Detection of PIT-Tagged Juvenile Salmonids in the Columbia River Estuary using Pair-Trawls, 2002

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EXECUTIVE SUMMARY

In 2002, we continued a study to detect juvenile anadromous salmonids *Oncorhynchus* spp. implanted with passive integrated transponder (PIT) tags using a large surface pair-trawl fitted with a PIT-tag detection antenna. In the Columbia River estuary at Jones Beach (river kilometer 75), we sampled for 693 h between 15 April and 31 July and detected 11,451 PIT-tagged juvenile salmonids of various species, runs, and rearing types. Not all stocks and rearing types were equally represented in the annual detection totals. For example, 16% of the detections were wild fish, with the remainder hatchery reared: 89% were Chinook salmon, 9% were steelhead, and the remaining 2% were other salmonid species.

During the spring migration period, the principal target fish (yearling migrants) were 545,028 PIT-tagged spring/summer Chinook salmon and 144,358 PIT-tagged steelhead released into the Snake River. Some of these fish migrated in-river to the estuary, and others were diverted to transportation barges at Lower Granite Dam or at other downstream collector dams; transported fish were then released in the Columbia River about 9 km downstream from Bonneville Dam. For the first time, we extended sampling into the summer migration period, targeting the more than 350,000 PIT-tagged subyearling fall Chinook salmon released into the Snake and upper Columbia Rivers for in-river migration or transportation from collector dams.

There were no major changes to the detection equipment or net design in 2002. We used the same antenna developed in 2001, and the trawl was also the same as used in previous years.

We increased sampling effort from single to double daily crews on 30 April, coincident with arrival to the estuary of in-river migrating yearling Chinook salmon and steelhead from the Snake River releases. We continued with the double crew until 9 June, when we reduced back to a single-daily crew. The exception to this schedule occurred on Mondays and Fridays when only single crews were used. Between 30 April and 9 June, we averaged 11.7 h daily of detector "on" time and detected 1.8% of all Chinook salmon and 2.3% of all steelhead previously detected at Bonneville Dam. These rates were a rough measure of sampling efficiency with the trawl.

Of the fish detected, 27% had been transported and released downstream from Bonneville Dam, 10% had been previously detected in the bypass system at Bonneville Dam, and the remaining 64% had not been transported or detected at Bonneville Dam.

These percentages were similar to the proportions of the various migration histories observed in previous years. Of our detections, 55% had been released in the Snake River, 41% in the upper Columbia River, and 4% downstream from McNary Dam. Only 16 non-transported PIT-tagged fish detected in the estuary had been released from sites downstream from Bonneville Dam.

During the peak of the spring migration period, we conducted weekly diel sampling sessions, with an average of 34.6 h of nearly continuous sampling per session. During these sessions we detected a total of 3,733 yearling Chinook salmon (299 wild) and 322 steelhead (226 wild). As in previous years, we had slightly higher detection rates for Chinook salmon during darkness than during daylight, while the opposite was true for steelhead (i.e., higher detection rates occurred during daylight than dark).

Daily average travel speed from Bonneville Dam to Jones Beach was significantly faster for in-river migrant yearling Chinook salmon (88 km/day) than those released from barges (72 km/day), but the difference for steelhead was not significant (94 and 92 km/day, respectively). In a cursory comparison between PIT-tagged and radio-tagged steelhead, we found no obvious differences in travel speed to the estuary for either transported or inriver migrant groups.

In 2001, we initiated development of a PIT-tag detection trawl for use in salt or brackish water. Electronic and net modifications were required. The goal was to deploy a smaller surface pair-trawl system in lower areas of the estuary, which are inaccessible to the large trawl system. A small, rapidly deployable, mobile PIT-tag detection system also has application in smaller rivers, high volume bypass channels, and other areas of the Columbia River or Pacific Ocean.

In 2002 we deployed the small trawl in the lower estuary. The trawl was 3.6 m square at its entrance and 9.1 m in length. Fish exited the trawl through a single PIT-tag detection antenna coil positioned 1.8 m beneath the surface. A floor of 1.8-cm stretch-measure webbing extended forward 3-m between the wings, and the wings extended 4.8 m forward along each side and then transitioned to 33-cm mesh for an additional 15 m.

Under tow, we maintained a distance of about 23 m between the wings, which resulted in an effective sample depth of about 3.3 m (measured at the center of the floor). The trawl was towed using a pair of 8-m long vessels. The antenna weighed about 700 kg in air, including ballast, with a fish passage opening 32 cm long, 81 cm wide, and 30 cm tall. A PIT-tag transceiver (Destron/Fearing model FS-1001A) was mounted on a pontoon barge towed at the rear of the trawl. Cables led from the underwater antenna to the barge, where a wireless modem transmitted PIT-tag detections and electronic status reports from the transceiver to a recording computer in the cabin of a tow vessel.

The small-trawl system was deployed early in the migration season and again at the end of the season, and was positioned directly in front of the large trawl at Jones Beach (146 h of "on" time, 90 total detections). A total of 6 PIT-tagged fish were recorded by both detection systems, and there was little indication of delay within the large trawl (median passage time from the small to the large trawl was 19 min). When numbers of PIT-tag detections increased in the upper estuary, we moved the small trawl system downstream to brackish water (rkm 0 to 35; 118 h of "on" time, 76 detections). No major problems with entanglements of bait fish or salmonids were encountered in the lower estuary. Three of the fish detected in brackish water had been previously detected in the large trawl upstream at Jones Beach. Travel times of the three detected fish between the two detection sites were 16, 29, and 41 h, and timing between sites corresponded to the number of flood tides encountered following detection at Jones Beach (1, 2, and 3 flood tides respectively).

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INTRODUCTION

In 2002, we continued a study to detect juvenile anadromous salmonids *Oncorhynchus* spp. implanted with passive integrated transponder (PIT) tags using a large surface pair-trawl fitted with a PIT-tag detection antenna (Ledgerwood et al. 2005). The study began in 1995 and has continued annually (except 1997) in the estuary at Jones Beach, approximately 75 km upstream from the mouth of the Columbia River (Ledgerwood et al. 1997, 2000, 2003, 2004). In 2002, we also used a small pair-trawl system to detect PIT-tagged juvenile salmonids in the brackish-water portions of the lower estuary (Ledgerwood et al. 2004) which allowed sampling in areas inaccessible to the larger freshwater surface-trawl detection system used upstream.

Over 1.7 million PIT-tagged juvenile salmonids were released into the Columbia River Basin in 2002. These fish were monitored during downstream migration using detectors installed by the National Marine Fisheries Service (NMFS) and the U.S. Army Corps of Engineers (USACE) at various hydroelectric facilities throughout the basin (Prentice et al. 1990a,b,c). The Columbia Basin PIT Tag Information Systems (PTAGIS) database was used to store and disseminate release and detection times and locations, as well as species, origin, and migration history of individual PIT-tagged fish (PSMFC 2002).

In addition to bypassing fish at dams, fishery managers have an option to transport and release fish downstream from Bonneville Dam, the lowermost dam in the Columbia River Basin at river kilometer (rkm) 234. In 2002, nearly 200,000 PIT-tagged fish were transported. The goal of our trawling efforts in the estuary was to monitor timing and survival of PIT-tagged fish that have migrated in-river through the hydro-power system to the estuary or have been transported by truck or barge around various dams for release downstream from Bonneville Dam.

Detection data from pair-trawl sampling was collected with the following objectives:

1) Compare migrational timing and relative survival to the estuary between in-river migrant and transported juvenile yearling Chinook salmon *O. tshawytscha* and steelhead *O. mykiss* during the spring migration period.

2) Assess migrational timing to the estuary for fish detected at Bonneville Dam and contribute data to estimates of passage-route survival.

3) Estimate in-river survival from McNary and Lower Granite Dams to Bonneville Dam for major groups of yearling salmonids.

4) Compare migrational timing between radio-tagged and PIT-tagged juvenile salmonids.

5) Compare migrational timing to the estuary between in-river migrant and transported subyearling fall Chinook salmon during late June through July.

6) Compare migrational timing of individual salmonids between the upper and lower estuary using a small trawl PIT-tag detection system designed to tolerate the brackish water in the lower estuary.

METHODS

Study Fish

In 2002, we continued to focus research on detecting large groups of PIT-tagged fish migrating through the upper Columbia River estuary near Jones Beach (rkm 75) from April through June. These groups included about 88,000 wild PIT-tagged fish released for a transportation study on the Snake River (Marsh et al. 1996, 1997, 1998, 2000, 2003) and about 200,000 PIT-tagged fish released for a comparative survival study (Berggren and Basham 2000; Berggren et al. 2003). Fish from other major and minor PIT-tagging studies were detected coincidentally as well.

These releases provided large groups of PIT-tagged migrants with known release locations and times that could be coordinated with trawl system operations. After tagging, transportation study fish were released either into the Snake River downstream from Lower Granite Dam (rkm 695) to continue their migration past the remaining dams or transported and released downstream from Bonneville Dam. In addition, some PIT-tagged in-river migrant fish were diverted to transportation barges at dams further downstream: Little Goose Dam, rkm 635; Lower Monumental Dam, rkm 589; and McNary Dam, rkm 470.

We included in our analysis of transportation all PIT-tagged fish diverted to barges, even hatchery fish and other tagged fish not specifically released for the transportation study at Lower Granite Dam. We created a database of detection records from PTAGIS for fish that were recorded as having been diverted to transportation barges. Intentional diversions were accomplished according to a separation-by-code procedure at specific dams (Stein et al. 2001). Diversion to transportation barges both intentionally and unintentionally (i.e., missed being diverted back to the river at slide gates) was confirmed by comparing the last monitor name on the PTAGIS site map listed for a PIT-tagged fish with the route ending at a transport raceway or barge.

Since 1987, over 1.5-million PIT-tagged fish have been assigned to this database of transported fish. We worked with the USACE (Paul Oaker, USACE, personal communication) to obtain accurate barge loading dates and times that enabled us to assign PIT-tagged fish to specific transport barges based on matching the last detection date and time with the next available barge at that facility.

In addition to the Snake River transportation study, there were several other studies in the Columbia River Basin that released large numbers of spring-migrating, PIT-tagged salmonids. In this report, we focus our analyses on the more numerous PIT-tagged yearling spring/summer Chinook salmon and juvenile steelhead; however, detections of PIT-tagged coho salmon (*O. kisutch*), sockeye salmon (*O. nerka*) and subyearling fall Chinook salmon were also considered.

Study Sites for Large and Small Trawls

We conducted large-trawl operations from Eagle Cliff, near rkm 83, to the west end of Puget Island, near rkm 61 (Figure 1). This is a freshwater reach characterized by frequent ship traffic, occasional severe weather, and river currents often exceeding 1.5 m s^{-1}. Tides in this area are semi-diurnal with about 7 h of ebb and 4.5 h of flood. During the spring freshet period (April-June), little or no flow reversal occurred at the study site during flood tides, particularly during years of medium to high river flow. The net was deployed adjacent to a 200-m-wide navigation channel which is maintained at a depth of 14 m.

In 1988, during net testing activities with the large trawl near rkm 10 (Ledgerwood unpublished data), it became apparent that sampling in the lower estuary would only be possible using a smaller trawl. Deployment and retrieval operations for the large trawl required ample space, which is not usually available in the lower estuary. Currents are stronger in the lower estuary than in the areas upstream sampled with the large trawl system (near Jones Beach, rkm75). Lower estuary currents often exceed 2 m · s^{-1} (4 knots) and are bi-directional, with strong daily ebb and flood tides. There are few, if any, unobstructed areas that would allow for the undirected drift of vessels required for deployment and retrieval of our large-trawl system.

Initial testing of a net and associated electronics for a smaller trawl system designed for brackish water began in 2001, with the goal of sampling PIT-tagged fish in areas that were inaccessible to the large vessel trawl (Ledgerwood et al. 2004). In 2002, we deployed the small trawl system in the brackish water region of the estuary during May. Generally, we concentrated sampling from the river mouth to an area near the Astoria-Megler Bridge (rkm 0 to 25; Figure 2). However, during a few strong flood tides, we sampled as far upstream as rkm 35. In addition, on a few dates at Jones Beach, we deployed the small trawl directly upstream from the large trawl to evaluate delay for river-run PIT-tagged fish between the two trawl systems.

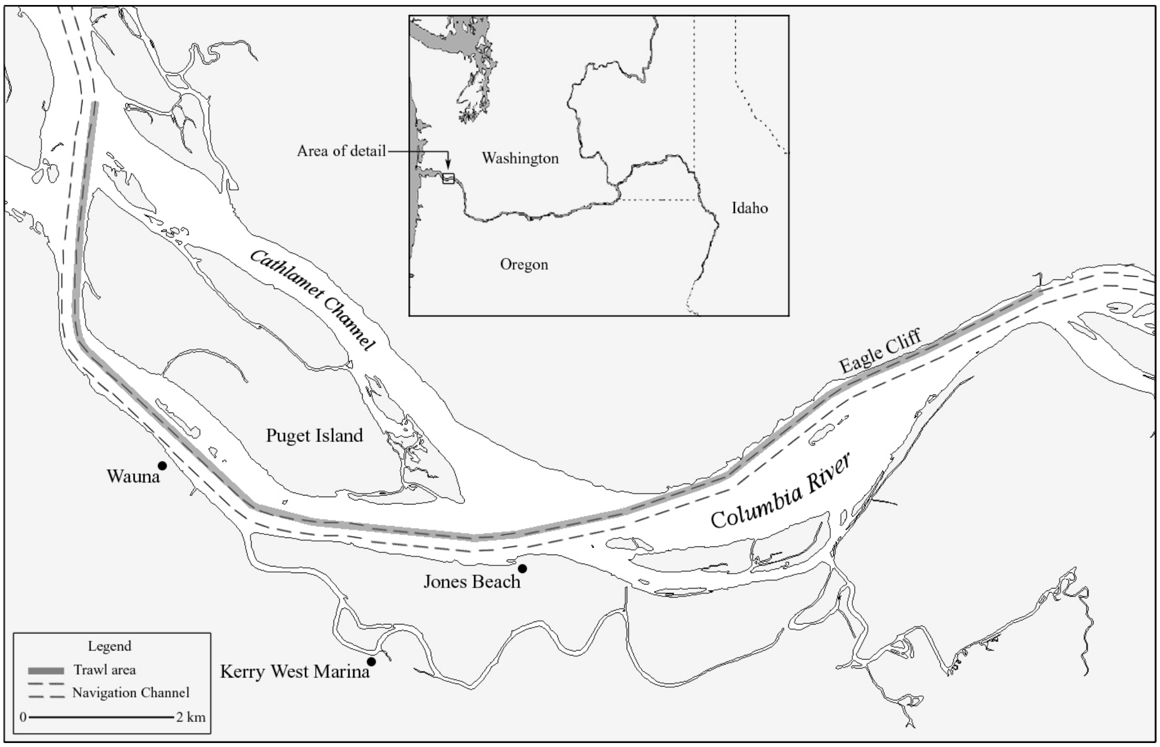


Figure 1. Trawling area adjacent to the ship navigation channel in the upper Columbia River estuary near Jones Beach at Columbia River kilometer 75.

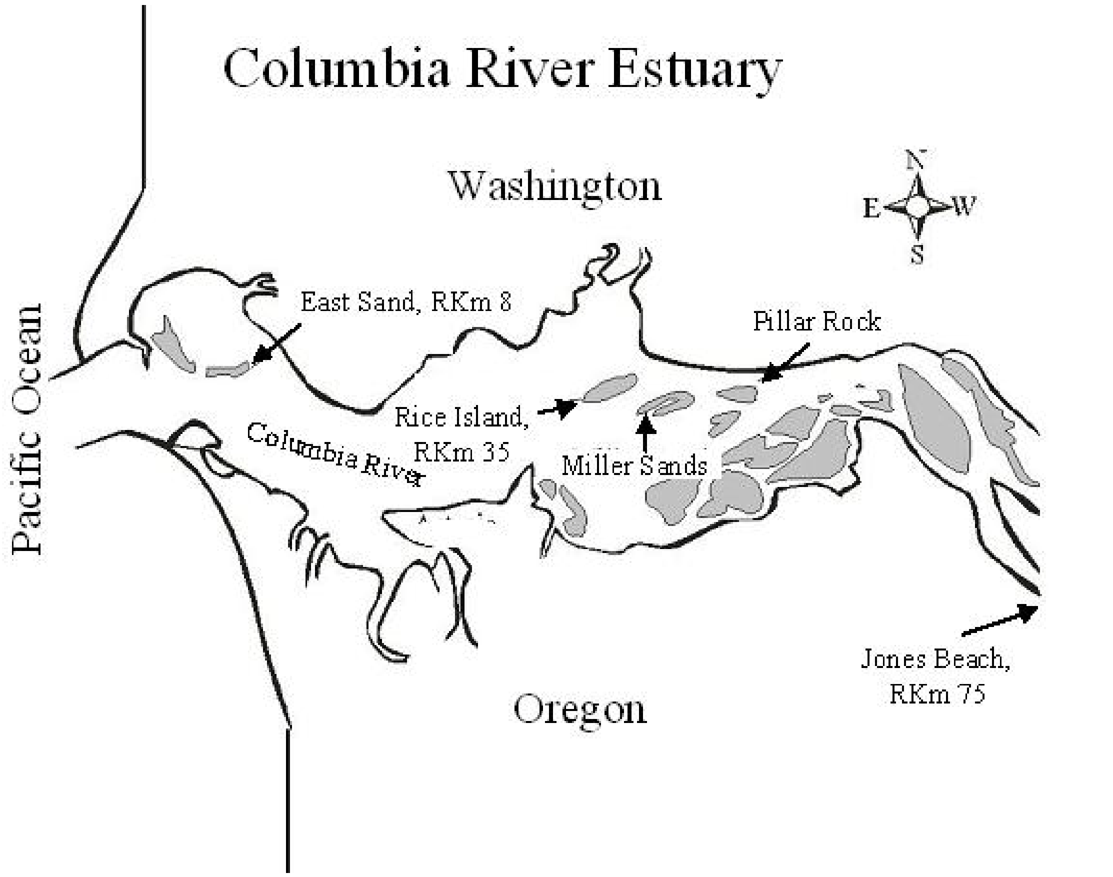


Figure 2. Trawling area for small trawl in the lower estuary in 2002.

Trawl and System Designs

The large-trawl components are described below, and their basic configuration remained fairly constant through the study period (Ledgerwood et al. 2005; Figure 3). To prevent turbulence on the net from the tow vessels, 73-m-long tow lines were used. The upstream end of each wing of the trawl initiated with a 3-m-long spreader bar, which was shackled to the wing section. The end of each wing was attached to the 14-m-long trawl body, for a total length of 105.5 m along each side of the trawl. The mouth of the trawl body opened between the wings and from the surface to a depth of 6.1 m; a floor extended 4.6 m forward from the mouth.

The detection antenna was centered at a depth of 1.8 m, and the trawl wings tapered upward from a sample depth of 6.1 m at the floor of the trawl body to 3 m at the tow bridle. However, drag on the trawl body when under tow tended to align the net components to the same depth, raising the trawl floor and causing curvature of the wing walls. This reduced the sample depth in earlier years to 3.5 m. To compensate for the lift and curvature, we attached an additional lead line to the perimeter of the trawl. Beginning in 2000, adaptation of a detector antenna suitable for 134.2-kHz PIT-tags allowed for a larger opening through the antenna and further reduced drag and lift, thus increasing sample depth of the trawl to 4.6 m.

During a typical deployment of the large trawl, the net is towed upstream facing into the current, with a distance of about 91 m between the wings of the trawl. Fish that enter between the wings are guided to the trawl body and exit through the antenna where the cod end is normally located. During net retrieval, the antenna is removed and then the net is inverted in the current to flush debris and release fish from between the small-mesh wings. The deployment/retrieval process of the large trawl requires about 30 min, during which time the vessels and net are adrift in tidal and river currents often exceeding 1.5 $m \cdot s^{-1}$ (3 knots).

The design of the small trawl was based upon the large surface pair trawl, but there were some basic changes required to allow for safe operation in the high-current and confined areas of the lower estuary (Figure 4). We initially deployed and tested the equipment in July 2001 near Chinook, WA (rkm 10), where adequate net handling procedures and electronic components were developed (Ledgerwood et al. 2004).

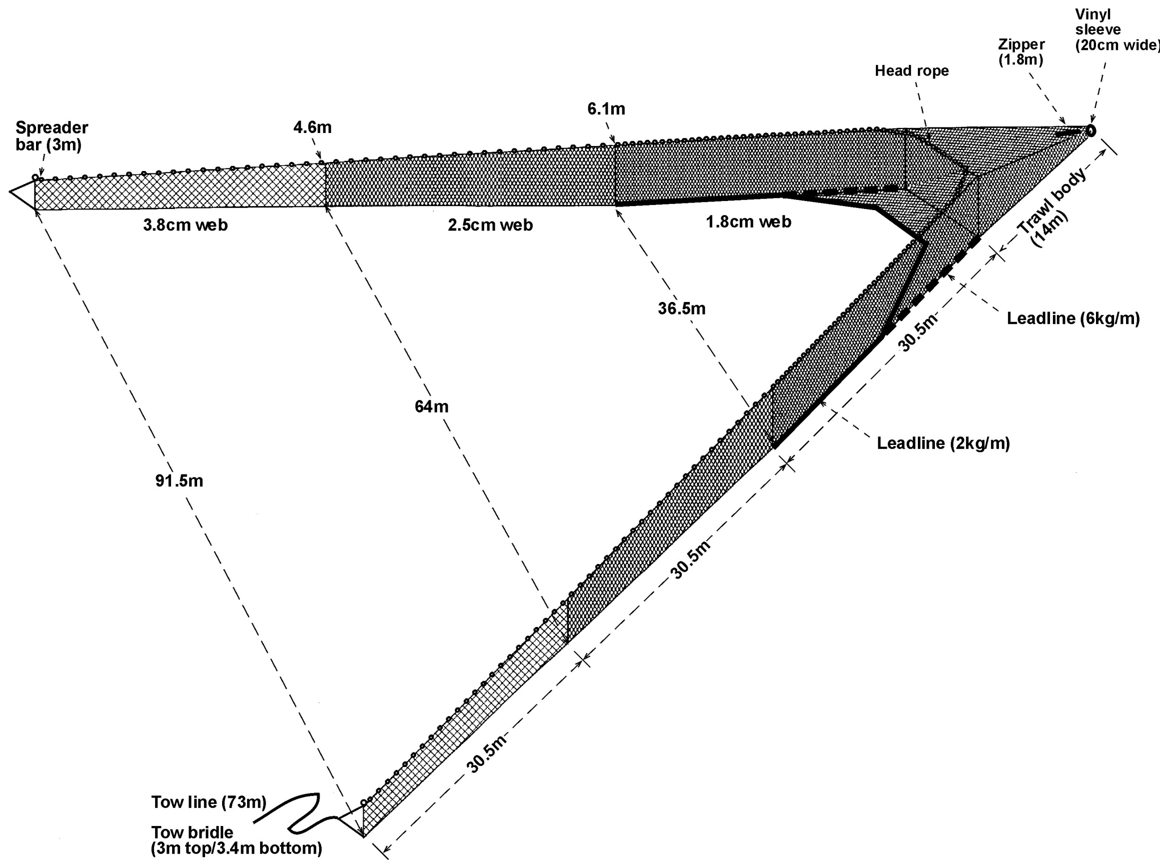


Figure 3. Basic design of the large surface pair trawl used in 2002 to sample PIT-tagged juvenile salmonids in the Columbia River estuary at Jones Beach, rkm 75.

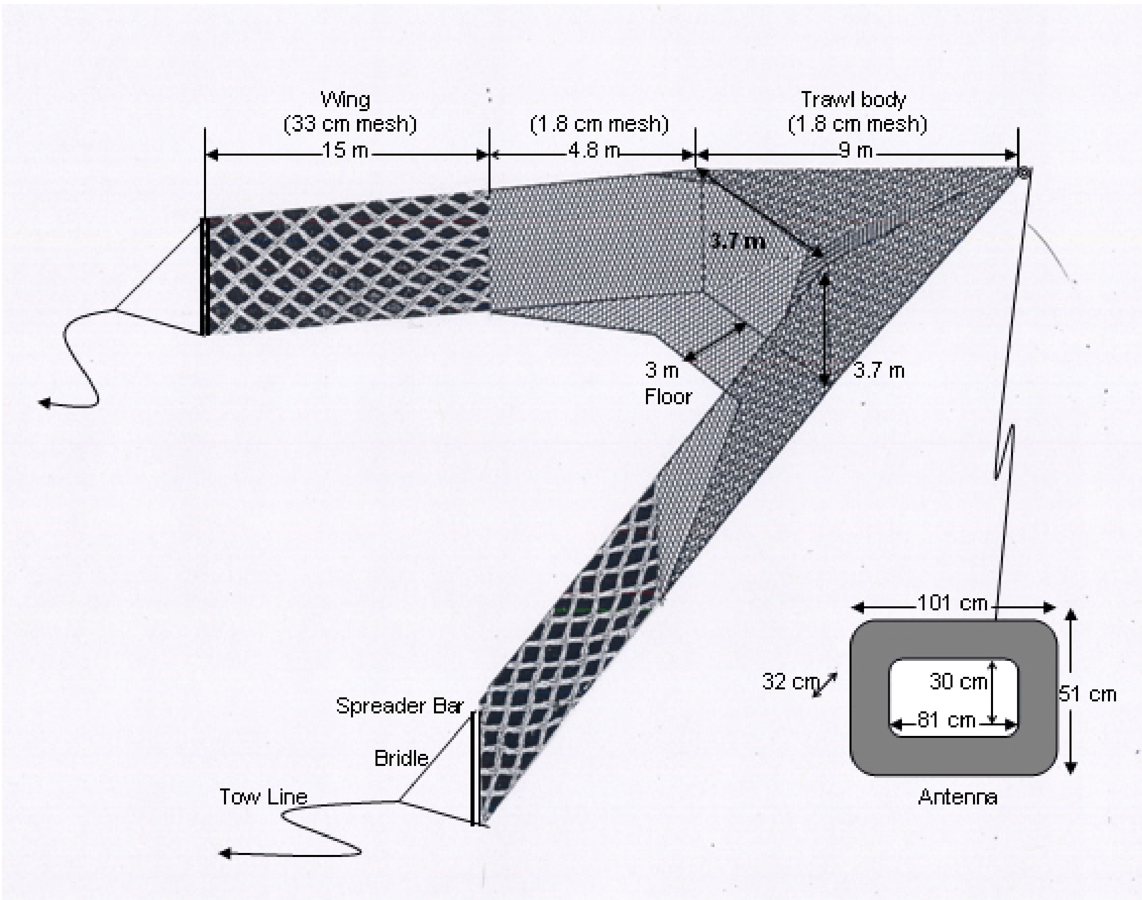


Figure 4. Schematic drawing of the small pair-trawl used with a salt-water compatible antenna, 2002.

In the lower estuary, we could not invert the net prior to retrieval. Inverting the net was required for the larger trawl because of the small mesh in the wings, which could entrap fish if the wings were collapsed for retrieval without inverting the net. We used a larger mesh size for the net of the small trawl, which also reduced drag on the net and thus facilitated use of smaller vessels. We used 33-m stretch mesh, based on field observations in 1997 at Jones Beach, which indicated that if the wings of the trawl were not positioned abruptly against the current (spread too wide), the 33-cm mesh would guide salmonids into the trawl body (Ledgerwood et al. 2000).

To further reduce drag and thus facilitate the use of smaller vessels, we also designed a smaller trawl body. We used a symmetrical design to simplify construction. The trawl was 3.6 by 3.6-m at its body entrance and tapered evenly to the antenna attachment centered at 1.8-m beneath the surface. The exit depth (antenna attachment depth) for the small and large trawls were the same, but the trawl body of the large trawl was asymmetrical in that the sidewalls began at a 6.1-m depth and created trawl construction difficulties.

The small trawl, as delivered, consisted of a 9.1-m long symmetrical trawl body having 15-m long wings. The trawl body was constructed with 1.8 cm stretch mesh, the same mesh size used in the trawl body of our larger trawl. The wings of the small trawl were 33-cm stretch-mesh webbing that tapered in depth from 3.6 m, where they attached to the trawl body, to 3 m where they attached to spreader bars and towing bridles. The spreader bars and towing bridles were similar to those of the larger trawl system and were used to hold the wings at their full sample depth. We used 70-m-long tow lines to minimize the influence of prop wash from the towing vessels on the net. Under tow, we maintained a distance of about 23 m between the wings so that the effective sample depth was about 3.3 m at the center of the floor.

Electronic Equipment and Operation

For the large trawl system, we used essentially the same electronic components and procedures as in 2001. A 10-m-long pontoon barge was towed near the exit to the trawl, and a gasoline generator powered all electronic equipment. Two Whit-Patten[1] transceivers and associated PIT-tag-detection electronics were mounted in the cabin of the barge, and cables led underwater to a tuner port on each of two detection antenna coils. A video camera mounted inside the antenna tunnel was used to monitor fish passage on a VCR/TV housed in the barge. The 200-kg antenna was 2.1 m long and had an 86-cm-diameter fish passage opening (Figure 5).

Once the antenna was energized, a computer software program (Multimon) automatically recorded time, date, detection code, and Global-positioning-system (GPS) coordinates (Downing et al. 2001). We maintained written logs for each sampling cruise, noting time and duration of net deployment, total detections, the number of impinged or injured fish, and the start and end of each net-flushing period.

PIT-tag-detection data files were periodically (about weekly) uploaded to PTAGIS using standard methods described in the *PIT-tag Specification Document* (Stein et al. 2001). The specification document, PTAGIS operating software and user manuals are available via the Internet (PSMFC 2002). Pair-trawl detections in the PTAGIS database were identified with site code "TWX" (towed array-experimental).

Records of PIT-tagged fish detected at Bonneville Dam were downloaded from PTAGIS for comparison with our detections (PSMFC 2002). In addition, the load sites, dates, times and corresponding release dates, times, and locations (rkm) of transport barges were provided by the USACE. An independent database (Microsoft Access) of detection information was also maintained to facilitate data management and analysis. We modified the PTAGIS release information within our database to reflect the date, time, and river kilometer of liberation of fish that were barged and released downstream from Bonneville Dam.

PIT-tag-detection electronic components for the small trawl system were contained in a 0.8-m long by 0.5-m wide by 0.3-m deep water-tight box mounted on a 1.9-m long by 1.2-m wide pontoon raft (Ledgerwood et al. 2004). A DC-powered Destron-Fearing model FS-1001A PIT-tag transceiver was used to power the underwater antenna and interrogate tagged fish.

1 Reference to trade name does not imply endorsement by NOAA, National Marine Fisheries Service.

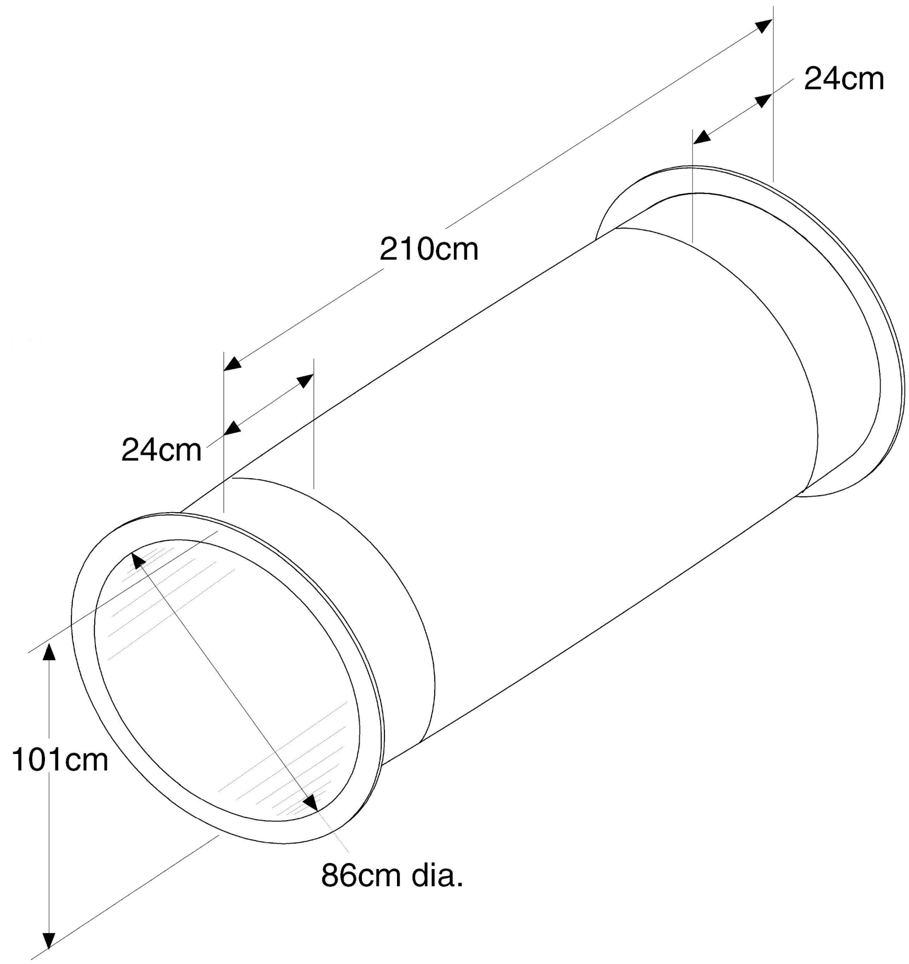


Figure 5. Basic design of antenna used in 2002 with a surface pair-trawl to sample PIT-tagged juvenile salmonid in the Columbia River estuary at Jones Beach, Rkm 75.

The FS1001A transceiver was specifically designed for installation at hydroelectric facilities on the Columbia and Snake Rivers. The unit included a serial maintenance port and a high-speed serial port for connection to a computer to monitor the status of the installation and for logging of individual PIT tags. We used a wireless modem to transmit data and reports to a portable computer mounted in a tow vessel.

Two 12-volt deep-cycle batteries provided power to the transceiver and modem, with one battery mounted on each pontoon of the raft for added stability in rough water. Fully-charged batteries provided sufficient power for at least a 10-h daily sample period. A 15-m long cable connected the transceiver to the underwater antenna. The antenna was strapped to the cod end of the trawl and suspended on a buoy 1.8 m beneath the surface. A strain-relief line was wrapped with the cable and bridled to the raft and the antenna to tow the raft and detection electronics with the trawl.

Salinity, temperature, and depth were recorded by a YSI model 6920 probe at 5-s intervals during most deployments of the small trawl in the lower estuary. The instrument was mounted on the top of the trawl about 1 m forward of the antenna. We had attempted to mount the unit directly on the antenna but discovered that it created unacceptable electronic interference with PIT-tag recording equipment.

PIT-tag detection and transceiver status monitoring software (Multimon) was utilized for recording purposes. In addition to the date, time, GPS position (of the tow vessel) and tag code of PIT-tagged fish, the software also recorded internal transceiver, diagnostic, and status reports. These reports were set to generate and record every 2 min as part of the standard Multimon data files. During unplanned power outages or computer failures, the internal buffering capability of the FS-1001A transceiver provided backup PIT-tag detection records for the small trawl, but the date and time of detection and the status and diagnostic reports for the transceiver were lost. Within PTAGIS, small-trawl data from sampling conducted at Jones Beach, were recorded as the secondary recorder (coil F1), and the large trawl as the primary recorder (coils 00 and 01).

Because of the preliminary nature of the sample effort in the lower estuary, we did not submit those data files to PTAGIS. All small trawl data files were incorporated into an independent database (Microsoft Access) and correlated with non-MULTIMON data. We also kept a hand-written log of sampling activities including date and time of each deployment/retrieval and net flush, GPS coordinates, salinity, temperature, diver observations, and impacts to fish (i.e., numbers of fish entrapped or killed in the trawl).

Detection Efficiency Tests

For both the large and small trawl systems, we used a weekly procedure for evaluating detection efficiency that did not require the release of test fish (Ledgerwood et al. 2004). A 2.5-cm-diameter polyvinyl chloride (PVC) pipe with a small plastic funnel on each end was positioned through the center of the antennas. The pipe extended past each end of the antenna beyond the range of the electronic field (about 0.5 m). We then attached 50 PIT-tags at known intervals and orientations to a vinyl-coated tape measure and passed the tape through the PVC pipe (Appendix Table 1).

We chose densities and orientations along the tape such that not all tags would be decoded; the relative consistency of tag detection helped validate electronic tune and identify possible problems with the electronics. During tests, we suspended the antenna underwater and pulled the tape back and forth several times through the PVC pipe. We used standard PIT-tag software to record detections and noted the start time of each pass in a log book. For each system, efficiency was calculated as the total number of unique tags decoded during each pass divided by the total tags passed through the antenna.

Impacts on Fish

For the large trawl system, we used nearly continuous video monitoring of fish exiting the antenna and periodic (about weekly) diver observations to assess impacts of trawling on fish. When debris accumulated or other problems were observed near the antenna on the video monitor, we reduced tow speed and pulled the cod-end and antenna to the surface for cleaning.

In the small trawl, the large-mesh wings allowed us to retrieve the net directly onto a tow vessel without having to invert the trawl to release fish. One drawback of this design was the occasional accumulation of significant quantities of debris. Since the net was not inverted for retrieval, debris had to be removed by hand either during the retrieval process, which required longer drifts, or back at the dock. During debris-removal, net-collection, and redeployment procedures for either trawl system, we recorded impinged or trapped fish as mortalities in operations log books.

Sample Period

As in previous years, sampling with the large trawl began in mid-April and continued through mid-June, coincident with the passage of PIT-tagged yearling Chinook salmon and steelhead from the Snake River transportation study. Beginning on 30 April and extending through 9 June, sampling increased from a single daily sampling crew to two daily crews. Generally, one work crew began before daylight and sampled for an 8- to 10-h period, and a second crew began in late afternoon and sampled until dark.

For the first time in 2002, sampling with the large trawl was extended through July to target PIT-tagged subyearling fall Chinook salmon, which migrate during that period. Transportation of subyearling salmonids is new, and little information on behavior and timing of these fish following release is available. During previous years, limited sampling at Jones Beach in the generally lower river flows of late June and July has suggested we would have adequate detection rates of subyearling salmonids to determine timing and behavior differences with a single sampling crew. Our goal was to detect about 1% of those fish previously detected at Bonneville Dam.

In 2002, we conducted extended sampling sessions on four occasions at Jones Beach to determine diel availability during the middle of the season. Sampling was nearly continuous during these sessions except for brief periods of net cleaning or when it was necessary to retrieve the net to move upstream. To compare diel curves among hatchery and wild fish on the same graphic scale, we weighted the detection data by total fish detected within each category and plotted the percentage of the total detections for each hour.

Statistical Analyses

Diel catch patterns (number of fish detected per hour during daylight hours compared to dark hours) of yearling Chinook salmon and steelhead were evaluated using one-way ANOVA (Zar 1999). The number of detections and the minutes within each hour that the detector was energized for each of the four diel sampling periods were separated into daylight- and darkness-hour categories, and mean hourly detection rates were pooled for wild and hatchery rearing types of each species.

Diel detection curves were prepared for yearling Chinook salmon and steelhead based on the average number of fish detected each hour weighted by the number of minutes within each hour that the detector was energized. There were too few detections of other species for meaningful analysis.

We plotted travel-time distributions and compared detection rates for three groups of yearling Chinook salmon and steelhead: fish marked and released at Lower Granite Dam and detected in the estuary, in-river migrant fish detected at both Bonneville Dam and Jones Beach, and transported fish released just downstream from Bonneville Dam and detected at Jones Beach. We made similar plots for subyearling fall Chinook salmon tagged or transported from McNary Dam in late June and July. The plots represent the seasonal durations of availability in the estuary for their respective groupings. Data from periods of availability in the estuary for the various subsets of fish were compared using analyses of travel-time distributions. Travel time (in days) to the estuary was calculated for each fish by subtracting date and time of release (at location of release or detection at Bonneville Dam) from date and time of detection at Jones Beach.

Multiple linear regression was used to evaluate differences in travel speed to Jones Beach between in-river migrants and transported fish for each year. Factors used in the regression models of travel speed included Julian date, flow, "treatment" (in-river migrant vs. transported), and two-way interaction terms for the three main effects. Flow data were daily-average-discharge rates at Bonneville Dam ($ft^3 s^{-1}$). When interaction terms for Julian date and flow were not significant, they were removed from the models. The travel speed data were presented graphically showing daily mean values, but all regression analyses were performed using data from individual fish.

Binary logistical regression analyses were used to compare daily detection rates among in-river migrants previously detected at Bonneville Dam to those released from transportation barges on the same dates as detection at Bonneville Dam. The daily groupings were treated as "cohorts" in the analysis (Hosmer and Lemeshow 1989). The daily in-river groups were paired to barged-released fish by date of barge release and selected to include only those PIT-tagged fish released at sites from McNary Dam upstream.

Early season barge releases often occurred before there were sufficient in-river migrating fish being detected at Bonneville Dam for comparison. Recovery percentages for both groups are shown for the entire season but were not used for analysis unless both groups were present. The regression lines fit through the data reflect only the date period used in the analysis.

Components of the logistic regression model were treatment (barge release or in-river migrant) as a factor and date as a covariate. The model estimated the log odds of the detection rate of the daily cohorts (i.e., $\ln[p/(1-p)]$) as a linear function of the components, assuming a binomial distribution for the errors. A stepwise procedure was used to determine the appropriate model. First, the model containing interaction between treatment and date was fit (i.e., estimated). If the interaction term was not statistically significant (>0.05), the reduced model without the interaction term was fit to the model. The model was further reduced depending on the significance of treatment and date.

Various diagnostic plots (e.g., Delta deviance vs. estimated probability and Leverage vs. original values) were examined to assess the appropriateness of the model. Extreme or highly influential data points were identified and included in, or excluded from, the analyses on an individual basis depending on the particular aspects of each point. Data for yearling Chinook salmon appears adequate for all years. Data for steelhead is also provided, but sample sizes for some years were small. All analyses in this report are preliminary.

The daily barged and in-river groups have similar distributions of availability in the sampling area and presumably pass the sample area at similar times and thus are subject to the same sampling biases (sample effort). If these assumptions are correct, the differences in their relative detection rates reflect differences in survival between the two groups from the area of release (near or at Bonneville Dam) to the estuary.

To test the assumptions that barged and in-river groups pass the sample area with similar diel timing, we divided the total seasonal detections for each group into interval hours based on the time they were detected. The hourly proportions were compared using a contingency table and the average differences presented for each hour by subtracting the in-river proportion from the barged proportion. No difference between groups during an interval-hour period indicates similar proportions of barged and in-river fish passed that hour; a positive difference indicates higher proportions of barged fish, and a negative difference indicates a higher proportion of in-river fish that hour. These data are preliminary and not weighted by date and number.

Detection data from the estuary are also essential to estimate survival of juvenile salmonids to Bonneville Dam, the last dam encountered by seaward migrants (Muir et al. 2001, Williams et al. 2001, Zabel et al. 2002). The probability of survival through an individual river reach was estimated from PIT-tag detection data using a multiple-recapture model for single release groups (Cormack 1964; Jolly 1965; Seber 1965; Skalski et al. 1998). This model requires detection probability estimates for the lowest downstream detection site (i.e., Bonneville Dam), and these estimates are calculated using detections below this site.

RESULTS

Large Trawl System Detections

Using the large trawl system, we detected 11,451 PIT-tagged juvenile salmonids of various species, runs, and rearing types at Jones Beach (Appendix Table 2). However, not all stocks and rearing types were equally represented. For example, of the total detections in 2002, 89% were Chinook salmon, 9% were steelhead, and the remaining 2% were other salmonid species (Table 1). Sixteen percent were wild fish, with the remainder hatchery-reared. Contributions of PIT tags to the estuary from the different river basins are shown in Figure 6. These variations in catch composition resulted primarily from differences in PIT-tagging strategies between years and complicate multi-year comparisons among species and run or rearing types.

Flow volume in the Columbia River during the 2002 spring migration season was approximately double that during 2001: mean flows from April through June were 7,471 $m^3 s^{-1}$ in 2002 and 3,797 $m^3 s^{-1}$ in 2001 (Figure 7). Trawl system equipment was energized for 693 h in 2002 and 646 h in 2001 (Figure 8). As a result of the low flow volumes in 2001, fish groups were likely to be more concentrated and to be present in the sample area longer. These tendencies increased sample efficiency, but further complicate direct comparisons of detection efficiencies between years, much like the comparisons between 2000 and 2001 (Ledgerwood et al. 2004). For example, despite much higher spring-time flows in 2002, sample numbers were nearly twice that of 2001 during the same time period (10,758 and 5,542 respectively).

According to the PTAGIS database there were about 38% more PIT-tagged fish released into the basin during 2002 than in 2001. Another factor that may explain the increased estuarine detection rate of 2002 was an overall increased survival of fish migrating during the higher flows of 2002. Sampling during late June and July in 2002 produced additional detections of primarily subyearling fall Chinook salmon during a time period not sampled in 2001.

Table 1. Species composition and rearing-type history for PIT-tagged fish detected in the large pair-trawl at Jones Beach, 2002.

Species\run	Hatchery	Wild	Unknown	Total
Spring/summer Chinook salmon	8,370	1,004	58	9,432
Fall Chinook salmon	497	6	309	812
Coho salmon	89	2	10	101
Steelhead	271	741	7	*1,019
Sockeye salmon	11	17	0	28
Sea-run cutthroat trout	0	1	0	1
Other	0	0	58	58
Grand total	9,238	1,771	442	11,451

* Includes 6 wild and 4 hatchery adult fish (kilts) tagged and released in 2002.

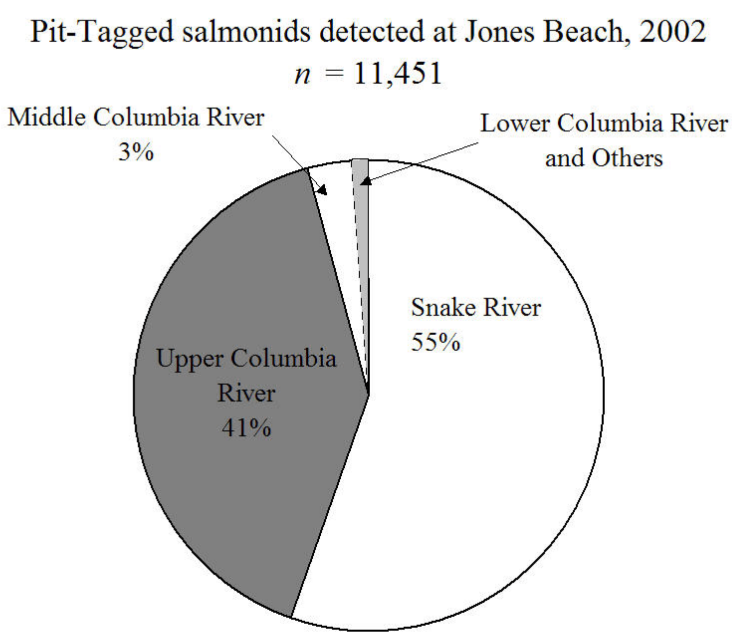


Figure 6. River basin sources of PIT-tagged fish detected in the Columbia River estuary at Jones Beach, Rkm 75, using a surface pair-trawl, 2002.

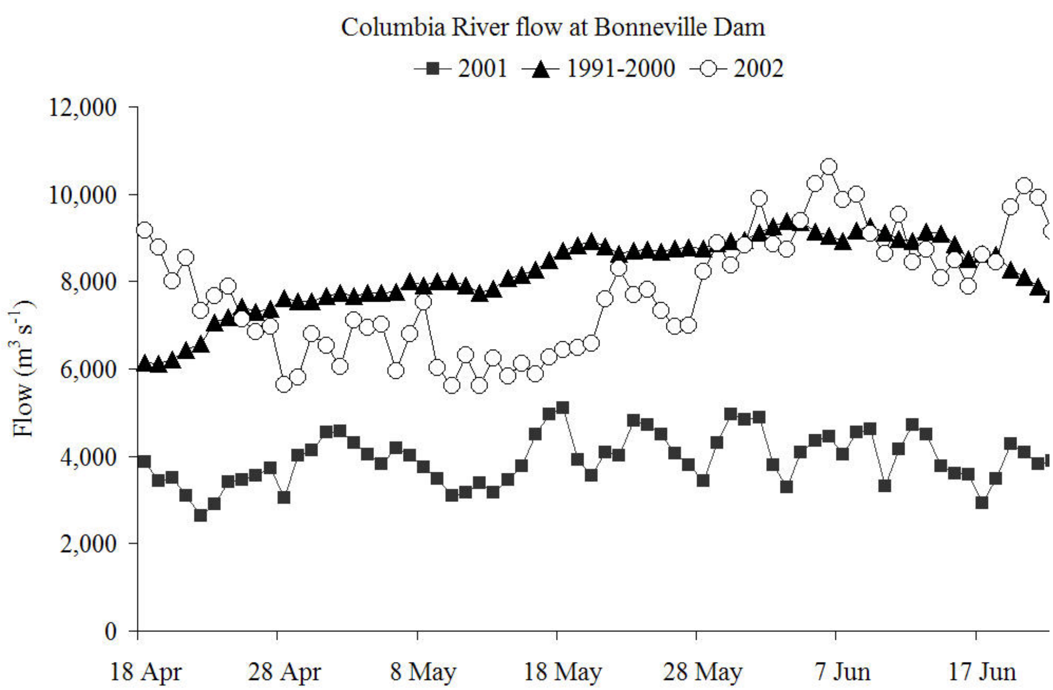


Figure 7. Columbia River flows at Bonneville Dam during the study periods of 2001 and 2002 and the average flow from 1991 to 2000.

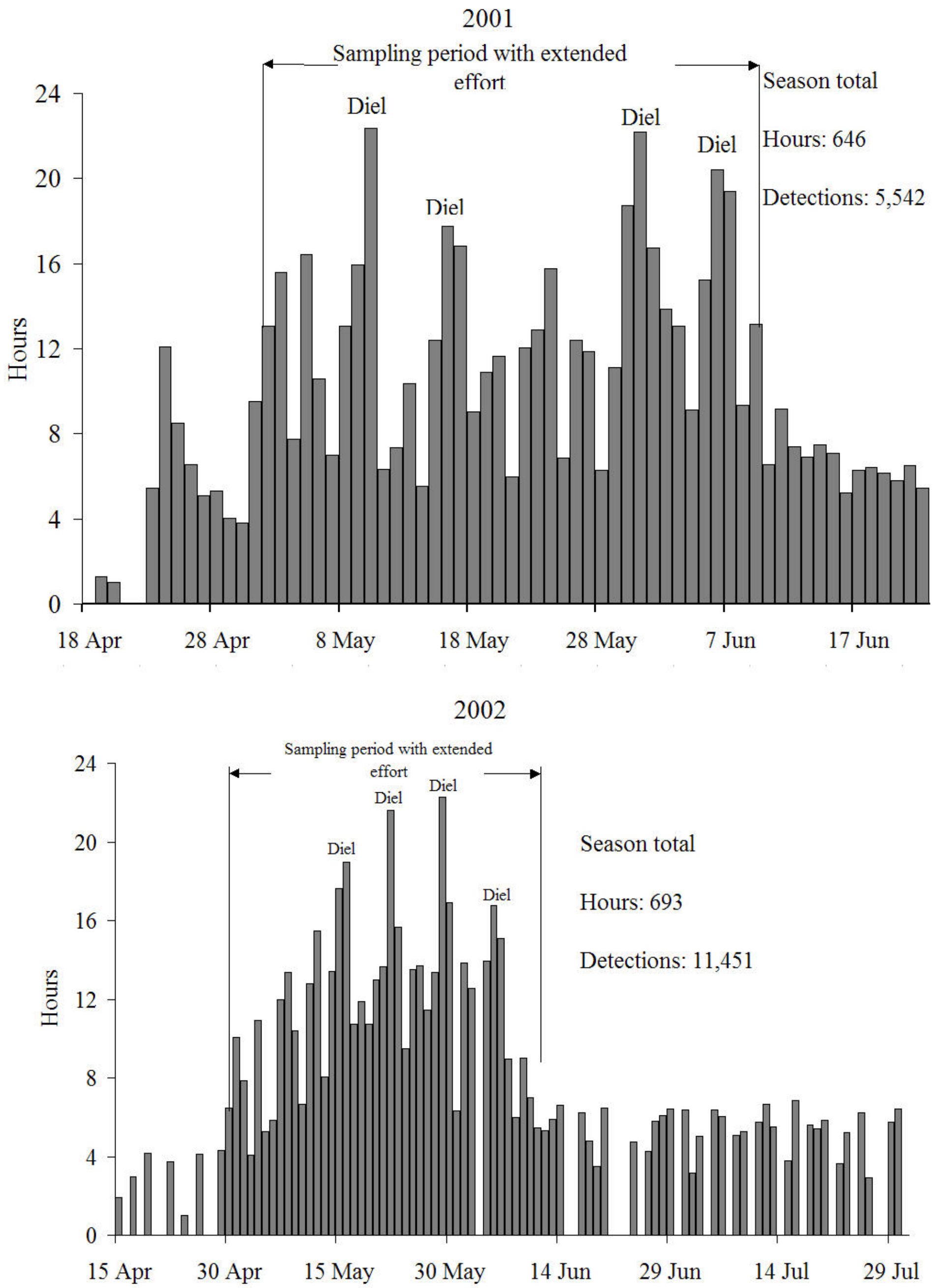


Figure 8. Sampling times during the 2001 and 2002 study periods using a PIT-tag detector surface pair trawl in the Columbia River estuary at Jones Beach, Rkm 75.

Small Trawl System Detections

Using the small trawl system, we sampled for 264 h and detected 168 PIT-tagged fish in fresh or brackish water portions of the estuary (Figure 9). In the brackish portion of the estuary, we generally sampled on the south side of the shipping channel between Buoy 10 and the Astoria-Megler Bridge (Figure 10). There was a strong bias towards detection of steelhead in the small trawl relative to the large trawl; 39% in the small trawl compared to about 9% during the same date period in the large trawl (Appendix Table 3).

This suggests that, much like terns, the small trawl samples fish passing primarily in surface waters. The 3.3 m sampling depth, large mesh wings, and relatively shallow floor in this trawl may not effectively guide juvenile salmonids to and through the antenna. In late June, divers observed that subyearling Chinook salmon within the trawl body would not exit volitionally through the antenna (Earl Dawley, NMFS-Ret. personal communication).

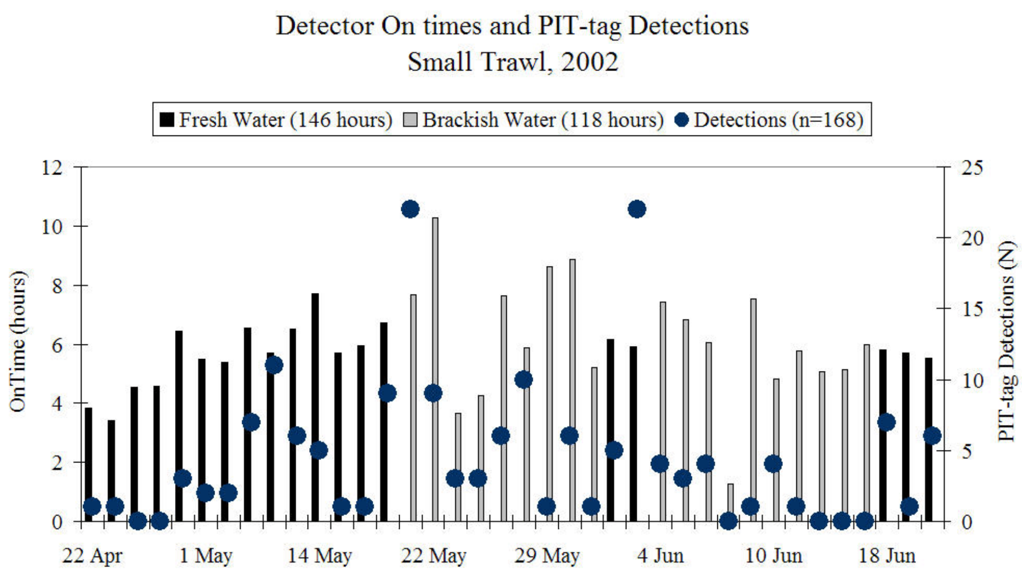


Figure 9. Daily sampling effort ("on" time) and detection numbers obtained using the small trawl in brackish and freshwater portions of the estuary, 2002.

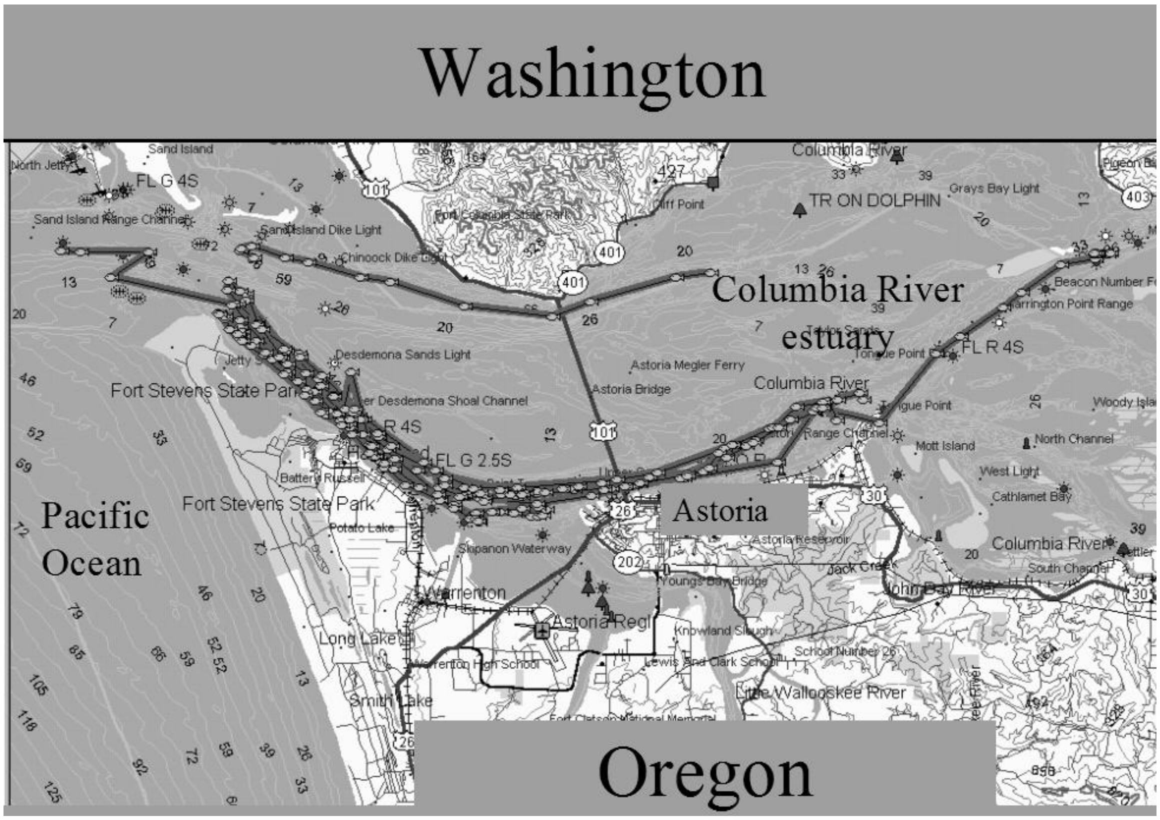


Figure 10. Map showing positions of 15-min net-flushing operations using the small trawl in the lower estuary, 2002.

Detection Efficiency

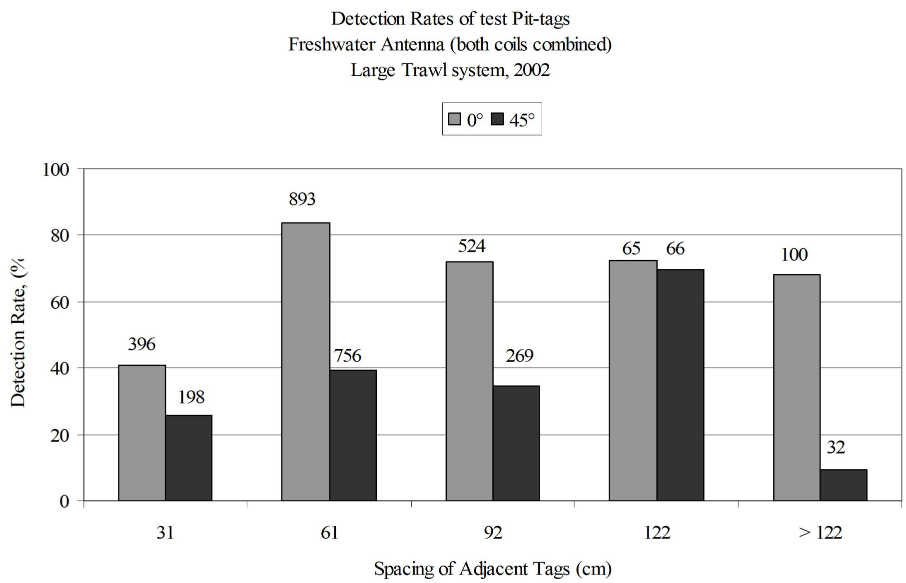
Detection efficiency of both trawl systems was evaluated by passing tags on a vinyl tape-measure through the center of the antenna. For the large trawl, a properly tuned electronic system read about 41% of the test-tags spaced 30-cm apart and held perpendicular to the electronic field, and 26% of similar tags oriented at 45-degrees to the electronic field (Figure 11, top). When spacing between tags was increased to 61 cm, detection efficiency increased to 83% for perpendicular tags and 39% for 45 degree tags. When tags were passed within about 20 cm of the antenna wall, rather than through the center of the antenna as above, detection rates increased to 98%, regardless of spacing or orientation.

In the small trawl, the salt-water antenna read about 80% of all tags in a similar test, regardless of tag spacing or orientation. Most of these tests were conducted in low salinity water (Figure 11, bottom).

In the large trawl, detection efficiency was also evaluated by comparing the number of fish originally detected on the front (upstream) antenna coil and subsequently detected on the rear (downstream) coil (Figure 12). Twenty-four percent of all individual fish detections were recorded on the rear coil only (missed by the front coil). The miss rate of the front coil was correlated with peak passage in mid to late May, and was undoubtedly related to electronic collision of tag codes (Downing et al. 2003). Increased 'miss rates' were also noted when the electronic components were not properly tuned.

We used daily front/rear fish detection proportions to help flag problems with large-trawl components. We also used the strongest reading of the two required transceivers with the rear antenna coil in accordance with fish behavior. Once fish entered the antenna and were swept downstream towards the exit, their tag orientation tended to improve: they held head-first into the current, with the tag presumably perpendicular to the electronic field.

Median passage time for fish between detection on front and rear coils was 4 seconds. Of the 8,625 individual fish detected on the front coil, only 641 were missed by the rear coil (7%). We believe that the combined detection rate of the two coils exceeded 95% of all PIT-tagged fish passing through the antenna.



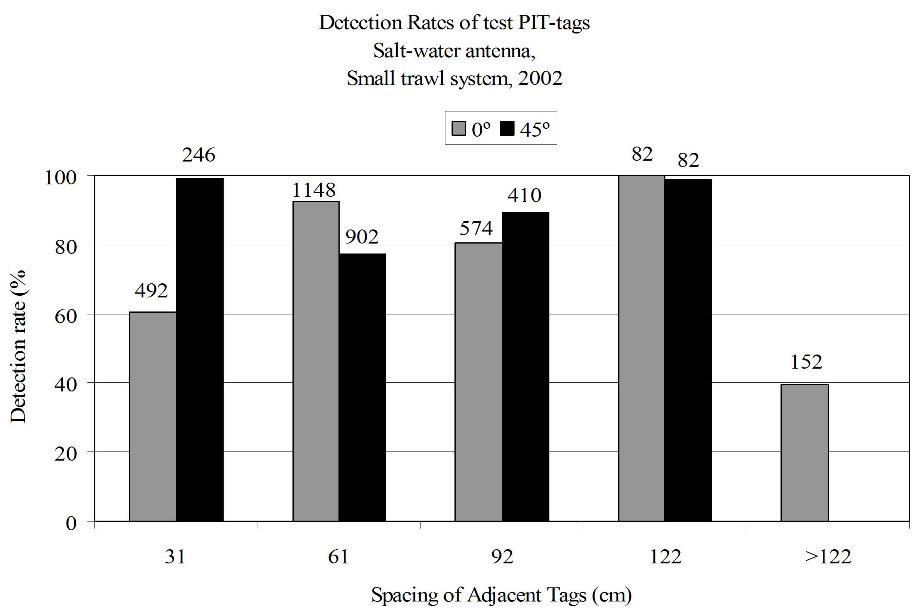


Figure 11. Antenna performance evaluation using PIT-tags attached to vinyl tape measures: freshwater antenna, top, and salt-water antenna, bottom. Various spacing between tags and angles to the electronic field were used (0° or 45° angle). Tags were passed through antennas repeatedly on different dates. Total potential tags used to evaluate spacing and orientation effects are shown above bars.

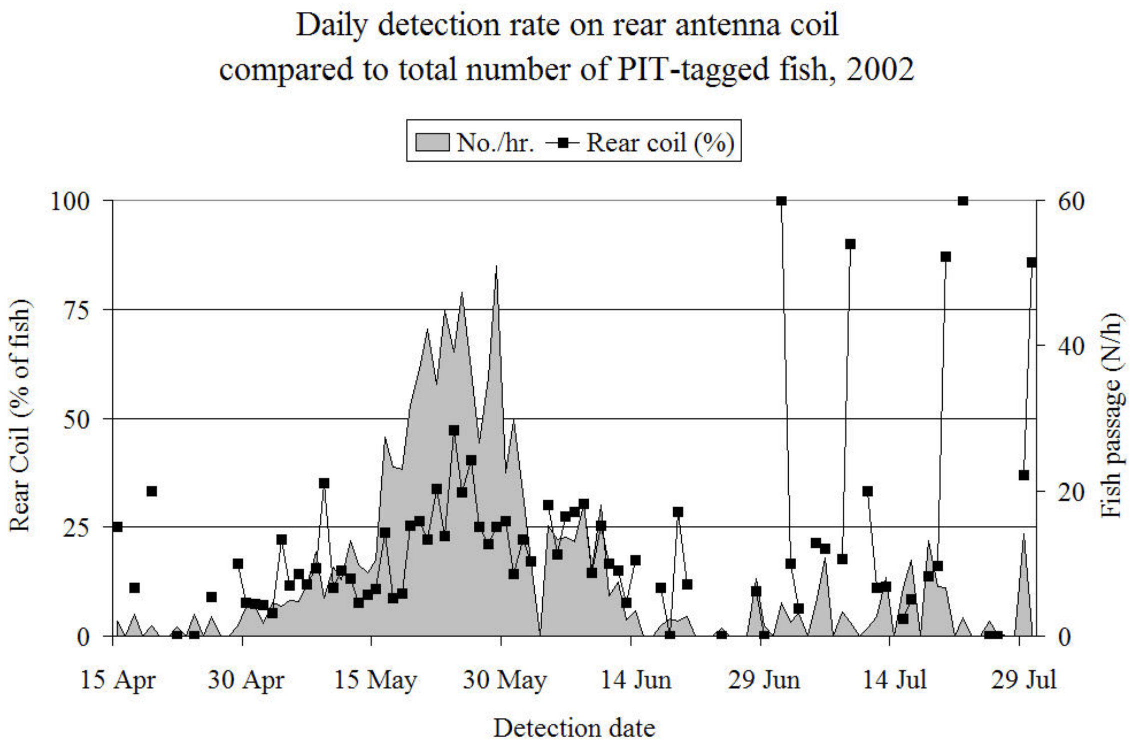


Figure 12. Proportion of PIT-tagged fish detected only on the rear antenna coil of the large trawl compared to daily fish passage, 2002.

Impacts on Fish

We used nearly continuous (daylight) video and periodic diver observations to visually assess impacts to fish in the large trawl and adjusted sampling operations accordingly. When debris accumulated or other problems were observed, we reduced tow speed and pulled the detection antenna to the surface to clean the cod end of the net. We disconnected the electronics and inverted the entire net to clear debris in extreme conditions. With the relatively short tow durations of the small trawl system, the net was cleaned during retrieval.

We recovered 201 impinged, gilled, or otherwise injured juvenile salmonids in the netting during the trawl inspections or upon retrieval of the trawls (Appendix Tables 4-5). It is possible that other mortalities and injuries to fish occurred but were not observed. In the large trawl during net inversions, dead fish could have been swept out of the submerged net. Likewise, in the small trawl, injured or dead fish could have passed through the antenna during net retrieval as remaining fish were gently shaken through the antenna. However, divers inspecting the trawl body and wing areas of the nets reported that it was rare to observe fish swimming close to the webbing except near the antennas. Rather, fish tended to linger near the entrance to the trawl body and directly in front of the antenna.

In previous years, we eliminated web size and color transitions in the trawl body and cod end that appeared to attract fish and delay their passage out of the net. We continued to flush the net (bring the trawl wings together) every 15 min to discourage fish from holding in the net and expedite their passage through the antenna. Some fish detected on the front antenna coil swam forward into the trawl again and were detected repeatedly on the front coil. Other fish detected on the front antenna coil passed downstream but were detected repeatedly on the rear antenna coil.

For example, one yearling Chinook salmon (3D9.1BF13C0038) was detected 82 times on the front coil and 5 times on the rear coil over 14 min. Another yearling Chinook salmon (3D9.1BF119C763) was detected 4 times on the front coil and 31 times on the rear coil over 95 min. Such observations were relatively rare, and only 27 fish had more than 10 multiple detections (Table 2). While volitional passage through the antenna occurred, the majority of fish were detected during the 5-min net-flushing periods.

Table 2. Listing of individual salmonids detected more than 10 times during passage through the large pair-trawl PIT-tag detection system, 2002. Species code 1 designates Chinook salmon and 3 steelhead.

Detection date	Species code	PIT tag code	Number of repeat detections
26 Apr	3	3D9.1BF0DCF13C	14
8 May	3	3D9.1BF0E16FAA	12
12 May	1	3D9.1BF13CDAE8	26
16 May	1	3D9.1BF141C9AD	17
16 May	1	3D9.1BF1531882	33
17 May	1	3D9.1BF1235A4C	44
17 May	1	3D9.1BF13CC238	19
18 May	1	3D9.1BF13C0038	87
18 May	1	3D9.1BF1673ABB	53
19 May	1	3D9.1BF11B3531	15
21 May	1	3D9.1BF1547B3F	19
22 May	1	3D9.1BF1277BE9	29
22 May	1	3D9.1BF145D49E	13
22 May	1	3D9.1BF157C1E4	58
23 May	1	3D9.1BF119C763	34
23 May	1	3D9.1BF1200CBB	29
23 May	1	3D9.1BF14254F6	16
23 May	1	3D9.1BF1571599	12
24 May	1	3D9.1BF11E3FD9	53
30 May	1	3D9.1BF144987F	21
30 May	3	3D9.1BF12FC4DB	13
1 Jun	1	3D9.1BF14A7B3B	22
2 Jun	1	3D9.1BF14503A5	20
5 Jun	1	3D9.1BF13D042D	23
5 Jun	3	3D9.1BF12FA0E3	13
7 Jun	1	3D9.1BF142B149	17
18 Jul	1	3D9.1BF124DB46	58

Diel Detection Patterns (Spring Migration)

We conducted four diel sampling cruises with the large trawl system during May and June 2002 and detected 3,733 yearling Chinook salmon and 322 steelhead during these cruises (Figure 13). Detections of juvenile sockeye and coho salmon were too few (<50) to provide meaningful comparisons. During these sampling sessions, the detector was energized and recorded data for a total of 146 h, with effort in the four periods ranging from 29 to 39 h (Appendix Table 6).

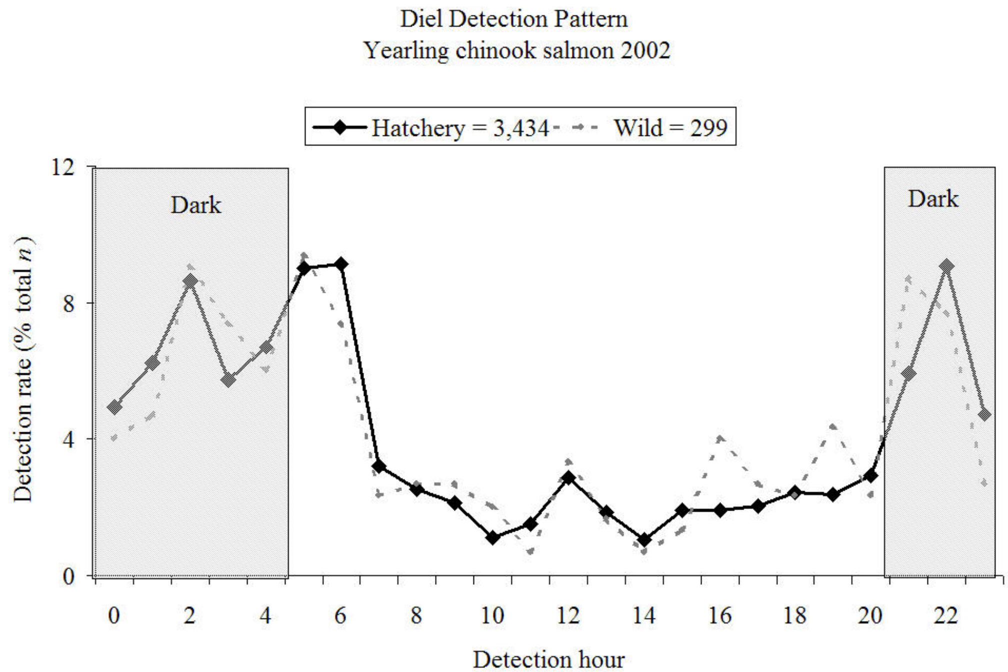
Detection rates for hatchery and wild yearling Chinook salmon were greater during darkness than daylight (32 vs.18 hatchery fish/h, $P = 0.01$ and 2.9 vs. 1.9 wild fish/h, $P = 0.05$, respectively). Diel trends for hatchery and wild steelhead were opposite those of yearling Chinook salmon, i.e., higher detection rates during daylight than darkness (0.4 vs. 1.0 hatchery fish/h, $P = 0.01$ and 0.8 vs. 2.2 wild fish/h, $P = 0.02$, respectively).

Timing and Migration History

Yearling Chinook Salmon and Steelhead (Spring migration)

For both yearling Chinook salmon and steelhead, travel time (in days) for in-river migrating fish was measured from the tailrace of Lower Granite Dam to detection in the large trawl at Jones Beach. Median travel times in 2002 were nearly two times shorter than during the low-flow drought year of 2001. In 2002, median travel times were 18 d for both species, while in 2001, median travel times were 33 d for yearling Chinook salmon and 29 d for steelhead (Table 3).

Travel time to the estuary for in-river migrants detected at Bonneville Dam was also faster in 2002 than in 2001 (yearling Chinook salmon medians 1.8 vs. 2.3 days and steelhead medians 1.7 vs. 2.5 days, respectively). Similarly, travel times from barge-release sites to the estuary were faster in 2002 than in 2001 (yearling Chinook salmon medians 2.1 vs. 3.0 days and steelhead medians 1.6 vs. 1.9 days, respectively). All between-year differences in median travel times were statistically significant ($P < 0.05$). Similar differences in travel times and distributions of fish were observed between the 2000 and 2001 study years (Ledgerwood et al. 2004).



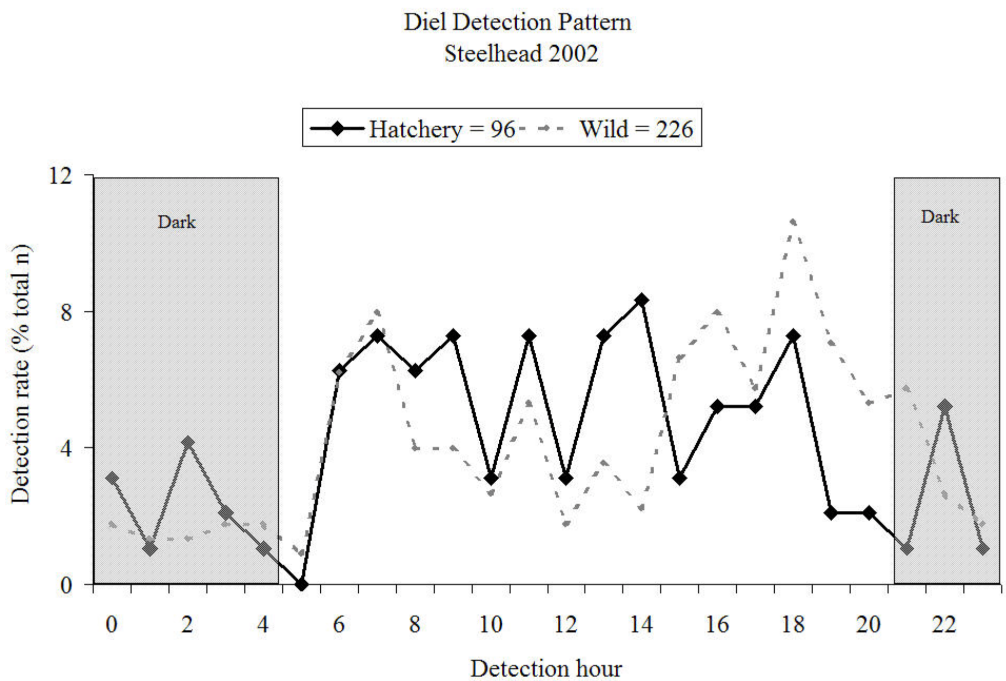


Figure 13. Average hourly detection rates in the large trawl system (weighted by total sample size for hatchery and wild fish) of yearling Chinook salmon and steelhead during four continuous diel sampling periods in the Columbia River estuary at Jones Beach (rkm 75), 2002.

Table 3. Median travel time to detection in the large trawl system at Jones Beach (rkm 75) for fish released at Lower Granite Dam, fish detected at Bonneville Dam, and fish released from transport barges in 2001 and 2002. Timing was evaluated for yearling Chinook salmon and steelhead, and fish released downstream from McNary Dam or detected at Jones Beach after 9 June were excluded.

Yearling Chinook salmon				Steelhead			
2001		2002		2001*		2002	
Travel time (days)	Sample (n)	Travel time (days)	Sample (n)	Travel time (days)	Sample (n)	Travel time (days)	Sample (n)
Release at Lower Granite Dam tailrace (rkm 695)							
32.7	617	18.2	538	29.1	39	17.8	93
Detection at Bonneville Dam bypass system (rkm 234)							
2.3	543	1.8	1,137	2.5	31	1.7	156
Release from fish transportation barge (rkm 225)							
3.0	1,248	2.1	886	1.9	327	1.6	293

* Between 15 April and 7 June 2001, the median flow volume at Bonneville Dam was 47% lower than in 2002 (3,847 m^3s^{-1} in 2001 vs. 7,234 m^3s^{-1} in 2002).

Travel times from detection in the upper estuary at Jones Beach to detection in the lower estuary for 3 yearling Chinook salmon were 16, 29, and 41 h (Table 4). Though we were unable to confirm the routes of travel through the estuary for these fish following detection at Jones Beach, the variation in travel times to the lower estuary corresponded to encounters with one, two, and three flood tides respectively. We also detected 3 fish at Jones Beach with the small trawl located directly (0.1 to 0.5 km) in front of the large trawl; travel time to exit the large trawl varied between 30 and 51 min.

Table 4a. Lapse time (minutes) between detections of individual fish detected in both the large and small trawls operating in close proximity in the upper estuary at Jones Beach (rkm 75), 2002.

Tag code	Small trawl detection (upstream)	Large trawl detection (downstream)	Lapse time (min)
3D9.1BF0E4221B	8-May 05:35:19	8-May 05:56:47	21.5
3D9.1BF1570E2D	8-May 06:18:25	8-May 06:49:15	30.8
3D9.1BF112C618	14-May 07:27:12	14-May 07:44:58	17.8
3D9.1BF14444C0	18-May 05:25:24	18-May 05:43:43	18.3
3D9.1BF12F50D6	18-May 05:48:41	18-May 06:03:09	14.5
3D9.1BF144CA2B	18-May 06:39:23	18-May 06:54:17	14.9

Table 4b. Lapse time between detections of fish in the large trawl (near rkm 75) and subsequent detection in the small trawl (lower estuary near rkm 10) with the number of flood tides between detections.

	Large trawl detection (upstream)		Small trawl detection (downstream)		Lapse time	Distance between trawls	Flood tides
Tag code	Date	rkm	Date	rkm	(h)	(km)	(n)
3D9.1BF11FF94D	29-May 17:13:45	69	30-May 09:18:21	23	16.1	45	1
3D9.1BF15779BC	22-May 07:06:41	71	23-May 12:15:21	15	29.1	54	2
3D9.1BF145F0DD	21-May 19:57:57	44	23-May 12:51:40	15	41.0	56	3

We also compared the daily differences in travel speed of fish to the estuary based on migration history (barged or in-river to Bonneville Dam) and river flow. Travel time to the estuary was generally slower for fish released from barges than for those detected at Bonneville Dam on the same date (i.e., fish migrating to the estuary from Bonneville Dam under similar conditions; Figure 14). However, interactions between date of release from a barge or detection at Bonneville Dam, flow, and migration history (transported vs. in-river) were present in some comparisons.

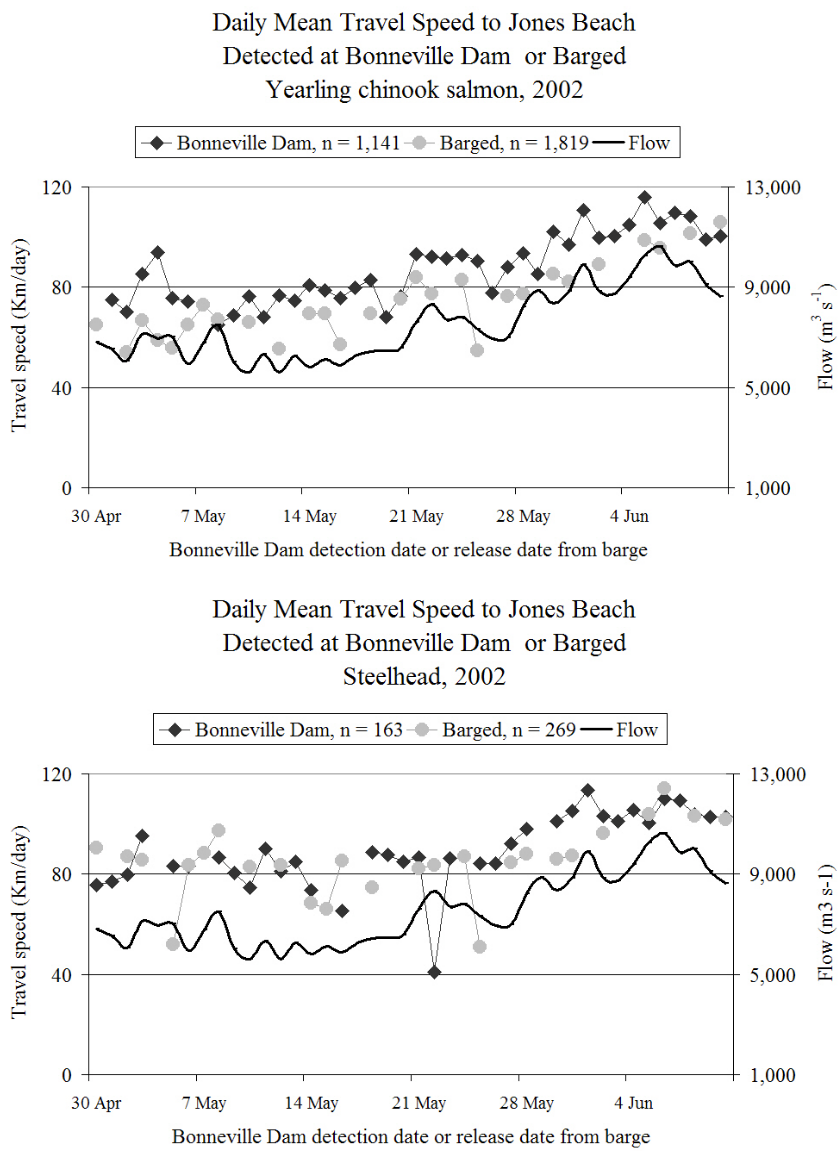


Figure 14. Daily mean travel speed from detection at Bonneville Dam or barge release to detection in the estuary (near rkm 75) using the large trawl system for yearling Chinook salmon and steelhead, 2002.

Subyearling Chinook Salmon (Summer Migration)

We detected 812 PIT-tagged juvenile subyearling Chinook salmon (i.e., those designated in the PTAGIS database as run code 3). The majority of these had been released from Snake River hatcheries to migrate as subyearlings. However, of the total 812 detections in 2002, 192 occurred prior to 10 June, 186 of which were fish released from hatcheries prior to 19 April (tagged in April with fork lengths >120 mm). The remaining 6 had been released as subyearlings in 2001 and had overwintered within the Columbia River Basin.

Of the 192 run-code 3 fish detected prior to 10 June, 88% had been released at one of the following Snake River acclimation ponds: Big Canyon Creek on the Clearwater River (77), Pittsburg Landing (72), and Captain Johns Pond on the main-stem Snake River (21).

The remaining 620 run-code 3 Chinook salmon were detected in the estuary after 10 June. All but four of these fish had been released after 21 May 2002 either in the Snake or mid- to upper-Columbia River (including those tagged for the transportation study at McNary Dam). The fork lengths of 95% of those we detected were less than 120 mm at tagging (PTAGIS), i.e., subyearling-size fish. We detected 204 fish that had been released from transportation barges downstream from Bonneville Dam, and 416 that had not been transported. Of the in-river migrants, 75 had been previously detected in the juvenile bypass system at Bonneville Dam.

Daily average travel speed of PIT-tagged subyearling fall Chinook salmon detected at Bonneville Dam decreased with river flow volume and was similar to averages of the three release groups of radio-tagged fish released at Bonneville Dam between mid-June and mid-July (Figure 15; radio-tag data courtesy of David Jepson, Oregon State University, personal communication). For transported fish, we speculated that the distributions of barged-released fish at the sample site would increase through the season concomitant with decreasing river flows and a propensity for later migrants to slow their migrations and possibly even overwinter in the estuary. The median travel time for barge-released subyearling fish to the estuary that were released before 13 July was 1.8 days compared to 2.2 days for those released later. However, there were insufficient fish detected to evaluate the distributions with high precision and confidence (Figure 15).

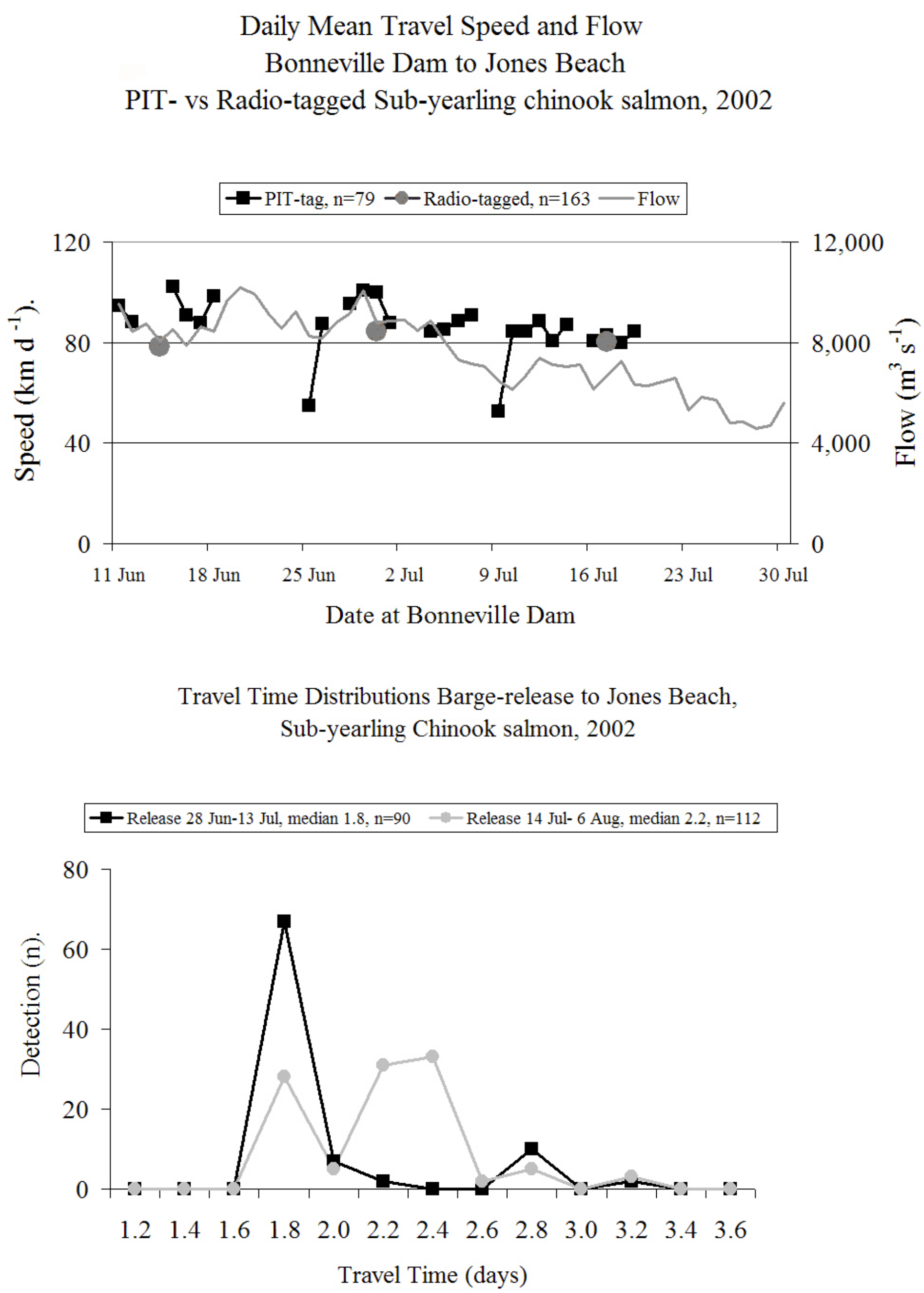


Figure 15. Daily average travel speed to Jones Beach (rkm 75) for subyearling Chinook salmon detected with the large trawl system and previously detected at Bonneville Dam compared to radio-tagged fish and flow (top). Distributions of travel time to Jones Beach for PIT-tagged fish released from transportation barges during early and late periods of the subyearling Chinook salmon migration, 2002 (bottom).

Transportation Evaluation

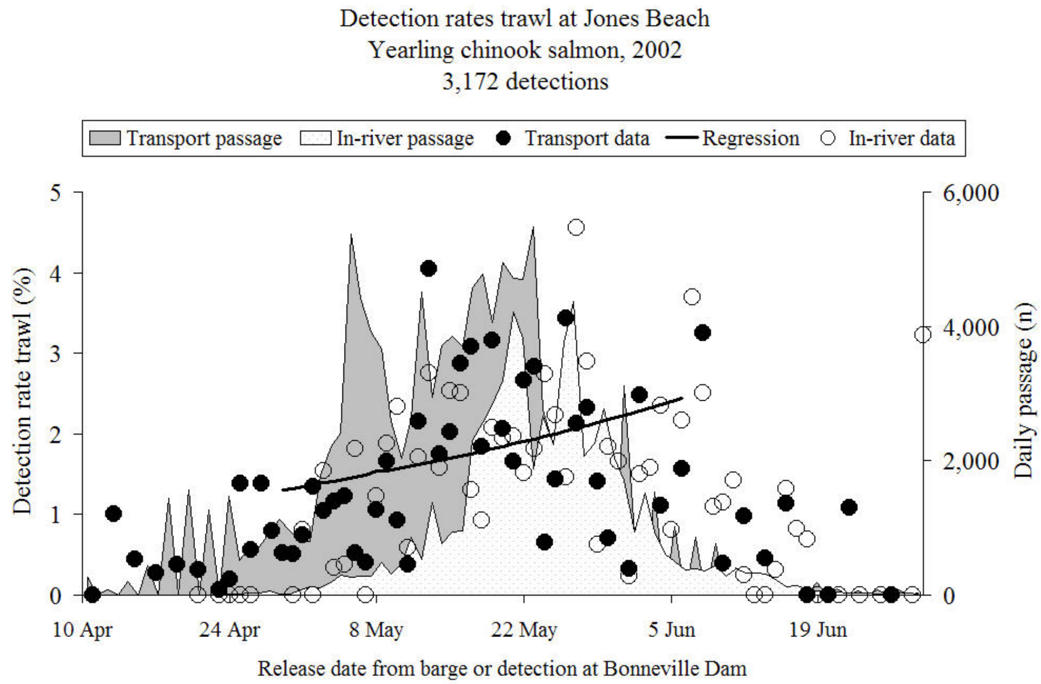
Of the 39,538 wild yearling Chinook salmon and 48,780 wild steelhead PIT-tagged for NMFS transportation study in 2002, 21,267 and 25,850 respectively were diverted at Snake and Columbia River dams for transport. Including river-run fish, a total of 160,806 yearling Chinook and 27,461 steelhead of both wild and hatchery origin were transported. Of this total, we detected 2,215 transported yearling Chinook and 373 transported steelhead in the estuary (Appendix Tables 7-8).

Of the fish that migrated in-river, 84,814 yearling Chinook salmon and 8,704 steelhead were detected in the juvenile bypass system at Bonneville Dam. Of these fish, we detected 1,325 yearling Chinook and 172 steelhead (Appendix Table 9). A portion of both barged and in-river migrant groups passed through the estuary either before or after the trawl sampling period.

Using logistic regression analysis, we compared the daily detection percentages of transported fish to the daily detection percentages of in-river migrant fish previously detected at Bonneville Dam during the period of our two-crew sampling effort. Barge releases early in the season often occurred before there were sufficient in-river migrant fish detected at Bonneville Dam for comparison. For analyses of migration history, we further selected the in-river fish from those that originated upstream from or at the transportation dams. We also compared the detection rates of fish released from the same barge but loaded at different dams.

Transported vs. In-river Migrant Fish Detected at Bonneville Dam

During our intensive two-crew sampling period (30 April-9 June), 107,967 PIT-tagged yearling Chinook salmon were released from transportation barges downstream from Bonneville Dam and another 57,955 were detected in the bypass system at Bonneville Dam. Of these, we detected 1,929 (1.8%) of the transported and 1,126 (1.9%) of the in-river migrant fish. Logistic regression analysis of recovery rates showed no significant interaction between date of barge release vs. date of Bonneville Dam detection ($P = 0.138$) and no significant difference in overall detection rates of barged or inriver migrant yearling Chinook salmon ($P = 0.753$, Figure 16). There was a significant change in detection rate ($P < 0.001$) from late April (about 1.3%) to early June (about 2.2%) for both groups.



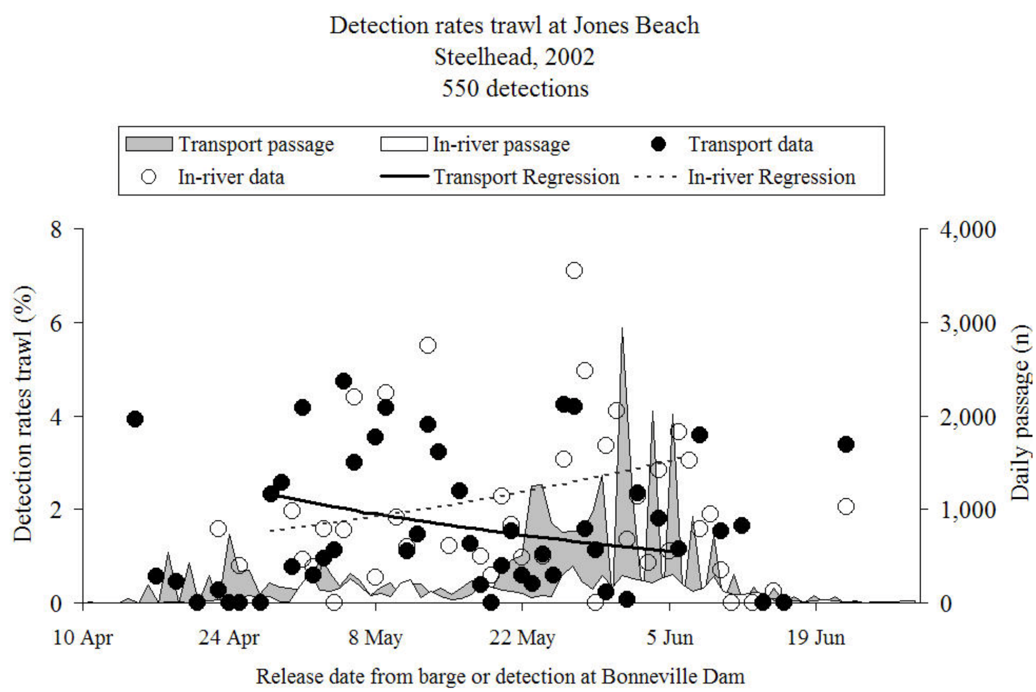


Figure 16. Logistic regression analysis of the daily detection percentages of barge-transported and in-river Chinook salmon and steelhead detected at Bonneville Dam, 2002.

During the intensive (two-crew) sampling period, we detected 300 (1.2%) of the 21,637 PIT-tagged steelhead released from transportation barges and 160 (2.3%) of the 6,762 detected at Bonneville Dam. Analysis showed a significant interaction between migration history and date of estuary detection during 2002 ($P < 0.001$, Figure 16). Detection efficiencies for transported steelhead declined through the season (from 2.2% in early May to1.8% in June), and during the same period, detection rates for in-river fish increased (from 1.8 to 2.4%).

Detections of Transported Fish by Barge Loading Site

We compared estuarine detection rates of fish released from the same transportation barge but loaded at different dams. Detection rates of fish loaded at Lower Granite Dam, the uppermost dam, were compared to individual or pooled detection data for fish loaded downstream at Little Goose, Lower Monumental, and McNary Dams.

During our intensive 2-crew sampling period, we detected 1.0% of the 26,132 PIT-tagged yearling Chinook salmon loaded at Lower Granite Dam and 1.5, 1.8 and 2.0% of the 28,432, 10,292, and 53,042 PIT-tagged fish loaded at Little Goose, Lower Monumental, and McNary Dams, respectively (Appendix Table 7). The average detection rate for the downstream transport dams was around 1.8%. We compared daily detection percentages for fish transported from Lower Granite Dam to those transported from the pooled estimates of the lower Snake River dams. For yearling Chinook salmon, there was significant interaction between release date and loading site ($P < 0.001$; Figure 17). Yearling Chinook salmon loaded at Lower Granite Dam were detected in the estuary at lower rates than fish loaded at the downstream dams in late-April (0.5 vs. 1.5%, respectively) but this difference disappeared by late May (both around 2.0%). For steelhead, there was no interaction between release date and loading site ($P = 0.726$) and no significant difference over time ($P = 0.180$) or between detection rates for fish loaded at Lower Granite Dam compared to the downstream dams ($P = 0.664$).

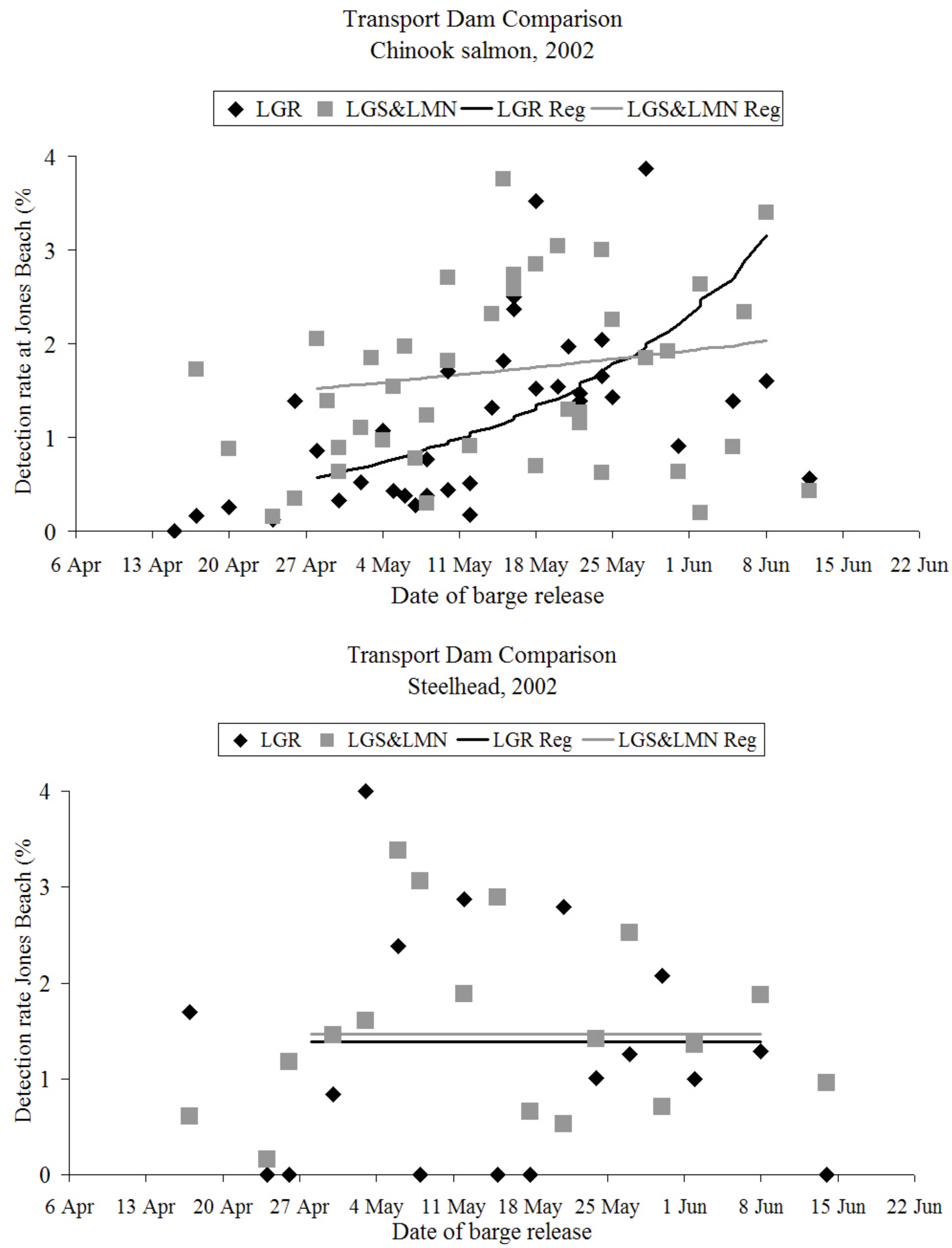


Figure 17. Daily recovery rates of yearling Chinook salmon and steelhead released from barges loaded at Lower Granite (LGR) or other downstream dams (LGS, Little Goose Dam; LMN, Lower Monumental Dam), 2002.

Survival Estimates of In-river Migrants to the Tailrace of Bonneville Dam

Detection data from the trawl are essential for calculating survival probabilities for juvenile salmonids to the tailrace of Bonneville Dam, the last dam encountered by seaward migrants (Muir et al. 2001, Williams et al. 2001, Zabel et al. 2002). Detections of yearling Chinook salmon and steelhead arriving at McNary Dam were pooled weekly, and survival probabilities of fish released in the Snake and mid-Columbia Rivers were estimated from McNary to John Day, John Day to Bonneville, and McNary to Bonneville Dams (Table 5). Estimated survival probabilities were higher in 2002 than 2001 (Ledgerwood et al. 2003) in every instance where sample sizes were adequate for an estimate.

For Snake River stocks, survival estimates from McNary Dam to Bonneville Dam were 76.3% for yearling Chinook salmon and 48.8% for steelhead. For mid-Columbia River stocks, survival of yearling Chinook salmon from McNary to Bonneville Dam was estimated at 74.5%. Sample sizes were insufficient for survival estimates of other stocks or reaches.

Seasonal average survival of in-river migrants from the tailrace of Lower Granite Dam to the tailrace of Bonneville Dam was 57.8 for yearling Chinook salmon and 26.2 for steelhead (Table 6). Survival probabilities through the entire hydropower system for both species in 2002 were similar to those in 1998-2000. In 2001, estimated survival probabilities for in-river migrants from Lower Granite Dam were considerably lower than in previous years, presumably due to low flows caused by drought conditions. However, most fish in the general population were transported that year.

Table 5. Weekly average survival percentages from the tailrace of McNary Dam to the tailrace of Bonneville Dam for yearling Chinook salmon and steelhead, 2002. Total fish used in the survival estimates, weighted average survivals, and standard errors (SE) for each species and water basin are presented.

		McNary to John Day Dam		John Day to Bonneville Dam		McNary to Bonneville Dam	
Week	*n*	%	SE	%	SE	%	SE
		Snake River yearling Chinook salmon					
20 Apr-26 Apr	781	92.2	15.3	23.5	14.2	21.7	12.6
27 Apr-03 May	2,871	94.3	6.3	108.0	69.3	101.8	65.0
04 May-10 May	15,173	87.1	3.2	82.2	13.9	71.6	11.8
11 May-17 May	28,713	92.4	2.3	103.4	11.6	95.6	10.4
18 May-24 May	23,041	92.4	3.0	82.9	7.6	76.6	6.6
25 May-31 May	7,403	83.4	4.3	48.4	8.2	40.3	6.5
Wt. Avg.	77,982	90.7	1.4	84.0	7.9	76.3	7.9
		Snake River steelhead					
27 Apr-03 May	912	90.8	11.0	69.1	26.1	62.8	22.4
04 May-10 May	963	86.9	15.6	120.9	79.7	105.2	66.7
11 May-17 May	633	64.0	11.7	103.6	91.2	66.4	57.1
18 May-24 May	1,284	96.8	18.2	43.7	14.1	42.3	11.1
25 May-31 May	1,011	60.0	9.5	51.3	16.1	30.8	8.4
01 Jun-07 Jun	857	100.2	37.3	38.8	27.1	39.0	23.0
Wt. Avg.	5,660	84.4	6.3	61.2	9.8	48.8	9.0
		Mid-Columbia River yearling Chinook salmon					
19 Apr-Apr 25	630	98.4	19.3	NA	NA	NA	NA
26 Apr-02 May	546	71.6	11.4	NA	NA	NA	NA
03 May-09 May	2,667	84.9	8.3	74.5	35.0	63.3	29.0
10 May-16 May	5,734	84.8	4.9	70.3	15.2	59.6	12.4
17 May-23 May	8,776	88.5	3.8	94.9	18.5	84.0	15.9
24 May-30 May	4,805	83.1	3.9	117.7	44.5	97.8	36.7
31 May-06 Jun	827	81.0	17.0	75.7	51.0	61.3	39.2
Wt. Avg.	23,985	85.5	1.5	86.7	7.9	74.5	6.9

Table 6. Estimated survival probabilities from the tailrace of Lower Granite Dam to the tailrace of Bonneville Dam for yearling Chinook salmon and steelhead, 1998-2002. SE = standard error and CI = 95% confidence limits for the respective means.

Migration year	Survival estimates					
	Yearling Chinook salmon			Steelhead		
	(%)	SE	95% CI	(%)	SE	95% CI
1998	53.8	4.6	44.8-62.8	50.0	5.4	39.4-60.6
1999	55.7	4.6	46.7-64.7	44.0	1.8	40.5-47.5
2000	48.6	9.3	30.4-66.8	39.3	3.4	32.6-46.0
2001	27.6	1.6	24.5-30.7	4.2	0.3	3.6-4.8
2002	57.8	6.0	46.0-69.6	26.2	5.0	16.4-36.0

DISCUSSION

We detected higher numbers of PIT-tagged fish in 2002 than in 2001 as a result of increased sampling effort, greater numbers of PIT-tagged fish released, and increased survival of in-river migrants. In both years, we use similar trawls and detection electronics, including the 2-coil antenna design for redundant detection. While detection numbers using the small trawl in the lower estuary were rather disappointing (less than 1 fish per h), we eventually established sampling routines and procedures which allowed for routine operations in the strong tidal and river currents existing there. We believe the electronics portion of the salt-water system functioned well based on detection efficiency of test tags.

The median travel time from Lower Granite Dam to Jones Beach for yearling Chinook salmon fish in 2002 (18.2 d) was similar to median travel times in the non-drought years of 1996 to 2000 (15-19 d), and notably faster than during the drought year of 2001 (median 32.7 d). Trends in travel times during these years were similar for steelhead. Trends in survival estimates for in-river migrants for both species also appeared related to annual river flow volumes, at least when flow was limiting, as in 2001 when most upriver stocks were transported. The proportion of transported fish we detected in 2002 (21%) was somewhat lower than in 2001 (31%).

The daily detection rates of transported and in-river migrant yearling Chinook salmon increased from about 1.0% in early May to over 2% by early June in 2002. There was no statistical difference in daily detection rates between these treatments. The ratio of daily detections between transported and in-river migrant steelhead declined from 1:1 in early May to 0.4 transport to 1.0 in-river fish by early June. By comparing detection percentages of barge-transported fish to those detected passing Bonneville Dam, we assumed that the sample distributions in the area were similar. Visual inspection of travel-time distribution plots supported this assumption, although additional analyses of these distributions is warranted. Comparison of trawl detections from fish released from barges with those detected at Bonneville Dam on the same day should properly reflect differences in survival to the estuary. Assuming that both groups were present on a given day, they were subject to the same sampling procedures and river conditions.

The differences in relative survival may reflect the degree of delayed mortality experienced by fish following transportation, and it is possible that for yearling Chinook salmon in 2002 there was little delayed mortality between barge release and the estuary.

Bonneville Dam and other dams now have detection systems designed for monitoring upstream migrating adult salmon containing 134.2-kHz PIT tags. Detections of adult fish at these sites will facilitate comparison of smolt-to-adult return ratios by date of transport and release.

Because of its size, the Columbia River estuary has previously been difficult to sample with sufficient consistency and rigor to discern trends in migration timing or survival of juvenile salmonids passing through it. PIT-tag technology has proven to be a valuable tool at hydroelectric facilities to specifically identify and evaluate fish groups of interest. In more recent years, development of the surface-trawl PIT-tag detection system has greatly enhanced our understanding of the differences in migration behavior and survival between a variety of fish populations with differing life histories that enter the Columbia River estuary.

For the first time in 2002, we extended sampling through July to obtain timing information for transported and in-river migrating subyearling fall Chinook salmon. We detected about 0.7% of the PIT-tagged fish using a single sampling crew. Daily flow volumes were about 25% higher in July 2002 than the 10-year average, and this higher flow no doubt reduced sampling efficiency by moving fish past the sample area more rapidly. Also for the first time in 2002, we extended this technology to obtain a sample of PIT-tagged fish from the brackish water portion of the estuary. Although the number of detections in this area were few, three fish were detected at both sites and their travel timing was rapid and correlated with the number of flood tides between detections.

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APPENDIX: Data Tables

Appendix Table 1. Design of the tape measure used to test antenna performance in 2002.

Position on tape measure (f)	Orientation (°)	Distance from previous tag (f)[a]	PIT-tag code[b]
117	0	0	3D9.1BF1011386
119	0	2	3D9.1BF100AB32
121	0	2	3D9.1BF101042C
123	45	2	3D9.1BF10091B6
125	45	2	3D9.1BF1011C76
128	0	3	3D9.1BF1008FBA
131	0	3	3D9.1BF1011AC3
134	0	3	3D9.1BF1010462
137	45	3	3D9.1BF100A707
140	45	3	3D9.1BF100BE5A
143	45	3	3D9.1BF1009593
145	0	2	3D9.1BF100A42E
147	0	2	3D9.1BF1011111
149	0	2	3D9.1BF1014524
150	0	1	3D9.1BF100971D
151	0	1	3D9.1BF10077C4
152	0	1	3D9.1BF100A8A6
155	0	3	3D9.1BF1009533
158	0	3	3D9.1BF10081F1
159	0	1	3D9.1BF10091EA
162	0	3	3D9.1BF1012045
163	0	1	3D9.1BF1009552
166	0	3	3D9.1BF10098C1
169	45	3	3D9.1BF1007D30
170	45	1	3D9.1BF100950A
172	0	2	3D9.1BF1008D28
173	0	1	3D9.1BF100A25D
175	0	2	3D9.1BF100A4E7
177	0	2	3D9.1BF100A0E8

Appendix Table 1. Continued.

Position on tape measure (f)	Orientation (°)	Distance from previous tag (f)[a]	PIT-tag code[b]
181	0	4	3D9.1BF100A239
183	0	2	3D9.1BF1009D7A
185	0	2	3D9.1BF10089A6
188	45	3	3D9.1BF1008A24
189	45	1	3D9.1BF100AA57
191	45	2	3D9.1BF10093E6
192	45	1	3D9.1BF100795B
194	45	2	3D9.1BF100A286
196	45	2	3D9.1BF1008738
200	45	4	3D9.1BF1007FC1
202	45	2	3D9.1BF100911E
204	45	2	3D9.1BF1007D3F
206	0	2	3D9.1BF10092EB
208	0	2	3D9.1BF100A865
210	0	2	3D9.1BF1009F26
212	0	2	3D9.1BF1008E89
214	45	2	3D9.1BF1009B08
216	45	2	3D9.1BF101074D
218	45	2	3D9.1BF1009A75
220	45	2	3D9.1BF1009A8A
225	0	5	3D9.1BF1009EA8

a. Distance from previous tag as measured in the direction from 117 to 225 ft.

b. PIT-tags were tested after each antenna evaluation with a hand-held reader and replaced as needed.

Appendix Table 2. Daily total PIT-tag sample time and detections for each salmonid species using a large pair-trawl at Jones Beach, 2002.

Date	Total time underway (h)	Pit-tag detections (N)					
		Unknown	Chinook salmon	Coho salmon	Steelhead	Sockeye salmon	Total
15 Apr	1.9	0	0	0	4	0	4
17 Apr	3.0	0	2	0	7	0	9
19 Apr	4.2	0	2	0	4	0	6
22 Apr	3.7	1	2	0	2	0	5
24 Apr	1.0	0	2	0	1	0	3
26 Apr	4.1	0	5	0	6	0	11
29 Apr	4.3	0	5	0	1	0	6
30 Apr	6.5	0	18	0	8	0	26
1 May	10.1	0	29	0	12	0	41
2 May	7.9	0	9	0	5	0	14
3 May	4.1	0	6	0	13	0	19
4 May	10.9	0	32	0	13	0	45
5 May	5.3	0	25	0	1	0	26
6 May	5.8	0	25	0	3	0	28
7 May	12.0	0	56	0	28	0	84
8 May	13.4	1	121	0	33	0	155
9 May	10.4	1	47	0	6	0	54
10 May	6.7	1	52	1	9	0	63
11 May	12.8	0	70	1	28	0	99
12 May	15.5	0	180	1	22	1	204
13 May	8.1	0	69	2	8	0	79
14 May	13.4	1	106	0	9	0	116
15 May	17.6	3	158	1	20	1	183
16 May	19.0	4	504	1	10	0	519
17 May	10.8	1	238	0	11	1	251
18 May	11.9	3	264	0	6	0	273
19 May	10.7	2	333	0	5	1	341
20 May	13.0	0	468	2	6	1	477
21 May	13.6	2	562	0	12	0	576

Appendix Table 2. Continued.

Date	Total time underway (h)	Pit-tag detections (N)					
		Unknown	Chinook salmon	Coho salmon	Steelhead	Sockeye salmon	Total
22 May	21.6	4	725	0	18	3	750
23 May	15.7	3	685	1	13	1	703
24 May	9.5	2	362	0	6	0	370
25 May	13.5	6	615	2	15	1	639
26 May	13.7	0	476	3	21	2	502
27 May	11.4	0	294	2	7	1	304
28 May	13.4	1	389	1	83	2	476
29 May	22.3	5	1,025	3	101	0	1,134
30 May	16.9	2	345	3	32	0	382
31 May	6.3	0	167	2	19	0	188
1 Jun	13.9	3	240	3	28	1	275
2 Jun	12.6	0	104	2	22	1	129
4 Jun	13.9	2	140	9	61	0	212
5 Jun	16.8	2	162	17	38	4	223
6 Jun	15.1	0	128	16	59	1	* 205
7 Jun	9.0	0	68	7	40	1	116
8 Jun	6.0	0	77	3	27	2	109
9 Jun	9.0	0	60	1	22	0	83
10 Jun	7.0	0	73	4	48	1	126
11 Jun	5.5	0	13	3	13	1	30
12 Jun	5.3	0	14	3	22	1	40
13 Jun	5.9	0	9	1	3	0	13
14 Jun	6.6	0	15	2	6	0	23
17 Jun	6.2	0	5	0	4	0	9
18 Jun	4.8	0	7	2	2	0	11
19 Jun	3.5	0	6	0	1	0	7
20 Jun	6.4	0	7	1	9	0	17
24 Jun	4.7	0	2	1	2	0	5
26 Jun	4.3	0	0	0	0	0	0

Appendix Table 2. Continued.

Date	Total time underway (h)	Pit-tag detections (N)					
		Unknown	Chinook salmon	Coho salmon	Steelhead	Sockeye salmon	Total
27 Jun	5.8	0	0	0	0	0	0
28 Jun	6.1	1	47	0	0	0	48
29 Jun	6.4	0	9	0	0	0	9
1 Jul	6.4	0	25	0	4	0	29
2 Jul	3.2	0	6	0	0	0	6
3 Jul	5.0	0	16	0	0	0	16
5 Jul	6.4	0	28	0	0	0	28
6 Jul	6.0	1	64	0	0	0	65
8 Jul	5.1	0	17	0	0	0	17
9 Jul	5.3	0	10	0	0	0	10
11 Jul	5.7	0	6	0	0	0	6
12 Jul	6.7	0	18	0	0	0	18
13 Jul	5.5	0	44	0	0	0	44
15 Jul	3.8	0	25	0	0	0	25
16 Jul	6.9	0	72	0	0	0	72
18 Jul	5.6	0	73	0	0	0	73
19 Jul	5.4	2	35	0	0	0	37
20 Jul	5.9	0	39	0	0	0	39
22 Jul	3.6	2	7	0	0	0	9
23 Jul	5.2	0	0	0	0	0	0
25 Jul	6.2	0	13	0	0	0	13
26 Jul	2.9	0	1	0	0	0	1
29 Jul	5.7	2	79	0	0	0	81
30 Jul	6.4	0	7	0	0	0	7
Totals	693.7	58	10,244	101	1,019	28	11,451

* One sea-run cutthroat trout was detected on 6 June.

Appendix Table 3. Daily total PIT-tag sample time and detections for each salmonid species using a salt-water-tolerant PIT tag antenna and small pair-trawl in the Columbia River estuary, 2002.

		Pit-tag detections (N)				
Date	Total time underway (h)	Unknown	Chinook salmon	Coho salmon	Steelhead	Total
18 Apr *	0.6	0	0	0	0	0
19 Apr *	2.8	0	0	0	0	0
22 Apr *	3.8	0	0	0	1	1
24 Apr *	3.4	0	1	0	0	1
26 Apr *	4.5	0	0	0	0	0
29 Apr *	4.6	0	0	0	0	0
30 Apr *	6.4	0	2	0	1	3
1 May *	5.5	0	1	0	1	2
2 May *	5.4	0	1	0	1	2
7 May *	6.5	0	3	0	4	7
8 May *	5.7	0	8	0	3	11
13 May *	6.5	0	2	0	4	6
14 May *	7.7	0	1	0	4	5
15 May *	5.7	0	0	0	1	1
16 May *	5.9	0	1	0	0	1
18 May *	6.7	0	9	0	0	9
21 May	7.7	0	19	1	2	22
22 May	10.3	1	6	0	2	9
23 May	3.7	0	2	0	1	3
24 May	4.3	0	3	0	0	3
25 May	7.7	0	5	0	1	6
27 May	5.9	0	7	0	3	10
29 May	8.6	0	1	0	0	1
30 May	8.9	0	4	0	2	6
31 May	5.2	0	1	0	0	1
1 Jun *	6.2	0	3	0	2	5
2 Jun *	5.9	0	12	0	10	22
4 Jun	7.4	0	0	0	4	4
5 Jun	6.8	0	0	0	3	3
6 Jun	6.1	1	0	1	2	4
7 Jun	8.8	0	0	0	1	1

Appendix Table 3. Continued.

Date	Total time underway (h)	Pit-tag detections (N)				
		Unknown	Chinook salmon	Coho salmon	Steelhead	Total
10 Jun	4.8	0	1	2	1	4
11 Jun	5.8	0	0	0	1	1
12 Jun	5.1	0	0	0	0	0
13 Jun	5.1	0	0	0	0	0
14 Jun	6.0	0	0	0	0	0
18 Jun *	5.8	0	3	0	4	7
19 Jun *	5.7	0	0	0	1	1
20 Jun *	5.5	0	0	0	6	6
24 Jun *	5.0	0	0	0	0	0
26 Jun *	5.0	0	0	0	0	0
27 Jun *	5.6	0	0	0	0	0
28 Jun *	6.7	0	0	0	0	0
2 Jul *	5.6	0	0	0	0	0
3 Jul *	7.4	0	0	0	0	0
Totals	251.1	2	4	2	13	19

* Sample day in freshwater at Jones Beach directly in front of the large trawl. Other days were downstream in the lower estuary–brackish water.

Appendix Table 4. Daily total of impinged fish using a PIT-tag detector trawl at Jones Beach (Columbia River kilometer 75), 2002.

Date	Chinook salmon Yearling	Chinook salmon Subyearling	Coho salmon	Steelhead	Sockeye salmon	Non-salmonid species
15 Apr	0	0	0	0	0	0
16 Apr	0	0	0	0	0	0
17 Apr	0	0	0	0	0	0
18 Apr	0	0	0	0	0	0
19 Apr	0	0	0	0	0	0
20 Apr	0	0	0	0	0	0
21 Apr	0	0	0	0	0	0
22 Apr	0	1	0	0	0	0
23 Apr	0	0	0	0	0	0
24 Apr	0	0	0	0	0	0
25 Apr	0	0	0	0	0	0
26 Apr	0	0	0	0	0	0
27 Apr	0	0	0	0	0	0
28 Apr	0	0	0	0	0	0
29 Apr	0	0	0	0	0	0
30 Apr	0	0	0	0	0	0
1 May	0	0	0	0	0	0
2 May	0	0	0	0	0	0
3 May	0	0	0	0	0	0
4 May	0	0	0	0	0	0
5 May	0	0	0	0	0	0
6 May	0	0	0	0	0	0
7 May	0	0	0	0	0	0
8 May	0	0	0	0	0	0
9 May	0	0	0	0	0	0
10 May	0	0	0	0	0	1 [a]
11 May	0	0	0	0	0	0
12 May	0	0	0	0	0	0
13 May	0	0	0	0	0	0
14 May	0	0	0	0	0	0
15 May	0	0	0	0	0	1 [b]
16 May	1	2	1	0	0	0
17 May	0	0	0	0	0	0
18 May	2	4	1	1	0	0
19 May	12	25	8	5	3	0
20 May	0	0	0	0	0	0

Appendix Table 4. Continued.

Date	Chinook salmon		Coho salmon	Steelhead	Sockeye salmon	Non-salmonid species
	Yearling	Subyearling				
21 May	0	0	0	0	0	0
22 May	0	0	0	0	0	0
23 May	4	8	3	2	1	0
24 May	4	7	3	2	1	0
25 May	7	14	5	3	2	0
26 May	4	9	3	2	1	0
27 May	7	14	5	3	2	0
28 May	0	0	0	0	0	0
29 May	3	6	2	1	1	0
30 May	2	4	1	1	0	0
31 May	0	0	0	0	0	0
1 Jun	0	0	0	0	0	0
2 Jun	0	0	0	0	0	0
3 Jun	0	0	0	0	0	0
4 Jun	0	0	0	0	0	0
5 Jun	0	0	0	0	0	0
6 Jun	0	0	0	0	0	0
7 Jun	0	0	0	0	0	0
8 Jun	0	0	0	0	0	0
9 Jun	0	0	0	0	0	0
10 Jun	0	0	0	0	0	0
11 Jun	0	0	0	0	0	0
12 Jun	0	0	0	0	0	0
13 Jun	0	0	0	0	0	0
14 Jun	0	0	0	0	0	0
15 Jun	0	0	0	0	0	0
16 Jun	0	0	0	0	0	0
17 Jun	0	0	0	0	0	0
18 Jun	0	0	0	0	0	0
19 Jun	0	0	0	0	0	0
20 Jun	0	0	0	0	0	0
21 Jun	0	0	0	0	0	0
22 Jun	0	0	0	0	0	0
23 Jun	0	0	0	0	0	0
24 Jun	0	0	0	0	0	0
25 Jun	0	0	0	0	0	0
26 Jun	0	0	0	0	0	0

Appendix Table 4. Continued.

Date	Chinook salmon		Coho salmon	Steelhead	Sockeye salmon	Non-salmonid species
	Yearling	Subyearling				
27 Jun	0	0	0	0	0	1 [c]
28 Jun	0	0	0	0	0	0
29 Jun	0	0	0	0	0	0
30 Jun	0	0	0	0	0	0
1 Jul	0	0	0	0	0	0
2 Jul	0	0	0	0	0	0
3 Jul	0	0	0	0	0	0
4 Jul	0	0	0	0	0	0
5 Jul	0	0	0	0	0	0
6 Jul	0	0	0	0	0	0
7 Jul	0	0	0	0	0	0
8 Jul	0	0	0	0	0	0
9 Jul	0	0	0	0	0	0
10 Jul	0	0	0	0	0	0
11 Jul	0	0	0	0	0	0
12 Jul	0	0	0	0	0	0
13 Jul	0	0	0	0	0	0
14 Jul	0	0	0	0	0	0
15 Jul	0	0	0	0	0	0
16 Jul	0	0	0	0	0	0
17 Jul	0	0	0	0	0	0
18 Jul	0	0	0	0	0	0
19 Jul	0	0	0	0	0	0
20 Jul	0	0	0	0	0	0
21 Jul	0	0	0	0	0	0
22 Jul	0	0	0	0	0	0
23 Jul	0	0	0	0	0	0
24 Jul	0	0	0	0	0	0
25 Jul	0	0	0	0	0	0
26 Jul	0	0	0	0	0	0
27 Jul	0	0	0	0	0	0
28 Jul	0	0	0	0	0	0
29 Jul	0	0	0	0	0	0
30 Jul	0	0	0	0	0	0
Totals	45	94	32	19	11	3

a bullhead
b juvenile shad
c adult shad

Appendix Table 5. Daily total of impinged fish using a saltwater tolerant PIT-tag detector pair-trawl in the Columbia River estuary, 2002.

Date	Chinook salmon Yearling	Chinook salmon Subyearling	Coho salmon	Steelhead	Sockeye salmon	Non-salmonid species
18 Apr	0	0	0	0	0	0
19 Apr	0	0	0	0	0	0
20 Apr	0	0	0	0	0	0
21 Apr	0	0	0	0	0	0
22 Apr	0	0	0	0	0	0
23 Apr	0	0	0	0	0	2 [a]
24 Apr	0	0	0	0	0	1 [a]
25 Apr	0	0	0	0	0	0
26 Apr	0	0	0	0	0	0
27 Apr	0	0	0	0	0	0
28 Apr	0	0	0	0	0	0
29 Apr	0	0	0	0	0	0
30 Apr	0	0	0	0	0	0
1 May	0	0	0	0	0	0
2 May	0	0	0	0	0	0
3 May	0	0	0	0	0	0
4 May	0	0	0	0	0	0
5 May	0	0	0	0	0	0
6 May	0	0	0	0	0	0
7 May	0	0	0	0	0	0
8 May	0	0	0	0	0	0
9 May	0	0	0	0	0	0
10 May	0	0	0	0	0	0
11 May	0	0	0	0	0	0
12 May	0	0	0	0	0	0
13 May	0	0	0	0	0	0
14 May	0	0	0	0	0	0
15 May	0	0	0	0	0	0
16 May	0	0	0	0	0	0
17 May	0	0	0	0	0	0
18 May	0	0	0	0	0	0

Appendix Table 5. Continued.

Date	Chinook salmon		Coho salmon	Steelhead	Sockeye salmon	Non-salmonid species
	Yearling	Subyearling				
19 May	0	0	0	0	0	0
20 May	0	0	0	0	0	0
21 May	0	0	0	0	0	0
22 May	0	0	0	0	0	0
23 May	0	0	0	0	0	0
24 May	0	0	0	0	0	0
25 May	0	0	0	0	0	0
26 May	0	0	0	0	0	0
27 May	0	0	0	0	0	12 [b]
28 May	0	0	0	0	0	0
29 May	0	0	0	0	0	0
30 May	0	0	0	0	0	0
31 May	0	0	0	0	0	0
1 Jun	0	0	0	0	0	0
2 Jun	0	0	0	0	0	0
3 Jun	0	0	0	0	0	0
4 Jun	0	0	0	0	0	8 [b]
5 Jun	0	0	0	0	0	0
6 Jun	0	0	0	0	0	100 [b]
7 Jun	0	0	0	0	0	0
8 Jun	0	0	0	0	0	0
9 Jun	0	0	0	0	0	0
10 Jun	0	0	0	0	0	100 [c]
11 Jun	0	0	0	0	0	27 [d]
12 Jun	0	0	0	0	0	0
13 Jun	0	0	0	0	0	0
14 Jun	0	0	0	0	0	0
15 Jun	0	0	0	0	0	0
16 Jun	0	0	0	0	0	0
17 Jun	0	0	0	0	0	0
18 Jun	0	0	0	0	0	0

Appendix Table 5. Continued.

Date	Chinook salmon		Coho salmon	Steelhead	Sockeye salmon	Non-salmonid species
	Yearling	Subyearling				
19 Jun	0	0	0	0	0	0
20 Jun	0	0	0	0	0	0
21 Jun	0	0	0	0	0	0
22 Jun	0	0	0	0	0	0
23 Jun	0	0	0	0	0	0
24 Jun	0	0	0	0	0	0
25 Jun	0	0	0	0	0	0
26 Jun	0	0	0	0	0	0
27 Jun	0	0	0	0	0	0
28 Jun	0	0	0	0	0	0
29 Jun	0	0	0	0	0	0
30 Jun	0	0	0	0	0	0
1 Jul	0	0	0	0	0	0
2 Jul	0	0	0	0	0	0
3 Jul	0	0	0	0	0	0
Totals	0	0	0	0	0	250

a anchovy
b surf smelt
c bait fish
d 24 bait fish, 2 surf smelt, 1 perch

Appendix Table 6. Diel sampling of yearling Chinook salmon and steelhead using a PIT-tag detector surface pair-trawl at Jones Beach (Columbia River kilometer 75), 2002. Effort, rounded to the nearest tenth, is presented as a decimal hour.

		Diel Period 1: 15-16 May							
		Yearling Chinook salmon				Steelhead			
Diel	Effort	n		n/h		n		n/h	
hour	(h)	Hatchery	Wild	Hatchery	Wild	Hatchery	Wild	Hatchery	Wild
0	1.0	23	2	23.8	2.1	0	1	0.0	1.0
1	1.0	17	2	17.0	2.0	0	0	0.0	0.0
2	1.0	42	2	42.0	2.0	0	1	0.0	1.0
3	1.0	64	6	64.0	6.0	0	1	0.0	1.0
4	1.0	47	7	47.0	7.0	0	0	0.0	0.0
5	1.0	99	7	99.0	7.0	0	1	0.0	1.0
6	1.5	53	4	36.6	2.8	0	2	0.0	1.4
7	2.0	6	0	3.0	0.0	0	0	0.0	0.0
8	2.0	5	2	2.5	1.0	0	0	0.0	0.0
9	2.0	4	0	2.0	0.0	0	0	0.0	0.0
10	2.0	6	2	3.0	1.0	0	0	0.0	0.0
11	2.0	3	0	1.5	0.0	0	0	0.0	0.0
12	1.0	0	1	0.0	1.0	1	0	1.0	0.0
13	0.8	1	0	1.3	0.0	0	0	0.0	0.0
14	1.0	5	1	5.0	1.0	2	0	2.0	0.0
15	1.0	5	0	5.0	0.0	0	3	0.0	3.0
16	1.0	4	2	4.0	2.0	1	1	1.0	1.0
17	1.0	2	0	2.0	0.0	1	2	1.0	2.0
18	1.0	5	0	5.0	0.0	2	1	2.0	1.0
19	1.0	11	2	11.0	2.0	1	2	1.0	2.0
20	1.0	2	2	2.0	2.0	0	0	0.0	0.0
21	0.9	26	8	27.9	8.6	1	0	1.1	0.0
22	1.0	37	1	37.0	1.0	0	0	0.0	0.0
23	1.0	17	2	17.0	2.0	0	1	0.0	1.0

Appendix Table 6. Continued.

		Diel Period 2: 21-23 May							
		Yearling Chinook salmon				Steelhead			
Diel	Effort	n		n/h		n		n/h	
hour	(h)	Hatchery	Wild	Hatchery	Wild	Hatchery	Wild	Hatchery	Wild
0	1.9	129	7	66.7	3.6	1	0	0.5	1.9
1	2.0	138	9	69.0	4.5	0	2	0.0	2.3
2	2.0	177	14	90.0	7.1	0	1	0.0	3.6
3	1.9	51	3	26.4	1.6	0	0	0.0	0.8
4	2.0	33	1	16.5	0.5	0	0	0.0	0.3
5	1.8	77	6	44.0	3.4	0	0	0.0	2.0
6	2.0	71	1	35.5	0.5	0	1	0.0	0.3
7	1.1	8	2	7.4	1.8	2	0	1.8	1.7
8	1.4	31	0	22.1	0.0	0	1	0.0	0.0
9	2.0	34	3	17.0	1.5	1	0	0.5	0.8
10	1.8	13	1	7.2	0.6	0	0	0.0	0.3
11	1.6	15	0	9.2	0.0	0	0	0.0	0.0
12	1.1	40	5	35.8	4.5	0	0	0.0	4.0
13	1.0	6	1	6.0	1.0	1	1	1.0	1.0
14	1.0	8	0	8.0	0.0	0	0	0.0	0.0
15	0.8	4	0	4.8	0.0	0	0	0.0	0.0
16	0.0	0	0	--	--	0	0	--	--
17	0.6	8	0	13.0	0.0	0	2	0.0	0.0
18	1.4	16	3	11.9	2.2	0	4	0.0	1.6
19	2.0	40	6	20.0	3.0	0	6	0.0	1.5
20	2.0	72	4	36.0	2.0	0	2	0.0	1.0
21	2.0	102	5	51.0	2.5	0	3	0.0	1.3
22	2.0	155	5	77.5	2.5	0	0	0.0	1.3
23	2.0	128	5	64.0	2.5	0	1	0.0	1.3

Appendix Table 6. Continued.

		Diel Period 3: 28-30 May							
		Yearling Chinook salmon				Steelhead			
Diel	Effort	n		n/h		n		n/h	
hour	(h)	Hatchery	Wild	Hatchery	Wild	Hatchery	Wild	Hatchery	Wild
0	1.9	10	3	5.2	1.6	0	2	0.0	1.0
1	2.0	45	3	22.5	1.5	0	1	0.0	0.5
2	2.0	76	10	38.0	5.0	2	1	1.0	0.5
3	2.0	77	11	38.5	5.5	1	1	0.5	0.5
4	2.0	146	10	73.0	5.0	0	3	0.0	1.5
5	1.8	114	14	62.2	7.6	0	1	0.0	0.5
6	2.0	178	15	89.0	7.5	4	7	2.0	3.5
7	2.0	75	5	37.5	2.5	3	8	1.5	4.0
8	1.2	15	1	12.9	0.9	2	1	1.7	0.9
9	1.2	11	0	9.2	0.0	0	1	0.0	0.8
10	2.0	7	1	3.5	0.5	0	1	0.0	0.5
11	2.0	24	1	12.0	0.5	4	4	2.0	2.0
12	2.0	53	4	26.5	2.0	2	4	1.0	2.0
13	1.2	56	4	47.3	3.4	4	7	3.4	5.9
14	1.0	23	1	23.0	1.0	6	5	6.0	5.0
15	1.0	57	4	57.0	4.0	3	12	3.0	12.0
16	1.0	56	10	56.0	10.0	4	17	4.0	17.0
17	1.0	51	8	49.4	7.7	2	9	1.9	8.7
18	2.0	59	4	29.7	2.0	5	19	2.5	9.6
19	1.5	29	3	19.1	2.0	0	7	0.0	4.6
20	1.1	22	1	20.3	0.9	2	8	1.8	7.4
21	2.0	55	8	27.5	4.0	0	8	0.0	4.0
22	2.0	103	13	51.5	6.5	3	6	1.5	3.0
23	2.0	8	0	4.0	0.0	0	2	0.0	1.0

Appendix Table 6. Continued.

		Diel Period 4: 4-6 June							
		Yearling Chinook salmon				Steelhead			
		n		n/h		n		n/h	
Diel hour	Effort (h)	Hatchery	Wild	Hatchery	Wild	Hatchery	Wild	Hatchery	Wild
0	1.9	8	0	4.2	0.0	2	1	1.1	0.5
1	1.8	14	0	8.0	0.0	1	0	0.6	0.0
2	1.0	2	1	2.0	1.0	2	1	2.0	1.0
3	1.0	5	2	5.0	2.0	1	1	1.0	1.0
4	1.0	4	0	4.0	0.0	1	1	1.0	1.0
5	1.5	19	1	13.0	0.7	0	0	0.0	0.0
6	1.2	12	2	10.0	1.7	2	4	1.7	3.3
7	2.0	21	0	10.5	0.0	2	10	1.0	5.0
8	2.0	36	5	18.0	2.5	4	7	2.0	3.5
9	2.0	24	5	12.0	2.5	6	8	3.0	4.0
10	2.0	12	2	6.0	1.0	3	5	1.5	2.5
11	1.9	10	1	5.2	0.5	3	8	1.6	4.1
12	1.0	5	0	5.0	0.0	0	0	0.0	0.0
13	0.4	1	0	2.7	0.0	2	0	5.5	0.0
14	0.0	6	0	--	--	0	0	--	--
15	0.9	9	0	10.6	0.0	0	0	0.0	0.0
16	0.8	4	0	5.2	0.0	0	0	0.0	0.0
17	1.0	2	2	2.0	2.0	2	0	2.0	0.0
18	0.8	5	0	6.0	0.0	0	0	0.0	0.0
19	1.0	20	5	20.0	5.0	1	1	1.0	1.0
20	1.8	0	0	0.0	0.0	0	2	0.0	1.1
21	2.0	0	0	0.0	0.0	0	2	0.0	1.0
22	2.0	16	4	8.0	2.0	2	0	1.0	0.0
23	2.0	9	1	4.5	0.5	1	0	0.5	0

Appendix Table 6. Continued.

		Average of 4 Diel Periods							
		Yearling Chinook salmon				Steelhead			
Diel	Effort	n		n/h		n		n/h	
hour	(h)	Hatchery	Wild	Hatchery	Wild	Hatchery	Wild	Hatchery	Wild
0	6.7	170	12	25.2	1.8	3	4	0.4	0.0
1	6.8	214	14	31.7	2.1	1	3	0.1	0.0
2	6.0	297	27	49.8	4.5	4	4	0.7	0.0
3	5.9	197	22	33.2	3.7	2	3	0.3	0.0
4	6.0	230	18	38.3	3.0	1	4	0.2	0.0
5	6.1	309	28	51.1	4.6	0	2	0.0	0.0
6	6.7	314	22	47.2	3.3	6	14	0.9	0.0
7	7.1	110	7	15.5	1.0	7	18	1.0	0.2
8	6.6	87	8	13.2	1.2	6	9	0.9	0.1
9	7.2	73	8	10.1	1.1	7	9	1.0	0.1
10	7.8	38	6	4.9	0.8	3	6	0.4	0.2
11	7.6	52	2	6.9	0.3	7	12	0.9	0.2
12	5.1	98	10	19.2	2.0	3	4	0.6	0.0
13	3.3	64	5	19.3	1.5	7	8	2.1	0.1
14	3.0	42	2	14.0	0.7	8	5	2.7	0.1
15	3.7	75	4	20.4	1.1	3	15	0.8	0.2
16	2.8	64	12	23.1	4.3	5	18	1.8	0.3
17	3.7	63	10	17.3	2.7	5	13	1.4	0.2
18	5.2	85	7	16.5	1.4	7	24	1.4	0.3
19	5.5	100	16	18.1	2.9	2	16	0.4	0.2
20	5.8	96	7	16.5	1.2	2	12	0.3	0.1
21	6.9	183	21	26.4	3.0	1	13	0.1	0.1
22	7.0	311	23	44.4	3.3	5	6	0.7	0.0
Totals									
	139.3	3434	299	24.7	2.1	96	226	0.7	1.6

Appendix Table 7. Number of PIT-tagged yearling Chinook salmon loaded on transport barges at each of four dams and numbers detected in the estuary. LGR, Lower Granite; LGO, Little Goose; LMN, Lower Monumental; MCN, McNary Dam. Transport dates were 9 April-18 August; trawl detector was operated 15 April-30 July, with intensive sampling 30 April-9 June 2002.

Release date and time	Numbers loaded at each dam and total fish loaded (n)*					Numbers detected from each dam and total numbers detected (n)					
	LGR	LGO	LMN	MCN	n	LGR	LGO	LMN	MCN	n	(%)
na	0	0	0	1	1	0.0	0.0	0.0	0.0	0	0.0
09 Apr 15:30	260	6	2	0	268	0.0	0.0	0.0	--	0	0.0
11 Apr 15:30	76	2	0	0	78	0.0	0.0	--	--	0	0.0
13 Apr 15:00	193	7	0	0	200	1.0	0.0	--	--	2	1.0
15 Apr 18:45	402	47	0	0	449	0.0	4.3	--	--	2	0.4
17 Apr 16:30	1,264	183	3	1	1,451	0.2	1.1	0.0	0.0	4	0.3
20 Apr 01:15	1,162	337	7	78	1,584	0.3	0.9	0.0	0.0	6	0.4
22 Apr 01:55	753	291	0	226	1,270	0.1	0.3	--	0.4	3	0.2
24 Apr 02:05	826	357	28	264	1,475	0.1	0.0	0.0	0.0	1	0.1
25 Apr 01:00	204	125	0	187	516	0.0	0.8	--	0.0	1	0.2
26 Apr 01:00	376	167	1	181	725	1.9	0.0	0.0	1.1	9	1.2
26 Apr 20:30	325	163	19	221	728	0.3	1.8	0.0	0.0	4	0.5
28 Apr 02:20	494	259	0	188	941	1.0	1.9	--	0.5	11	1.2
29 Apr 02:00	481	433	0	219	1,133	0.4	1.4	--	0.5	9	0.8
30 Apr 01:20	447	336	0	173	956	0.2	0.6	--	0.6	4	0.4
30 Apr 18:30	279	292	24	185	780	0.4	0.7	0.0	0.5	4	0.5
2 May 02:05	306	246	28	228	808	0.7	1.2	0.0	0.4	6	0.7
3 May 00:00	324	539	615	333	1,811	0.0	1.7	2.1	0.9	25	1.4
4 May 02:10	237	939	519	525	2,220	2.5	0.9	1.2	0.6	23	1.0
5 May 01:20	473	1,117	58	776	2,424	0.4	1.3	1.7	0.9	25	1.0
6 May 03:05	1,591	2,104	542	1,154	5,391	0.4	1.7	2.2	0.7	62	1.2
7 May 01:45	1,449	1,576	375	1,038	4,438	0.3	0.5	1.9	0.4	23	0.5
8 May 13:30	1,879	1,023	7	1,013	3,922	0.4	0.3	0.0	0.6	16	0.4
8 May 22:00	1,046	807	257	1,578	3,688	0.9	0.9	2.7	1.1	41	1.1

Appendix Table 7. Continued.

Release date and time	Numbers loaded at each dam and total fish loaded (n)b					Numbers detected from each dam and total numbers detected (n)					
	LGR	LGO	LMN	MCN	n	LGR	LGO	LMN	MCN	n	(%)
10 May 00:45	706	655	171	1,060	2,592	1.7	1.8	1.8	1.4	42	1.6
10 May 18:15	684	512	6	848	2,050	0.4	2.7	0.0	0.2	19	0.9
12 May 00:15	391	361	197	1,699	2,648	0.3	0.8	0.5	0.2	8	0.3
12 May 21:00	577	361	2,247	1,429	4,614	0.2	1.4	1.6	4.1	99	2.1
14 May 01:00	304	426	10	2,213	2,953	1.3	6.8	10.0	3.9	120	4.1
15 May 00:15	552	643	131	2,402	3,728	1.8	3.6	4.6	1.1	65	1.7
16 May 02:20	422	449	134	2,863	3,868	2.4	2.0	4.5	1.9	78	2.0
16 May 15:30	1,160	599	25	1,917	3,701	2.5	2.2	16.0	3.1	106	2.9
18 May 02:35	568	613	348	3,050	4,579	3.5	2.6	3.2	3.1	141	3.1
18 May 23:20	659	1,257	331	2,542	4,789	1.5	0.8	0.6	2.7	90	1.9
20 May 01:05	586	942	48	2,493	4,069	1.5	3.2	2.1	3.6	130	3.2
21 May 01:00	813	807	355	2,975	4,950	2.0	1.0	2.0	2.4	102	2.1
22 May 03:20	815	627	328	2,959	4,729	1.5	1.4	0.6	1.9	78	1.6
22 May 21:25	790	919	28	2,957	4,694	1.4	1.2	3.6	3.4	125	2.7
24 May 02:30	490	1,575	357	3,063	5,485	2.0	2.9	3.4	2.8	155	2.8
24 May 20:20	365	978	466	945	2,754	1.6	0.7	0.4	0.3	18	0.7
25 May 22:40	419	708	47	1,051	2,225	1.4	2.3	2.1	0.9	32	1.4
27 May 02:05	79	314	300	2,339	3,032	6.3	5.1	6.0	2.8	105	3.5
28 May 03:30	177	253	184	1,410	2,024	4.5	1.6	3.8	1.8	44	2.2
28 May 18:10	209	359	19	875	1,462	2.4	1.9	0.0	2.5	34	2.3
30 May 04:49	154	315	311	1,068	1,848	0.0	2.2	1.6	1.3	26	1.4
31 May 02:30	23	466	319	602	1,410	0.0	0.9	0.3	0.8	10	0.7
2 Jun 04:20	484	1,128	412	1,088	3,112	1.2	0.2	0.2	0.1	10	0.3
2 Jun 22:30	38	544	141	167	890	0.0	2.4	3.5	2.4	22	2.5
5 Jun 00:00	187	684	320	353	1,544	1.6	1.2	0.3	1.4	17	1.1
6 Jun 17:20	324	414	272	11	1,021	0.0	2.4	2.2	0.0	16	1.6
8 Jun 23:30	240	229	302	95	866	3.8	3.1	3.6	1.1	28	3.2
10 Jun 22:20	136	318	252	67	773	0.0	0.0	0.4	3.0	3	0.4
12 Jun 22:40	50	270	100	0	420	2.0	0.4	2.0	--	4	1.0
14 Jun 16:15	20	47	153	1	221	0.0	0.0	0.7	0.0	1	0.5

Appendix Table 7. Continued.

Release date and time	Numbers loaded at each dam and total fish loaded (n)b					Numbers detected from each dam and total numbers detected (n)					
	LGR	LGO	LMN	MCN	n	LGR	LGO	LMN	MCN	n	(%)
16 Jun 23:20	22	25	27	18	92	4.5	0.0	0.0	0.0	1	1.1
18 Jun 22:30	28	50	9	17	104	0.0	0.0	0.0	0.0		0.0
20 Jun 22:00	95	102	22	7	226	0.0	0.0	0.0	0.0		0.0
22 Jun 17:00	50	52	7	1	110	0.0	1.9	0.0	0.0	1	0.9
24 Jun 16:15	38	29	1	1	69	0.0	0.0	0.0	0.0		0.0
27 Jun 00:00	63	25	0	2,871	2,959	1.6	0.0	--	1.3	38	1.3
28 Jun 22:25	33	53	1	2,563	2,650	0.0	0.0	0.0	0.1	2	0.1
30 Jun 16:15	16	9	4	0	29	0.0	0.0	0.0	--		0.0
2 Jul 22:05	74	37	5	1,345	1,461	0.0	0.0	0.0	0.1	1	0.1
4 Jul 22:40	7	3	2	3,762	3,774	0.0	0.0	0.0	1.1	42	1.1
6 Jul 16:50	21	14	4	57	96	0.0	0.0	0.0	0.0		0.0
8 Jul 15:30	47	21	3	20	91	0.0	0.0	0.0	0.0		0.0
11 Jul 01:00	11	9	0	1,104	1,124	0.0	0.0	--	0.3	3	0.3
13 Jul 00:35	6	8	0	1,213	1,227	0.0	0.0	--	0.4	5	0.4
15 Jul 01:50	4	7	1	2,806	2,818	0.0	0.0	0.0	0.5	13	0.5
17 Jul 02:00	9	5	0	47	61	0.0	0.0	--	0.0		0.0
19 Jul 03:15	26	3	0	2,706	2,735	0.0	0.0	--	1.3	35	1.3
21 Jul 01:00	11	3	1	1,644	1,659	0.0	0.0	0.0	0.5	9	0.5
23 Jul 02:05	22	3	1	21	47	0.0	0.0	0.0	0.0		0.0
25 Jul 00:05	6	2	1	45	54	0.0	0.0	0.0	0.0		0.0
27 Jul 02:25	6	1	4	33	44	0.0	0.0	0.0	0.0		0.0
29 Jul 13:50	10	0	0	2,753	2,763	0.0	--	--	2.0	56	2.0
31 Jul-18 Aug	42	2	2	16,260	16,306	0.0	0.0	0.0	0.0	0	0.0
Totals/means	27,916	29,592	10,894	92,404	160,806	1.0	1.5	1.8	1.4	2,215	1.4

* Beginning in mid-June most PIT-tagged Chinook salmon detected in the estuary were subyearling migrants tagged in the upper Columbia River or Snake River.

Appendix Table 8. Number of PIT-tagged steelhead loaded at each of four dams and number and rate of fish detected in the estuary. Dams: LGR, Lower Granite; LGO, Little Goose; LMN, Lower Monumental; MCN, McNary. Transport dates were 9 April-18 August; trawl was operated 15 April-30 July, with intensive sampling 30 April-9 June 2002.

Release date and time	Numbers loaded at each dam and total fish loaded (n)					Numbers detected from each dam and total numbers detected (n)					
	LGR	LGO	LMN	MCN	n	LGR	LGO	LMN	MCN	n	(%)
09 Apr 15:30	0	5	3	0	8	0.0	0.0	0.0	0.0	0	0.0
11 Apr 15:30	2	0	0	0	2	0.0	0.0	0.0	0.0	0	0.0
13 Apr 15:00	44	6	0	0	50	16.7	0.0	--	--	1	2.0
15 Apr 18:45	110	85	0	0	195	5.9	3.6	--	--	9	4.6
17 Apr 16:30	152	380	4	1	536	0.3	1.3	0.0	0.0	3	0.6
20 Apr 01:15	210	216	6	1	432	0.0	1.0	0.0	0.0	2	0.5
22 Apr 01:55	14	271	0	3	285	0.0	0.0	--	0.0	0	0.0
24 Apr 02:05	381	324	21	1	726	0.6	0.0	0.0	0.0	2	0.3
25 Apr 01:00	4	327	0	5	331	0.0	0.0	--	0.0	0	0.0
26 Apr 01:00	139	211	0	4	350	0.0	0.0	--	0.0	0	0.0
26 Apr 20:30	3	71	9	2	83	0.0	0.0	0.0	0.0	0	0.0
28 Apr 02:20	121	93	0	1	214	0.0	0.0	--	0.0	0	0.0
29 Apr 02:00	56	115	0	1	171	2.6	1.8	--	0.0	4	2.3
30 Apr 01:20	60	96	0	0	156	4.2	0.0	--	--	4	2.6
30 Apr 18:30	4	120	5	2	129	0.8	0.0	0.0	0.0	1	0.8
2 May 02:05	3	81	9	3	93	2.5	0.0	11.1	33.3	4	4.3
3 May 00:00	44	105	362	1	511	0.0	2.3	0.6	0.0	3	0.6
4 May 02:10	53	64	199	1	316	0.0	5.7	0.0	0.0	3	0.9
5 May 01:20	75	86	11	4	172	1.2	1.3	0.0	0.0	2	1.2
6 May 03:05	48	158	106	5	312	4.4	4.2	5.7	0.0	15	4.8
7 May 01:45	3	92	136	2	231	2.2	0.0	2.9	50.0	7	3.0
8 May 13:30	3	72	2	4	77	4.2	0.0	0.0	25.0	4	5.2
8 May 22:00	6	60	104	3	170	5.0	0.0	1.9	0.0	5	2.9
10 May 00:45	26	36	151	3	213	2.8	0.0	5.3	0.0	9	4.2
10 May 18:15	39	17	5	3	61	0.0	2.6	0.0	0.0	1	1.6
12 May 00:15	65	15	125	2	205	0.0	1.5	0.8	0.0	2	1.0
12 May 21:00	35	13	153	5	201	0.0	2.9	0.7	0.0	2	1.0

Appendix Table 8. Continued.

Release date and time	Numbers loaded at each dam and total fish loaded (n)					Numbers detected from each dam and total numbers detected (n)					
	LGR	LGO	LMN	MCN	n	LGR	LGO	LMN	MCN	n	(%)
18 May 23:20	39	80	136	1	255	1.2	0.0	0.0	0.0	1	0.4
20 May 01:05	42	63	12	3	117	0.0	0.0	0.0	0.0	0	0.0
21 May 01:00	54	100	221	3	375	1.0	1.9	0.5	0.0	3	0.8
22 May 03:20	47	166	239	6	452	0.6	6.4	1.3	0.0	7	1.5
22 May 21:25	71	419	15	6	505	0.2	2.8	0.0	0.0	3	0.6
24 May 02:30	228	519	495	11	1,242	0.8	0.0	0.2	0.0	5	0.4
24 May 20:20	99	764	397	7	1,260	0.5	2.0	1.8	0.0	13	1.0
25 May 22:40	390	372	84	5	846	0.8	0.0	2.4	0.0	5	0.6
27 May 02:05	1	245	507	4	753	4.5	0.0	4.1	0.0	32	4.2
28 May 03:30	327	201	212	3	740	4.0	2.8	7.1	0.0	32	4.3
28 May 18:10	211	529	15	4	755	0.9	2.8	6.7	0.0	12	1.6
30 May 04:49	221	407	341	3	969	1.5	1.4	0.6	0.0	11	1.1
31 May 02:30	2	797	559	0	1,358	0.1	0.0	0.4	--	3	0.2
2 Jun 04:20	520	1,325	1,097	3	2,942	0.1	0.2	0.0	0.0	2	0.1
2 Jun 22:30	3	721	390	0	1,114	2.1	0.0	2.8	--	26	2.3
5 Jun 00:00	276	1,178	600	2	2,054	1.3	2.5	2.3	50.0	37	1.8
6 Jun 17:20	406	893	710	3	2,009	0.7	1.5	1.5	0.0	23	1.1
8 Jun 23:30	192	254	477	0	923	4.3	1.0	4.2	--	33	3.6
10 Jun 22:20	99	293	330	0	722	2.4	1.0	0.9	--	11	1.5
12 Jun 22:40	34	130	139	0	303	3.1	0.0	0.7	--	5	1.7
14 Jun 16:15	37	11	124	0	172	0.0	0.0	0.0	--	0	0.0
16 Jun 23:20	46	68	48	0	162	0.0	0.0	0.0	--	0	0.0
18 Jun 22:30	0	42	21	0	63	7.1	--	14.3	--	6	9.5
20 Jun 22:00	4	20	53	0	77	0.0	0.0	0.0	--	0	0.0
22 Jun 17:00	7	15	46	0	68	0.0	0.0	4.3	--	2	2.9
24 Jun 16:15	4	8	15	0	27	0.0	0.0	0.0	--	0	0.0
27 Jun 00:00	3	6	7	0	16	0.0	0.0	0.0	--	0	0.0
28 Jun 22:25	2	1	4	0	7	0.0	0.0	0.0	--	0	0.0
30 Jun 16:15	1	0	7	0	8	--	0.0	0.0	--	0	0.0
2 Jul 22:05	0	1	7	0	8	0.0	--	0.0	--	0	0.0
4 Jul 22:40	0	1	3	0	4	0.0	--	0.0	--	0	0.0
6 Jul 16:50	0	0	1	0	1	--	--	0.0	--	0	0.0

Appendix Table 8. Continued.

Release date and time	Numbers loaded at each dam and total fish loaded (n)					Numbers detected from each dam and total numbers detected (n)					
	LGR	LGO	LMN	MCN	n	LGR	LGO	LMN	MCN	n	(%)
8 Jul 15:30	0	1	0	0	1	0.0	--	--	--	0	0.0
11 Jul 01:00	0	0	1	0	1	--	--	0.0	--	0	0.0
13 Jul 00:35	0	0	2	0	2	--	--	0.0	--	0	0.0
15 Jul 01:50	0	1	0	0	1	0.0	--	--	--	0	0.0
17 Jul 02:00	1	0	2	0	3	--	0.0	0.0	--	0	0.0
19 Jul 03:15	0	0	0	0	0	--	--	--	--	0	--
21 Jul 01:00	0	0	0	0	0	--	--	--	--	0	--
23 Jul 02:05	0	0	0	0	0	--	--	--	--	0	--
25 Jul 00:05	0	0	1	0	1	--	--	0.0	--	0	0.0
27 Jul 02:25	1	0	2	0	3	0.0	--	0.0	--	0	0.0
29 Jul 13:50	0	0	1	0	1	--	--	0.0	--	0	0.0
31 Jul-16 Aug	0	0	9	1	10	--	--	0.0	0.0	0	0.0
Totals/means	5,203	13,092	9,007	149	27,461	1.2	1.2	1.7	3.4	373	1.4

Appendix Table 9. Detection rates in the Columbia River estuary of PIT-tagged juvenile Chinook salmon and steelhead previously detected at Bonneville Dam, 2002. The juvenile bypass system at Bonneville Dam operated 25 March-22 October; the trawl was operated 15 April-30 July, with intensive sampling between 30 April and 9 June 2002.

Detection at	Bonneville Dam detections		Jones Beach detections			
Bonneville Dam	Chinook salmon (*n*)	steelhead (*n*)	Chinook salmon (*n*)	steelhead (*n*)	Chinook salmon (%)	steelhead (%)
25 Mar-18 Apr	172	1	0	0	0.0	0.0
19 Apr	143	7	1	0	0.7	0.0
20 Apr	105	13	0	0	0.0	0.0
21 Apr	89	24	0	0	0.0	0.0
22 Apr	128	35	0	0	0.0	0.0
23 Apr	133	23	0	0	0.0	0.0
24 Apr	148	55	1	0	0.7	0.0
25 Apr	158	82	2	0	1.3	0.0
26 Apr	156	55	0	0	0.0	0.0
27 Apr	178	66	0	0	0.0	0.0
28 Apr	93	11	1	0	1.1	0.0
29 Apr	244	12	1	0	0.4	0.0
30 Apr	248	184	3	4	1.2	2.2
1 May	470	328	3	3	0.6	0.9
2 May	286	133	1	1	0.4	0.8
3 May	466	130	3	2	0.6	1.5
4 May	533	163	2	0	0.4	0.0
5 May	440	258	3	3	0.9	1.2
6 May	445	185	6	6	1.3	3.2
7 May	410	79	1	0	0.2	0.0
8 May	768	109	11	1	1.4	0.9
9 May	476	68	7	3	1.5	4.4
10 May	600	224	12	4	2.0	1.8
11 May	1,128	261	7	3	0.6	1.1
12 May	636	59	11	3	1.7	5.1
13 May	1,592	133	49	6	3.1	4.5
14 May	869	71	14	1	1.6	1.4
15 May	1,051	38	24	0	2.3	0.0
16 May	1,027	52	28	2	2.7	3.8

Appendix Table 9. Continued.

Detection at Bonneville Dam	Bonneville Dam detections Chinook salmon (*n*)	steelhead (*n*)	Jones Beach detections Chinook salmon (*n*)	steelhead (*n*)	Chinook salmon (%)	steelhead (%)
17 May	2,455	95	34	0	1.4	0.0
18 May	2,706	214	27	2	1.0	0.9
19 May	2,966	182	62	1	2.1	0.5
20 May	3,322	142	64	3	1.9	2.1
21 May	4,316	127	84	2	1.9	1.6
22 May	3,903	109	60	1	1.5	0.9
23 May	2,071	65	39	2	1.9	3.1
24 May	2,705	82	73	0	2.7	0.0
25 May	2,366	70	51	1	2.2	1.4
26 May	3,809	303	56	9	1.5	3.0
27 May	4,524	406	203	28	4.5	6.9
28 May	2,102	224	60	11	2.9	4.9
29 May	2,389	147	14	0	0.6	0.0
30 May	2,978	310	54	10	1.8	3.2
31 May	2,276	177	39	7	1.7	4.0
1 Jun	1,787	307	5	4	0.3	1.3
2 Jun	1,002	268	14	6	1.4	2.2
3 Jun	1,586	241	26	2	1.6	0.8
4 Jun	968	218	23	7	2.4	3.2
5 Jun	637	278	5	3	0.8	1.1
6 Jun	524	305	11	11	2.1	3.6
7 Jun	397	198	14	6	3.5	3.0
8 Jun	416	130	11	3	2.6	2.3
9 Jun	389	162	4	3	1.0	1.9
10 Jun	451	288	5	2	1.1	0.7
11 Jun	293	124	5	0	1.7	0.0
12 Jun	583	89	1	0	0.2	0.0
13 Jun	366	88	0	0	0.0	0.0
14 Jun	522	114	1	0	0.2	0.0
15 Jun	340	107	1	1	0.3	0.9
16 Jun	234	26	3	2	1.3	7.7
17 Jun	176	19	1	0	0.6	0.0
18 Jun	205	29	1	2	0.5	6.9

Appendix Table 9. Continued.

Detection at Bonneville Dam	Bonneville Dam detections		Jones Beach detections			
	Chinook salmon (*n*)	steelhead (*n*)	Chinook salmon (*n*)	steelhead (*n*)	Chinook salmon (%)	steelhead (%)
19 Jun	259	15	0	0	0.0	0.0
20 Jun	159	18	0	0	0.0	0.0
21 Jun	196	34	0	0	0.0	0.0
22 Jun	187	17	0	0	0.0	0.0
23 Jun	99	13	0	0	0.0	0.0
24 Jun	89	11	0	0	0.0	0.0
25 Jun	229	5	2	0	0.9	0.0
26 Jun	230	3	6	0	2.6	0.0
27 Jun	160	17	0	0	0.0	0.0
28 Jun	265	7	1	0	0.4	0.0
29 Jun	466	19	4	1	0.9	5.3
30 Jun	510	17	3	0	0.6	0.0
1 Jul	369	13	1	0	0.3	0.0
2 Jul	436	2	0	0	0.0	0.0
3 Jul	410	2	0	0	0.0	0.0
4 Jul	395	0	4	0	1.0	--
5 Jul	498	5	4	0	0.8	0.0
6 Jul	568	1	2	0	0.4	0.0
7 Jul	437	0	1	0	0.2	--
8 Jul	419	0	1	0	0.2	--
9 Jul	451	0	1	0	0.2	--
10 Jul	403	1	1	0	0.2	0.0
11 Jul	820	0	8	0	1.0	--
12 Jul	609	1	2	0	0.3	0.0
13 Jul	1,119	0	7	0	0.6	--
14 Jul	1,641	0	11	0	0.7	--
15 Jul	1,124	1	0	0	0.0	0.0
16 Jul	621	0	8	0	1.3	--
17 Jul	681	0	7	0	1.0	--
18 Jul	368	0	7	0	1.9	--
19 Jul	311	0	2	0	0.6	--
20 Jul-22 Oct	1,501	0	0	0	0.0	--
Totals	84,814	8,704	1,325	172	1.6	2.0