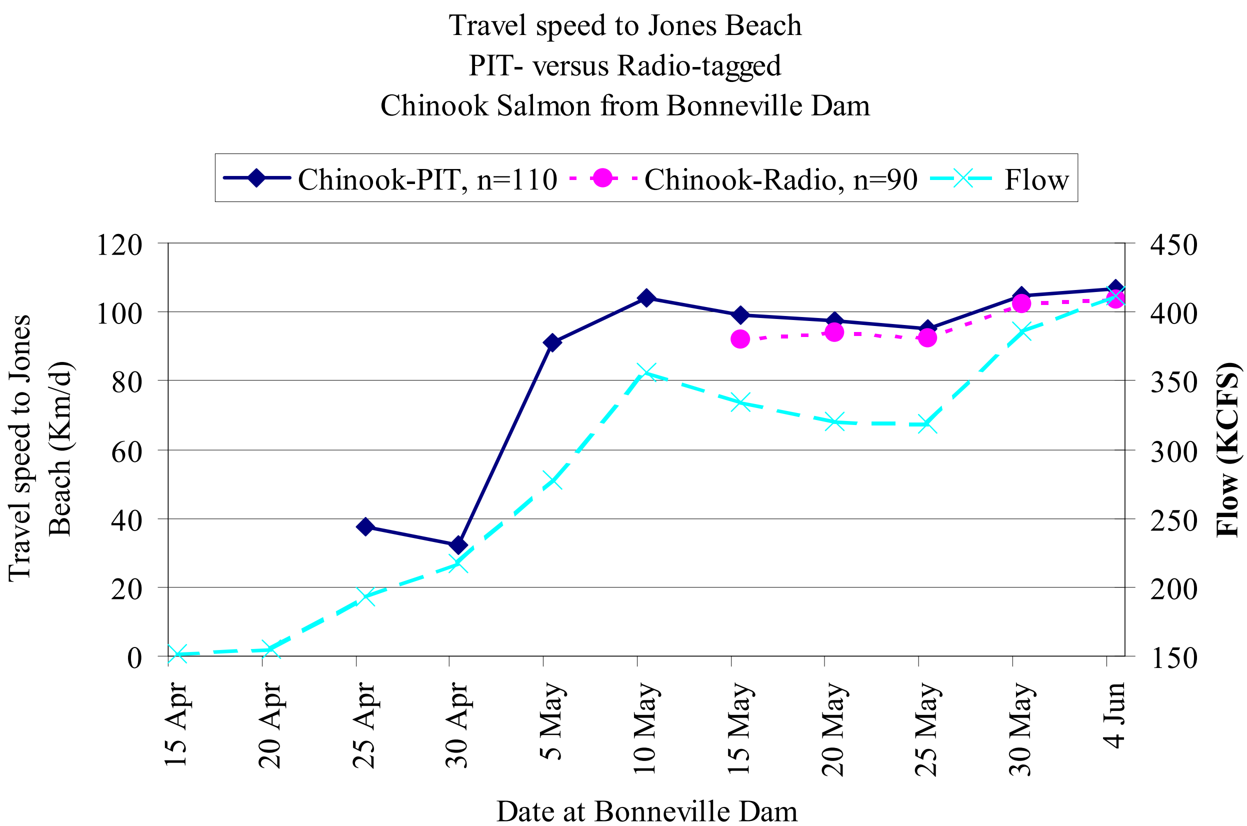


Figure 20. Travel speed to Jones Beach and 5-day average river flow for PIT- and radio-tagged chinook salmon detected at or marked and released at Bonneville Dam, 1998.

Survival Estimates

Using detections of PIT-tagged steelhead (hatchery and wild rearing types combined) downstream from Bonneville Dam, Williams et al. (in review) estimated average survival from McNary Dam to Bonneville Dam of 77%. Combined with their estimate of 65% survival from Lower Granite Reservoir to McNary Dam, this resulted in a survival estimate of 50% from the tailrace of Lower Granite Dam to the tailrace of Bonneville Dam (Table 4). The 95% confidence interval for the estimate was 39.2 to 60.7% (Steven G. Smith, NMFS, NWFSC, Seattle, Pers. commun, March 2000). Detections of spring/summer chinook salmon downstream from Bonneville Dam (pair-trawl and bird colony detections) were insufficient for calculating a reliable survival estimate from McNary Dam to Bonneville Dam.

Detection Efficiency of PIT-Tagged Salmonids

We detected PIT-tagged fish released from many study groups in addition to those from the transportation study. More than 100 individual fish were detected from 12 different study groups (Table 5). For the 12 groups, the combined average detection rate was 0.8% (n = 3,342 detections) of the total fish released (n = 444,022). There were no significant differences among species (P = 0.6) in detection rates in the estuary.

As a measure of our sampling efficiency, we compared our detection rate of PIT-tagged fish with the detection rate of fish monitored in the bypass system at Bonneville Dam. For this analysis we again selected the 12 groups for which we had at least 100 individuals detected at Jones Beach (Table 5). Detection rates for these fish groups at Bonneville Dam averaged 5.6% (n = 21,932), and detection rates for subsequent detections of these fish at Jones Beach averaged 1.2% (n = 276).

Table 4. Detection numbers and derived survival estimates for juvenile spring/summer chinook salmon and steelhead from the tailrace of Lower Granite Dam (LGR) to Bonneville Dam (BON), 1998. Estimates included pair-trawl data and PIT-tag data collected from predacious bird colonies in the lower estuary.

Release group (by PTAGIS code or pooled estimate)	Salmonid species	Number in tailrace at LGR	Number detected at BON	Number detected in estuary (pair-trawl + birds)	Number detected at BON and in estuary (pair-trawl + birds)	Mean survival (%) from LGR to BON	95% Confidence lower limit	95% Confidence upper limit
Non-LGRRRR[a]	Spring/summer chinook	29,425	1,969	764	53			
Transportation study (LGRRRR)	Spring/summer chinook	70,547	5,039	1,861	177			b
All	Spring/summer chinook	NA[b]	NA	NA	NA	NA[c]	NA	NA
Non-LGRRRR	Steelhead	15,814	1,263	1,562	207			
Survival Study (LGRRRR)	Steelhead	30,161	2,728	3,007	458			c
All	Steelhead					50.0[d]	39.2	60.7

[a] PITAGIS code LGRRRR = fish released into the tailrace of Lower Granite Dam for inriver migration.
[b] Not available
[c] Release dates for only those releases having estuarine PIT-tag detections.
[d] Survival estimate obtained using method described in Williams et al. (in review).

Table 5. Detection rates for major PIT-tag release groups detected at both Jones Beach and Bonneville Dam, 1998.

Species/release site (code)[a]	Number released	PIT-tag detection: Bonneville Dam Number detected	Bonneville Dam Rate (%)	Jones Beach Number detected[b]	Jones Beach Rate (%)	Both Jones beach and Bonneville Dam Number detected	Both Jones beach and Bonneville Dam Rate (%) of Bonneville number
Yearling Chinook Salmon							
North Fork Clearwater R. (CLWRNF)	47,704	1,705	3.6	425	0.9	28	1.6
Imnaha River Weir (IMNAHW)	19,169	731	3.8	116	0.6	5	0.7
Knox Bridge (KNOXB)	47,460	1,370	2.9	224	0.5	13	0.9
Lookingglass Hatchery (LOOH)	43,939	971	2.2	266	0.6	14	1.4
Lower Granite Dam–into tailrace for inriver migration (LGRRRR)	70,547	5,039	7.1	848	1.2	78	1.5
McNary Dam–into gatewell(s) (MCNGWL)	9,515	875	9.2	126	1.3	11	1.3
McNary Dam–into tailrace (MCNTAL)	8,343	843	10.1	124	1.5	11	1.3
Rapid River Hatchery (RAPH)	48,357	1,435	3.0	337	0.7	16	1.1
Rock Island Dam (RIS)	31,141	1,980	6.4	196	0.6	19	1.0
Rocky Reach Dam (RRE)	33,383	1,341	4.0	183	0.5	8	0.6
Coho salmon							
The Dalles Dam–into spillway (TDASPL)	24,148	2,894	12.0	140	0.6	27	0.9
The Dalles Dam–into tailrace (TDATAL)	26,390	3,245	12.3	161	0.6	18	0.6
Steelhead							
Lower Granite Dam–into tailrace for inriver migration (LGRRRR)	30,161	2,728	9.0	237	0.8	31	1.1

[a] Release site code as listed in PTAGIS regional database.

[b] Groups presented have > 100 PIT-tag detections at Jones Beach.

DISCUSSION

As in previous years, the longer, more uniform period of availability in the estuary of inriver migrant fish compared to that of transported fish probably accounted for the greater number of inriver migrants. Transported fish apparently did not disperse during the 154-km migration from the Bonneville Dam release area to Jones Beach, and they also had a patchy distribution in the sampling area. These factors resulted in detection rates that were affected by duration and time of daily sampling effort and probably invalidate a direct comparison of detection percentages between the transportation study fish groups.

Transported fish groups arrived in the estuary and subsequently entered the ocean several days to weeks prior to their inriver-migrating cohorts. Ocean conditions and other factors, such as the degree of smoltification over time, often change rapidly and can affect survival. Thus comparisons between fish groups with different timing for ocean entrance can be invalid. However, by sampling for PIT-tagged fish in the estuary, we were able to better define timing of the respective fish groups to the ocean, and this information should facilitate evaluation of subsequent adult returns. These data will also provide a valuable baseline to compare relative vulnerabilities between wild and hatchery rearing types or barged and non-barged fish to avian predators concentrated on breeding colonies in the lower estuary (Roby et al. 1998).

The diel behavior of PIT-tagged fish led us to speculate that juvenile steelhead and possibly juvenile chinook salmon travel deeper in the water column at night. Based on this behavior, and on earlier work, we concluded that juvenile salmonids, particularly steelhead, orient to the bottom and perhaps stop in deeper areas of the channel at night (Ledgerwood et al. 1991). Diel sampling of PIT-tagged juvenile salmonids supported this earlier conclusion of deeper orientation at night; lower detection rates during darkness suggests that travel was deeper in the water column. However, radio-tagging data from similarly transported fish did not indicate a decrease in migration rate for those fish at night. Radio-tagged fish apparently continue migrating in surface waters during darkness where it is possible to receive their transmitted signal (Larry Davis, Cooperative Fishery Unit, Oregon State University, Pers. commun., August 1998).

We completed several design and equipment changes since 1996 that provided a more reliable and efficient mobile underwater PIT-tag detection system. Changes in vessels, net design, and detection equipment gave us confidence to extend the daily sampling schedule in 1998 from 8 to 16 hours per day and the weekly schedule from 5 to 7 days per week. In addition, completion of PIT-tag interrogation systems at Bonneville Dam meant that we were able to obtain precise timing information on PIT-tagged fish detected both at Bonneville Dam and Jones Beach. Observations provided by these inriver migrant fish provided a valuable comparison to transported fish released downstream from Bonneville Dam. The numbers of PIT-tagged fish released into the watershed continue to provide ample targets and we extended our goal to detect about 2% of the available PIT-tagged fish passing into the estuary in 1998.

Changing from underpowered to full powered tow vessels gave us an ability to attempt using tow speed as a method to increase volitional fish passage through the system. During the initial 2 years of sampling we required near maximum vessel power to move the net through the water at about 0.6 m/s (1.2 knots). Vessels used in 1998 could pull the net at about 0.9 m/s (3 knots); however, we soon discovered that increased tow speed increased the potential for fish impingement, and thus we decided that a moderate tow speed of about 0.7 m/s (1.4 knots) was optimal. The larger vessels also allowed us to mount the net reel in a position to deploy and retrieve the trawl over the stern rather than over the side, which increased efficiency by allowing for faster and safer net-handling operations.

We added various perimeter zippers with vinyl borders to the floored-body section of the pair-trawl to ease repair and attachment of the cod-end. We also added horizontal zippers in the cod-end to enable removal of debris without having to remove the detector. While the debris-removal zippers proved their worth, fish appeared to orient to the perimeter zippers, especially where the net changed from webbing to Nitex. These design flaws probably contributed to delay in passage through the detector. We therefore eliminated the Nitex webbing and used the same sized webbing throughout the trawl body and cod-end to the attachment point with the detector.

By changing to the 3-pipe detector antenna from the original 2-tunnel (295 kg) antenna, we also increased operation efficiency by attaching the detector to the net following deployment rather than during deployment. The pontoon barge was a much improved platform for housing the detector electronics and accessing the cod-end of the net for debris removal. By routing the cabling for the video camera independently from the PIT-tag detection cables we were able to continuously monitor the detector entrance; this was not possible with the old system when the detector was attached during deployment.

Volitional fish passage through the detector remained a problem using the 3-pipe system in 1998. To avoid fatiguing fish reluctant to exit the trawl, we continued to bring the wings of the net together to “flush” fish, and most detections (about 90%) came during the flushing procedure. The 3-pipe detection antenna performed well electronically and was reliable compared to the original system. The electronic switching device used to isolate each adjacent antenna coil acted to eliminate interference between coils. However, we believe that the roughly 2 in of required insulation around each antenna pipe created a small hydraulic buffer in front of the detector that fish could recognize, and that their orientation to this buffer slowed passage.

CONCLUSIONS

1) The electronic detection equipment used in 1998 was much improved and more reliable than in earlier years. This reliability allowed for extended sampling efforts, and as a result, 1.2% of all transportation study fish released were detected at Jones Beach. The increased detection rate coupled with PIT-tag detections obtained from bird colonies in the estuary enabled calculation of survival estimates for inriver migrant juvenile steelhead from the tailrace of Lower Granite Dam to the tailrace of Bonneville Dam (point estimate 50.0%, with 95% confidence interval 39.2-60.7%). The number of PIT-tag detections in the estuary for spring/summer chinook salmon were insufficient for reliable survival estimates.

2) The estuarine detections of PIT-tagged fish in the pair-trawl provides precise timing information for fish migrating downstream from Bonneville Dam to Jones Beach for both inriver migrating and transported salmonids. This information allows for improved estimates on timing of ocean entrance for the two groups and more accurate correlations between ocean conditions and within-season variance in smolt-to-adult return ratios.

3) As in previous years, diel sampling results indicated decreased detection rates during darkness for steelhead but not for chinook salmon. For chinook salmon, the average number of detections per hour of detector operation decreased from 7.6 during daylight to 6.0 during darkness; for steelhead the average number of detections per hour decreased from 1.3 to 0.3 from daylight to darkness.

4) Comparison of migration behavior for yearling chinook salmon using PIT- and radio-tag technologies indicated similar and rapid travel for both groups of test fish between Bonneville Dam and Jones Beach. Travel speeds to Jones Beach for PIT-tagged or radio-tagged juvenile chinook salmon released from barges just downstream from Bonneville Dam were highly correlated to total river flow. There were no significant differences in travel speed between barged PIT-tagged or barged radio-tagged chinook salmon ($P = 0.54$) or between PIT-tagged chinook salmon detected at Bonneville Dam and run-of-the-river chinook salmon radio-tagged and released at Bonneville Dam ($P = 0.17$). Travel speed to Jones Beach of PIT-tagged chinook salmon detected at Bonneville Dam was significantly higher than those PIT-tagged fish released from barges during the same date period (98 and 73 km/day respectively, $P = 0.001$).

5) About 0.8% of all PIT-tags released in the basin were subsequently detected in the pair-trawl. These detections provided ratios of wild to hatchery fish and known numbers of barged and inriver fish available just upstream from large breeding colonies of piscivorous birds. This estuarine timing and other information provide baseline data to compare relative vulnerabilities to avian predators (PIT-tag data are also being collected from the bird colonies).

RECOMMENDATIONS

1) Continue with development of a larger diameter 400-kHz PIT-tag detection antenna for use in 1999. Theoretically, a "high-power" 400-kHz system can be constructed that would provide a 46-cm-diameter antenna opening. A 91-cm or larger antenna opening may be possible with a 134-kHz system. This detection system is planned for implementation throughout the Columbia River Basin in the year 2000.

2) Future net construction should avoid changes in webbing and other perimeter devices (zippers and vinyl) that change structure and flow near the trawl exit. Fish tend to orient to these areas, which delays their passage through the detector and out of the trawl.

3) Date, time, and location of barged-releases should be recorded for all fish transportation barges. This information should be made available through the regional PTAGIS information database. PTAGIS information for PIT-tagged barged fish now shows the date and river kilometer where fish were released into the raceway at the marking facility, not where the fish are liberated from the barges. Care should be made to identify onto which barge PIT-tagged fish are loaded.

ACKNOWLEDGMENTS

We thank David Marvin of PSMFC, Portland, Oregon, for his assistance in obtaining information from the PTAGIS database. We thank Michael Halter of COE, Lower Granite Dam, for providing the dates, times, and locations that fish were released from transportation barges. We thank Thomas Stahl of the Cooperative Fishery Unit at Oregon State University for information concerning the radio-tracking study. Special thanks go the boat operations crews for their personal flexibility while keeping us safe and "on-line" for the extended sampling periods in 1998.

REFERENCES

Berggren, T. J., and L. R. Basham. 2000. Comparative survival rate study (CSS) of hatchery PIT tagged chinook: status report for migration years 1996-1998 mark/recapture activities. Report to Bonneville Power Administration, Contract 8712702, 45 p. plus appendices. (Available from Fish Passage Center, 2501 SW First Ave., Suite 230, Portland, OR 97201.)

Cormack, R. M. 1964. Estimates of survival from the sightings of marked animals. Biometrika 51:429-438.

Dawley, E. M., L. G. Gilbreath, R. F. Absolon, B. P. Sandford, and J. W. Ferguson. 2000. Relative survival of juvenile salmon passing through the spillway and ice and trash sluiceway of The Dalles Dam, 1998. Report to U.S. Army Corps of Engineers, Contract MIPR E96970020 & W66QKZ82167243 & W66QKZ83437725, 89 p. (Available from Northwest Fisheries Science Center, 2725 Montlake Blvd. E., Seattle, WA 98112-2097.)

Dawley, E. M., R. D. Ledgerwood, T. H. Blahm, C. W. Sims, J. T. Durkin, R. A. Kirn, A. E. Rankis, G. E. Monan, and F. J. Ossiander. 1986. Migrational characteristics, biological observations, and relative survival of juvenile salmonids entering the Columbia River estuary, 1966-1983. Report to Bonneville Power Administration, Contract DE-A179-84BP39652, 256 p. (Available from Northwest Fisheries Science Center, 2725 Montlake Blvd. E., Seattle, WA 98112-2097.)

Destron Fearing. 1993. Passive integrated transponder (PIT) tag identification system. User manual. Destron Fearing and the National Marine Fisheries Service. (Available from Destron Fearing Corporation, 490 Villaume Avenue, South St. Paul, MN 55075.)

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 appendices. (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, B. P. Sandford, and S. J. Grabowski. 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. Report to U.S. Army Corps of Engineers, Contract DACW57-85-H-0001, 53 p. plus appendices. (Available from Northwest Fisheries Science Center, 2725 Montlake Blvd. E., Seattle, WA 98112-2097.)

Ledgerwood, R. D., E. M. Dawley, B. W. Peterson, and R. N. Iwamoto. 1997. Estuarine recovery of PIT-tagged juvenile salmonids from the Lower Granite Dam Transportation Study, 1996. Report to U.S. Army Corps of Engineers, Contract E8960100, 54 p. plus appendices. (Available from Northwest Fisheries Science Center, 2725 Montlake Blvd. E., Seattle, WA 98112-2097.)

Ledgerwood, R. D., F. P. Thrower, and E. M. Dawley. 1991. Diel sampling of migratory juvenile salmonids in the Columbia River estuary. Fish. Bull., U.S. 89:69-78.

Marsh, D. M., J. R. Harmon, N. N. Paash, K. L. Thomas, K. W. McIntyre, B. P. Sandford, and G. M. Matthews. 1997. Research related to transportation of juvenile salmonids on the Columbia and Snake Rivers, 1996. Report to U.S. Army Corps of Engineers, Contract E86960099, 26 p. plus appendices. (Available from Northwest Fisheries Science Center, 2725 Montlake Blvd. E., Seattle, WA 98112-2097.)

Marsh, D. M., J. R. Harmon, N. N. Paash, K. L. Thomas, K. W. McIntyre, B. P. Sandford, and G. M. Matthews. 1998. Research related to transportation of juvenile salmonids on the Columbia and Snake Rivers, 1997. Report to U.S. Army Corps of Engineers, Contract E86960099, 17 p. plus appendices. (Available from Northwest Fisheries Science Center, 2725 Montlake Blvd. E., Seattle, WA 98112-2097.)

Marsh, D. M., J. R. Harmon, N. N. Paash, K. L. Thomas, K. W. McIntyre, B. P. Sandford, and G. M. Matthews. 2000. Research related to transportation of juvenile salmonids on the Columbia and Snake Rivers, 1998. Report to U.S. Army Corps of Engineers, Contract DACW68-84-H0034, 34 p. plus appendices. (Available from Northwest Fisheries Science Center, 2725 Montlake Blvd. E., Seattle, WA 98112-2097.)

Miller, D. R. 1992. Distribution, abundance, and food of juvenile chinook salmon in the nearshore ocean adjacent to the Columbia River. Workshop on the growth, distribution, and mortality of juvenile Pacific salmon in coastal waters. p. 1-33. Sidney, British Columbia, Oct. 17-18 1992. (Available from Northwest Fisheries Science Center, 2725 Montlake Blvd. E., Seattle, WA 98112-2097.)

Miller, D. R., J. G. Williams, and C. W. Sims. 1983. Distribution, abundance, and growth of juvenile salmonids off the coast of Oregon and Washington, summer 1980. Fish. Res. 2:1-17.

Muir, W. D., S. G. Smith, J. G. Williams, E. E. Hockersmith, and J. R. Skalski. In press. Survival estimates for PIT-tagged migrant yearling chinook salmon and steelhead in the lower Snake and lower Columbia Rivers, 1993-1998. N. Am. J. Fish. Manage.

PSFMC (Pacific States Marine Fisheries Commission). 1992--. The Columbia Basin PIT Tag Information System (PTAGIS). Pacific States Marine Fisheries Commission, Gladstone, Oregon. Online database available through internet: www.psmfc.org/pittag)

Prentice, E. F., T. A. Flagg, C. S. McCutcheon, and D. F. Brastow. 1990. PIT-tag monitoring systems for hydroelectric dams and fish hatcheries. Am. Fish. Soc. Symposium 7:323-334.

Roby, D. D., D. P. Craig, K. Collis, and S. L. Adamany. 1998. Avian predation on juvenile salmonids in the lower Columbia River. Report to Bonneville Power Administration and U.S. Army Corps of Engineers. 87 p. (Available from Oregon Cooperative Wildlife Research Unit, Dep., of Fisheries and Wildlife, 104 Nash Hall, Oregon State University, Corvallis, OR 97331-3803.

Skalski, J. R., S. G. Smith, R. N. Iwamoto, J. G. Williams, and A. Hoffman. 1998. Use of passive integrated transponder tags to estimate survival of migrant juvenile salmonids in the Snake and Columbia Rivers. Can. J. Fish. Aquat. Sci. 55:1484-1493.

Stein, C. (ed.). 1996. 1996 PIT tag specification document. Columbia River Basin PIT tag information system data source input specifications. Prepared by PIT Tag Technical Steering Committee. 50 p. plus appendices. (Available from Pacific States Marine Fisheries Commission, 45 SE 82nd Drive, Suite 100, Gladstone, OR 97027-2522.)

Williams, J. G., S. G. Smith, and W. D. Muir. In review. Survival estimates for downstream migrant yearling juvenile salmonids through the Snake and Columbia River hydropower system, 1966 to 1980 and 1993 to 1999. N. Am. J. Fish. Manage. (Available from Northwest Fisheries Science Center, 2725 Montlake Blvd. E., Seattle, WA 98112-2097.)

APPENDIX A

PIT-tag antenna mockup testing at Jones Beach, 1997

Background

In 1995 and 1996, we used a prototype 400-kHz underwater PIT-tag detector attached to the pair-trawl. The prototype detector was difficult to deploy and retrieve, was subject to leaks (which created electronic failures), and fish resisted passing through it to exit the trawl. The basic design was a cubic plywood box measuring about 110 cm (4 ft) on a side with a total weight of over 650 pounds. It required about 1.5 hours to deploy/retrieve the detector and trawl, during which time no PIT-tag interrogation could be conducted. These and other factors contributed to reduced detection efficiency of the prototype detector and suggested that design and operational changes would improve detection efficiency.

It was originally anticipated that 1997 would be a transition year for converting from the 400-kHz PIT tag to the new International Standards Organization (ISO) 134.2-kHz PIT tag in the Columbia River Basin. Due in part to the expected low number of outmigrant salmonids in 1997, few juvenile fish were to be PIT tagged during the transition year, and as a result we had no plans for deployment of the 400-kHz PIT-tag detector/trawl equipment after 1996. However, implementation of 134.2-kHz PIT-tag detector systems at dams on the Columbia and Snake Rivers was delayed until 2000, and PIT-tag research studies using 400-kHz PIT-tags were scheduled in the Columbia River Basin from 1997 to 1999. Two major studies (transportation study and hatchery fish survival study) planned for 1998 and beyond would utilize perhaps as many as 400,000 of the 400-kHz PIT tags annually. The continued release of large numbers of 400-kHz PIT tags prompted our efforts to improve the 400-kHz PIT-tag detection equipment based upon mockup work conducted at Jones Beach in 1997. We believe that results from the 1997 development research are also applicable to the 134.2-kHz PIT-tag detection equipment.

Methods

No electronics were used during the mockup evaluations in 1997; instead, fish passage through a new detector shape based on a 3-pipe bundle of 8- to 10-in-diameter plastic pipes was tested. The tests occurred 2-10 June in the Columbia River at Jones Beach, RKm 75.

Multiplex electronic technology enabling on/off cycling of PIT-tag detection coils provided an option of placing multiple detection coils in close proximity without electronic interference, a placement that previously required a spacer between adjacent coils. The detector used in the earlier research required a 16-in spacer between two adjacent 8- by 24-in detection tunnels. By utilizing a 3-pipe bundle of detector coils and multiplex technology, we expected the overall dimension of the new detector to be about 20-in diameter, and if a single coil per pipe were installed, perhaps as short as 6 in. However, before constructing such a detector, we tested fish passage through mockups. We also obtained more powerful towing vessels for the trawl than were previously available, which gave us greater flexibility in towing speed and faster deployment/retrieval of the pair trawl and detector equipment.

Three mockups were constructed: one of 1-ft lengths of white polyvinyl chloride (PVC) pipe using 8-, 10-, and 12-in-diameter pipe; a second of clear plastic pipe (8-in diameter only); and a third of 10-in-diameter clear cast acrylic pipe (8-in length). Three sections of pipe were bundled together. No webbing or other material was added to prevent fish passing between or around the interstices of the bundled pipes, as would be the case with a real detector. Detector tunnels constructed using 10-in-diameter or smaller pipes theoretically provide greater than 90% detection (reading) efficiency utilizing a single antenna coil, whereas tunnels greater than 10-in diameter required two coils per tunnel to attain 90% reading efficiency. Our goal for the mockup was to achieve rapid fish passage through a tunnel of the largest possible diameter that would allow 90% percent reading efficiency with a single antenna coil per tunnel (shortest length).

The cod-end section of the pair-trawl used in 1996 was modified by adding additional Nitex webbing (1,600-µ mesh) to taper the cod-end down to the dimension of the test mockups. A sea anchor (3-ft-diameter opening) was attached to the rear of the mockup to keep the cod-end webbing taut. The trawl with an attached mockup was deployed in the river and divers observed fish passage.

Results

Inriver tests were limited to mockups made using 8- and 10-in-diameter pipes. We achieved acceptable fish passage with these mockups, so declined to test 12-in pipes because they would have required a total of six antenna coils and a longer overall length. Tests with the 10-in-diameter cast acrylic pipe mockup were satisfactory.

At a 1,200-rpm tow speed, fish were observed passing through the mockup only when the trawl wings were closed in a "flush" configuration, similar to results using the original detector in 1996 research. However, at a 1,400-rpm tow speed, fish passage appeared to be steady with the net open in a fishing configuration. Similar results were obtained using mockups constructed of 8-in-diameter pipes, but debris accumulation was worse using these pipes, so we recommend using 10-in-diameter pipes for construction of future 400-kHz detectors.

APPENDIX B

PIT-tag detection data at Jones Beach, 1998

Appendix Table B1. Daily PIT-tag detections for each salmonid species at Jones Beach, 1998.

Detection date	Chinook salmon	Coho salmon	Steelhead	Sockeye salmon	Unknown
20 April	5	0	0	0	0
21 April	2	0	0	0	0
22 April	13	0	0	0	0
23 April	11	0	1	0	0
24 April	10	0	0	0	1
25 April	5	0	0	0	1
27 April	35	0	0	0	2
28 April	47	0	2	0	0
29 April	63	0	2	0	1
30 April	25	0	1	0	0
1 May	55	0	1	0	0
2 May	44	0	0	0	2
3 May	41	1	2	0	0
4 May	128	2	6	0	0
5 May	114	2	4	0	2
6 May	105	3	4	0	1
7 May	120	3	11	0	1
8 May	242	18	12	2	4
9 May	515	42	46	1	3
10 May	187	24	24	5	5
11 May	363	55	36	2	3
12 May	351	32	94	4	8
13 May	164	7	14	5	2
14 May	243	16	64	3	1
15 May	104	0	9	2	3
16 May	197	22	54	3	2
17 May	50	7	15	2	1
18 May	70	13	22	3	3
19 May	79	14	22	1	1
20 May	75	10	21	3	1
21 May	101	7	16	3	0
22 May	84	4	18	3	3
23 May	61	14	9	2	2
26 May	5	5	2	4	0
27 May	23	18	16	0	0
28 May	35	17	20	10	1
29 May	14	12	3	3	0
1 June	3	8	5	2	0
3 June	5	0	1	1	0
4 June	0	0	1	0	0
5 June	9	3	0	2	4
Totals	3,803	359	558	66	58

Appendix Table B2. Diel sampling of juvenile spring/summer chinook salmon using a PIT-tag detector/trawl at Jones Beach, Columbia River Kilometer 75, 1998.

Period 1: 8-9 May				Period 2: 14-15 May			
Hour	Effort (decimal hour)	n	n/hour	Hour	Effort (decimal hour)	n	n/hour
0	1.00	27	27.0	0	1.00	12	12.0
1	1.00	30	30.0	1	1.00	14	14.0
2	0.88	16	18.1	2	1.00	14	14.0
3	1.00	8	8.0	3	1.00	18	18.0
4	0.83	15	18.0	4	0.80	8	10.0
5	1.00	22	22.0	5	2.00	17	8.5
6	0.75	44	58.7	6	1.45	47	32.4
7	1.68	45	26.7	7	1.92	26	13.6
8	2.00	44	22.0	8	1.28	19	14.8
9	1.47	44	30.0	9	2.00	22	11.0
10	0.47	42	90.0	10	1.23	29	23.5
11	0.78	0	0.0	11	1.00	5	5.0
12	1.00	11	11.0	12	0.80	13	16.3
13	0.80	24	30.0	13	0.82	18	22.0
14	0.78	15	19.2	14	0.00	-	-
15	1.00	13	13.0	15	0.00	-	-
16	1.00	3	3.0	16	0.00	-	-
17	1.53	29	18.9	17	0.37	3	8.2
18	2.00	74	37.0	18	1.00	9	9.0
19	2.00	59	29.5	19	1.70	19	11.2
20	2.00	54	27.0	20	2.00	12	6.0
21	2.00	96	48.0	21	2.00	10	5.0
22	1.30	14	10.8	22	1.10	17	15.5
23	1.00	14	14.0	23	1.00	11	11.0

Appendix Table B2. Continued.

Period 3: 21-22 May				Average for all 3 Periods			
Hour	Effort (decimal hour)	n	n/hr	Hour	Effort (decimal hour)	n	n/hr
0	1.00	1	1.0	0	3.00	40	13.3
1	1.00	1	1.0	1	3.00	45	15.0
2	1.00	2	2.0	2	2.88	32	11.1
3	0.00	-	-	3	2.00	26	13.0
4	0.00	-	-	4	1.63	23	14.1
5	0.20	0	0.0	5	3.20	39	12.2
6	1.55	13	8.4	6	3.75	104	27.7
7	1.92	12	6.3	7	5.52	83	15.1
8	2.00	26	13.0	8	5.28	89	16.9
9	2.00	7	3.5	9	5.47	73	13.4
10	0.97	5	5.2	10	2.67	76	28.5
11	1.17	14	12.0	11	2.95	19	6.4
12	0.82	17	20.8	12	2.62	41	15.7
13	1.00	11	11.0	13	2.62	53	20.3
14	0.50	2	4.0	14	1.28	17	13.3
15	0.00	-	-	15	1.00	13	13.0
16	0.43	0	0.0	16	1.43	3	2.1
17	1.00	2	2.0	17	2.90	34	11.7
18	1.92	8	4.2	18	4.92	91	18.5
19	1.97	37	18.8	19	5.67	114	20.1
20	1.33	6	4.5	20	5.33	72	13.5
21	1.02	12	11.8	21	5.02	118	23.5
22	1.00	7	7.0	22	3.40	38	11.2
23	1.00	0	0.0	23	3.00	25	8.3

Appendix Table B3. Diel sampling of juvenile steelhead using a PIT-tag detector/trawl at Jones Beach, Columbia River Kilometer 75, 1998.

Period 1: 8-9 May				Period 2: 14-15 May			
Hour	Effort (decimal hour)	n	n/hr	Hour	Effort (decimal hour)	n	n/hr
0	1.00	0	0.0	0	1.00	0	0.0
1	1.00	0	0.0	1	1.00	2	2.0
2	0.88	1	1.1	2	1.00	0	0.0
3	1.00	0	0.0	3	1.00	0	0.0
4	0.83	0	0.0	4	0.80	0	0.0
5	1.00	0	0.0	5	2.00	1	0.5
6	0.75	3	4.0	6	1.45	2	1.4
7	1.68	4	2.4	7	1.92	5	2.6
8	2.00	7	3.5	8	1.28	4	3.1
9	1.47	3	2.1	9	2.00	9	4.5
10	0.47	7	15.0	10	1.23	14	11.4
11	0.78	0	0.0	11	1.00	3	3.0
12	1.00	2	2.0	12	0.80	3	3.8
13	0.80	1	1.3	13	0.82	10	12.2
14	0.78	0	0.0	14	0.00	-	-
15	1.00	3	3.0	15	0.00	-	-
16	1.00	1	1.0	16	0.00	-	-
17	1.53	6	3.9	17	0.37	1	2.7
18	2.00	4	2.0	18	1.00	3	3.0
19	2.00	4	2.0	19	1.70	10	5.9
20	2.00	2	1.0	20	2.00	2	1.0
21	2.00	9	4.5	21	2.00	0	0.0
22	1.30	0	0.0	22	1.10	1	0.9
23	1.00	0	0.0	23	1.00	1	1.0

Appendix Table B3. Continued.

Period 3: 21-22 May				Average for all 3 Periods			
Hour	Effort (decimal hour)	n	n/hr	Hour	Effort (decimal hour)	n	n/hr
0	1.00	1	1.0	0	3.00	1	0.3
1	1.00	0	0.0	1	3.00	2	0.7
2	1.00	0	0.0	2	2.88	1	0.4
3	0.00	-	-	3	2.00	0	0.0
4	0.00	-	-	4	1.63	0	0.0
5	0.20	0	0.0	5	3.20	1	0.3
6	1.55	1	0.7	6	3.75	6	1.6
7	1.92	0	0.0	7	5.52	9	1.6
8	2.00	11	5.5	8	5.28	22	4.2
9	2.00	5	2.5	9	5.47	17	3.1
10	0.97	2	2.1	10	2.67	23	8.6
11	1.17	1	0.9	11	2.95	4	1.4
12	0.82	0	0.0	12	2.62	5	1.9
13	1.00	1	1.0	13	2.62	12	4.6
14	0.50	0	0.0	14	1.28	0	0.0
15	0.00	-	-	15	1.00	3	3.0
16	0.43	0	0.0	16	1.43	1	0.7
17	1.00	1	1.0	17	2.90	8	2.8
18	1.92	3	1.6	18	4.92	10	2.0
19	1.97	2	1.0	19	5.67	16	2.8
20	1.33	1	0.8	20	5.33	5	0.9
21	1.02	2	2.0	21	5.02	11	2.2
22	1.00	2	2.0	22	3.40	3	0.9
23	1.00	0	0.0	23	3.00	1	0.3

Appendix Table B4. Daily releases and Jones Beach detection percentages for juvenile spring\summer chinook salmon from the Snake River Transportation study, 1998. Release dates and times for transported fish adjusted to reflect the times that the fish were liberated from the transportation barges.

A. Released downstream from Lower Granite Dam for inriver migration.

	Hatchery		Wild	
Release date/time	Release (no.)	Recovery (%)	Release (no.)	Recovery (%)
7 April/06:00	351	1.425	329	1.520
8 April/06:00	69	2.899	53	0.000
9 April/09:00	210	2.381	239	0.418
10 April/07:00	530	1.509	262	2.290
11 April/06:00	1858	1.453	532	3.008
12 April/06:00	1524	1.575	411	2.190
13 April/06:00	2018	1.041	457	1.094
14 April/06:00	1199	1.251	267	1.873
15 April/06:00	3500	1.343	617	1.783
16 April/06:00	1841	1.358	465	1.720
17 April/06:00	1278	0.782	200	0.500
18 April/06:00	1949	1.591	283	2.473
19 April/06:00	1330	1.353	253	0.395
20 April/06:00	3733	1.527	433	0.924
21 April/06:00	1469	1.225	203	0.985
22 April/06:00	1903	1.156	274	0.730
23 April/06:00	4265	1.688	623	1.284
24 April/06:00	3962	1.742	499	1.403
25 April/06:00	1801	1.222	178	3.933
26 April/06:00	2860	1.503	303	1.320
27 April/06:00	1277	1.253	137	0.730
28 April/06:00	1207	1.574	76	5.263
29 April/06:00	3077	0.942	231	0.433
30 April/06:00	1665	0.841	104	0.000
1 May/00:00	1522	0.920	123	0.000
2 May/06:00	2328	1.160	287	0.697
3 May/06:00	852	0.822	107	2.804
5 May/06:00	391	1.790	54	0.000
6 May/06:00	1243	1.046	187	1.604
7 May/06:00	2244	0.758	281	0.356
8 May/06:00	891	0.224	126	0.000
9 May/06:00	1135	0.176	107	0.935
10 May/06:00	1344	0.298	207	0.966
12 May/06:00	1052	0.475	195	0.513
13 May/00:00	164	0.000	16	0.000
14 May/06:00	619	0.323	51	0.000
15 May/06:00	598	0.167	71	0.000
Totals/mean	59,259	1.157	9,241	1.193

Appendix Table B4. Continued.

B. Transported from Lower Granite Dam and released downstream from Bonneville Dam.				
	Hatchery		Wild	
Release date/time	Release (no.)	Recovery (%)	Release (no.)	Recovery (%)
11 April/00:20	201	0.000	99	0.000
12 April/20:00	1586	0.063	584	0.000
14 April/19:15	2097	0.048	668	0.749
16 April/20:00	2586	0.309	513	0.780
18 April/19:15	2374	0.211	501	0.200
20 April/19:25	2195	0.228	341	0.293
22 April/19:25	2826	0.035	564	0.177
24 April/20:05	4387	0.433	595	0.840
26 April/19:00	3352	0.835	324	3.395
28 April/06:20	124	0.806	10	0.000
29 April/00:30	2133	0.469	174	1.149
29 April/19:15	877	0.456	69	0.000
30 April/19:20	1855	1.240	124	3.226
2 May/01:45	1045	2.392	73	1.370
2 May/21:10	983	1.628	58	0.000
4 May/22:40	1679	0.834	318	1.258
6 May/23:45	477	2.096	60	1.667
7 May/20:55	851	2.233	83	1.205
8 May/19:15	1342	0.820	104	1.923
10 May/01:15	805	1.615	107	1.869
11 May/07:15	1034	1.838	129	0.000
11 May/19:20	656	1.067	116	1.724
13 May/19:45	700	0.143	88	0.000
14 May/20:45	189	0.000	29	0.000
15 May/20:10	469	0.426	83	0.000
16 May/15:25	517	0.387	48	2.083
17 May/23:45	129	0.775	30	3.333
20 May/14:30	46	2.174	16	0.000
21 May/22:30	38	0.000	6	0.000
23 May/19:15	340	0.000	56	0.000
24 May/15:30	78	0.000	39	2.564
Totals/mean	37,971	0.760	6,009	0.961

Appendix Table B5. Corrections to the PTAGIS[a] release information for Snake River transportation study fish placed on transportation barges at Lower Granite Dam, 1998.

Barge number	PTAGIS[a] load date[b]	PTAGIS load time	Barge release date[c]	Barge release time	RKm[b]
8107	9 April	6:00	11 April	00:20	227
8106	11 April	9:00	12 April	20:00	225
8105	13 April	6:00	14 April	19:15	224
8105	13 April	9:00	14 April	19:15	224
4394	15 April	6:00	16 April	20:00	225
4394	15 April	9:00	16 April	20:00	225
8106	17 April	9:00	18 April	19:15	227
8107	19 April	6:00	20 April	19:25	227
8107	19 April	9:00	20 April	19:25	227
8105	21 April	6:00	22 April	19:25	227
8106	23 April	6:00	24 April	20:05	227
8105	25 April	6:00	26 April	19:00	227
8105	25 April	9:00	26 April	19:00	227
4382	26 April	6:00	28 April	06:20	227
2817	26 April	9:00	28 April	06:20	227
8106	27 April	6:00	29 April	00:30	225
2127	27 April	9:00	29 April	00:30	225
8107	28 April	9:00	29 April	19:15	225
8105	29 April	9:00	30 April	19:20	227
4382	30 April	6:00	2 May	01:45	222
4394	30 April	9:00	2 May	01:45	222
8106	1 May	6:00	2 May	21:10	225
2127	1 May	6:00	2 May	21:10	225
8107	1 May	9:00	3 May	19:35	222
8105	2 May	9:00	4 May	22:40	222
2817	3 May	9:00	4 May	22:40	222
4394	4 May	6:00	5 May	22:25	222
4382	4 May	9:00	5 May	22:25	222
8106	5 May	6:00	6 May	23:45	224
2127	5 May	9:00	6 May	23:45	224
8107	6 May	6:00	7 May	20:55	223
2817	6 May	9:00	7 May	20:55	223
8105	7 May	09:00	8 May	19:15	227
4394	8 May	06:00	10 May	01:15	224

Appendix Table B5. Continued.

Barge number	PTAGIS[a] load date[b]	PTAGIS load time	Barge release date[c]	Barge release time	RKm[b]
4382	8 May	09:00	10 May	01:15	224
8106	9 May	06:00	11 May	07:15	224
2127	9 May	09:00	11 May	07:15	224
8107	10 May	06:00	11 May	19:10	222
2817	10 May	09:00	11 May	19:20	222
8105	11 May	06:00	12 May	18:45	227
4382	12 May	06:00	13 May	19:45	222
4394	12 May	09:00	13 May	19:45	222
8106	13 May	06:00	14 May	20:45	225
2127	13 May	09:00	14 May	20:45	225
8107	14 May	06:00	15 May	20:10	224
2817	14 May	09:00	15 May	20:10	224
8105	15 May	09:00	16 May	15:25	226
4382	16 May	06:00	17 May	23:45	224
4394	16 May	09:00	17 May	23:45	224
8106	17 May	06:00	18 May	20:45	225
2127	17 May	09:00	18 May	20:45	225
8107	18 May	06:00	19 May	16:00	224
2817	18 May	09:00	19 May	16:00	224
8105	19 May	09:00	20 May	14:30	227
4394	20 May	06:00	21 May	22:30	224
4382	20 May	09:00	21 May	22:30	224
8107	22 May	06:00	23 May	19:15	222
2187	22 May	09:00	23 May	19:15	222
8106	23 May	09:00	24 May	15:30	224
8105	25 May	06:00	26 May	23:15	225
4382	25 May	09:00	26 May	23:15	225
8107	27 May	06:00	28 May	17:00	224
8106	29 May	06:00	30 May	16:05	222
8107	31 May	06:00	1 June	16:15	222
8106	2 June	06:00	3 June	17:40	222
8107	4 June	06:00	5 June	23:40	225
8106	6 June	06:00	8 June	00:40	225

[a] Passive Integrated Transponder Tag Information System (PTAGIS 1996) regional database.

[b] Date and time that the barge was loaded at Lower Granite Dam. This corresponds to the PTAGIS release date and time that reflects when the fish (PIT-tagged fish having PTAGIS release site code LGRRBR) were tagged and placed in holding raceway ponds prior to barge loading.

[c] Corrected release date reflecting when the barge was emptied downstream from Bonneville Dam.

[d] River kilometer (RKm) where the barge was emptied downstream from Bonneville Dam.