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Fish Ecology Division

Northwest Fisheries Science Center

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Seattle, Washington

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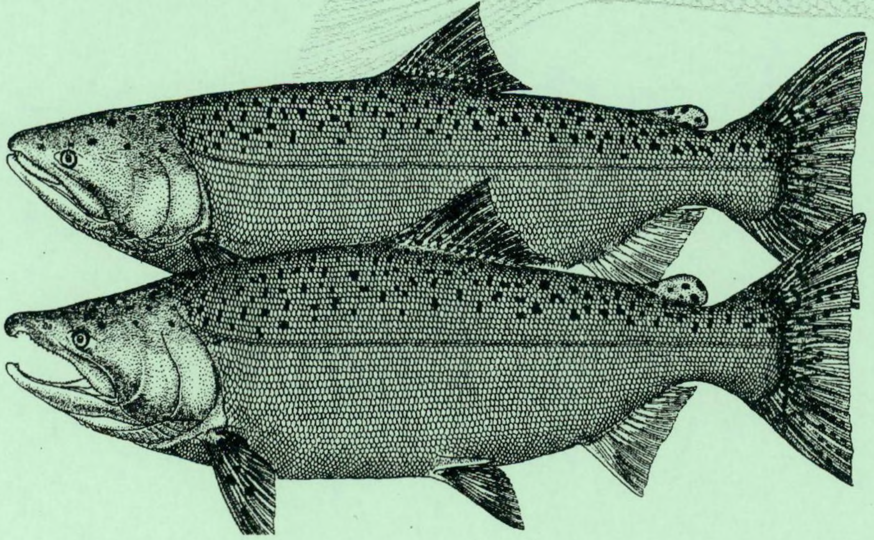
January 2010



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Report of research by

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2725 Montlake Boulevard East
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EXECUTIVE SUMMARY

In 2007, we continued a multiyear study to detect juvenile anadromous salmonids *Oncorhynchus* spp. implanted with passive integrated transponder (PIT) tags using a surface pair-trawl fitted with a PIT-tag detection antenna. We sampled in the upper Columbia River estuary between river kilometers (rkm) 61 and 83 for 1,144 h between 7 March and 19 July. During this time, we detected 19,470 PIT-tagged juvenile salmonids of various species, runs, and rearing types. Of these 19,470 detections 78% were Chinook salmon, 18% were steelhead, and 4% were other salmonid species or unknown species. For all species combined 17% of the total detections were wild fish, 81% were hatchery fish, and the remaining 2% were fish of unknown origin.

For the majority of the 2007 sample season, we employed a newly constructed and slightly modified trawl net. The cod-end of this trawl and backup trawls were fitted for an older, 0.9-m-diameter detection antenna because the 1.1-m-diameter antenna used during 2006 was compromised (leaked). A separate vessel, the *RV* Electric Barge was positioned directly above the antenna and used for data collection and antenna deployment. We used a multiplexing transceiver to record PIT-tag detections, which were coupled with global positioning system location at time of detection.

A camera was mounted inside the antenna to provide continual daytime video surveillance of fish passage and debris accumulation. The antenna was attached to the trawl, which was towed using two 12.5-m vessels. Under tow, the two vessels maintained a distance of 91.5-m between the trawl wings, which resulted in an effective sample depth of 5 to 6 m from the center of the trawl floor to the surface. Hand-written logs, including land marks and events, were also maintained.

Coincidental with arrival in the estuary of yearling Chinook salmon and steelhead from Snake River releases, we began sampling with a single crew 3-5 d per week on 7 March. Sample effort gradually increased, and we began using a second daily crew on 23 April and continued through 28 June. During this two-crew period, we sampled on average 12 h d^{-1} and detected 3.6% of Chinook salmon and 3.9% of steelhead previously detected at Bonneville Dam. Simultaneously, we detected 3.0 and 2.5% of Chinook salmon and steelhead that had been transported and released downstream from Bonneville Dam. As detection numbers declined in late June, we reduced sample effort to a single daily crew (Monday through Friday) through 20 July.

Our annual detection totals in 2007 were 16% transported fish and 13% inriver migrants previously detected at Bonneville Dam. The remaining 71% had not been transported or detected at Bonneville Dam and generally represented fish that passed Bonneville Dam via spillway or turbines, which lack detection capability. A small

portion of our detections were fish released downstream from Bonneville Dam. Detection percentages of these migration histories were similar those observed in previous years. During the two-crew sampling period, we averaged 11 and 27 yearling Chinook salmon detections per hour of daylight and darkness, respectively ($P = 0.001$). We also averaged four steelhead detections per hour, regardless of time of day ($P = 0.598$).

For yearling Chinook salmon, mean travel speed from Bonneville Dam to Jones Beach was significantly faster for inriver migrants (92 km d^{-1}) than for transported fish (69 km d^{-1}; $P = 0.000$). Conversely, for juvenile steelhead, mean travel from the barge release site to Jones Beach was significantly faster for transported (94 km d^{-1}) than for inriver migrant fish (85 km d^{-1}; $P = 0.000$). With the exception of inriver migrant steelhead, travel speeds were lower in 2007 than in 2006. Average river flow volume at Bonneville Dam during the sampling period was 24% lower in 2007 than in 2006, which affected travel speed to the estuary as seen in previous years.

In 2007, we continued development of a larger detection antenna with a fish passage opening measuring 2.6 m wide by 3.0 m tall. The new antenna was composed of front and back components, providing two chances to detect a PIT-tagged fish. This "matrix" design consisted of two side-by-side coils in the front joined by a 1.5-m-long mesh web tunnel to a rear three-coil component (outside dimension of each antenna component was 2.6 × 3.0 m). The matrix system was towed using two 12.5-m long vessels.

Initially, we sampled with the single component 2-coil matrix system in the same area as the cylindrical antenna system during a tandem sampling test for 35.9 h and detected 233 and 730 fish, respectively. However, we experienced high levels of electromagnetic interference during these tests. To possibly reduce tag collision and interference around the antenna, we constructed a 3-coil component. In mid-July, we tested a 5-coil matrix system using a front 2-coil component and rear 3-coil component. In about 16 h of sampling with each system, we detected 70 fish with the matrix system and 12 fish with the cylindrical system. We concluded that the matrix system detected more fish than the cylindrical system due to a greater volume of water passing through the antenna and a larger opening from the trawl which reduced fish avoidance and possible escapement.

In 2007 we again sampled with a shoreline trawl detection system design to detect fish in shallow water areas not accessible to the larger trawl system. We adapted the prototype matrix system to a modified trawl and deployed the system at Jones Beach (rkm 75). After 43 total h of deployment, no fish were detected and few were observed on camera.

CONTENTS

INTRODUCTION

In 2007, we continued a multi-year survival and timing study of juvenile anadromous salmonids *Oncorhynchus* spp., in the Columbia River estuary (Ledgerwood et al. 2006, 2007; Magie et al. 2008). A large surface pair-trawl was used to guide migrant fish through an electronic antenna mounted at the cod-end of the trawl (Ledgerwood et al. 2004). Target fish were those implanted with passive integrated transponders (PIT) tags for various research projects in natal streams, hatcheries, or other upstream locations prior to migration (PSMFC 2007). As PIT-tagged fish exited the trawl their tag code, date, time, and GPS position were recorded without handling. This study began in 1995 and has continued annually (except 1997) in the estuary near Jones Beach, approximately 75 river kilometers (rkm) upstream from the mouth of the Columbia River (Ledgerwood et al. 1997, 2003, 2006).

Nearly 1.5 million juvenile salmonids were PIT tagged and released into the Snake and Columbia River basins in 2007 (PSMFC 2007). 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 and elsewhere 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 information, detection times and locations, as well as species, origin, and migration history of individual PIT-tagged fish.

In addition to bypassing fish at dams, fisheries managers have the option to transport and release fish downstream from Bonneville Dam, the lowermost dam in the Columbia River basin (rkm 234). In 2007, 155,702 PIT-tagged fish were transported. The goal of our trawling effort in the estuary was to monitor timing and survival of PIT-tagged fish that have migrated in the river through the hydropower system to the estuary or have been transported by barge around various dams for release downstream from Bonneville Dam.

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

1) Compare migration timing and estimated survival through the Columbia River hydropower system for inriver migrant and transported juvenile yearling Chinook salmon *O. tshawytscha* and steelhead *O. mykiss* during the spring migration period.

2) Evaluate migration timing of subyearling Chinook salmon *O. tshawytscha* in the summer and fall months.

3) Continue to develop and test a larger detection antenna and related equipment during the migration period. Verify PIT-tag read efficiencies and develop procedures required for safe deployment/retrieval of the large antenna system.

METHODS

Study Fish

We continued to focus research on large groups of PIT-tagged fish released for research during the spring migration, in particular, those entering the upper estuary from late April through late July. According to PTAGIS, these groups included nearly 201,000 PIT-tagged fish released for a transportation study on the Snake River (Marsh et al. 2007) and over 145,000 PIT-tagged fish released for a comparative hatchery fish survival study (Berggren et al. 2007). Of the PIT-tagged fish released in the Columbia River basin for migration in 2007, over 155,000 were diverted to transport barges and trucks and released downstream from Bonneville Dam. We also detected fish PIT-tagged for other studies that used PIT tagged or double tagged fish (PIT and acoustic tags).

We coordinated trawl system operations with the expected passage of large groups of fish with known release locations and dates. After tagging at Lower Granite Dam, transportation study fish were either released to the Snake River downstream from Lower Granite Dam (rkm 695) to continue migration in the river. As these fish passed the remaining dams, some were diverted to barges at transportation facilities at Little Goose Dam, rkm 635; Lower Monumental Dam, rkm 589; or McNary Dam, rkm 470.

Our transportation analysis included all PIT-tagged fish diverted to barges, including those diverted at Lower Granite Dam. We created a separate database for information associated with PIT-tagged fish recorded in PTAGIS as having been diverted, or possibly diverted, to transportation at any of the four transport dams. Intentional diversions of PIT-tagged fish at these dams were accomplished according to a "separation-by-code" procedure (Stein et al. 2004). Diversion to transportation barges either intentionally or unintentionally (i.e., missed being diverted back to the river at slide gates) was confirmed by comparing the last monitor name listed for a PIT-tagged fish to the PTAGIS site map to the route ending at a transport raceway or barge. Fish thought to be diverted to transportation but that could not be verified were flagged in our database, as were fish removed for biological or other samples.

Since 1987, almost 2.3 million PIT-tagged fish have been recorded as being transported in the PTAGIS database. The USACE (Scott Dunmire, USACE, personal communication) provided individual barge loading dates and times at each dam through the season. We then matched barge loading times to the last detection date and time of PIT-tagged fish diverted for transportation in order to assign each transported fish to a transport barge (each was assigned to the next available transport barge after its last detection). Specific barge release dates and locations (rkm) were also provided by the

USACE, so that a release time and location could be assigned to each transported PIT-tagged fish. Detections of transported fish, which were released almost daily during the peak of the migration, were then used to calculate travel time, which was compared to the travel times of fish detected passing Bonneville Dam on the same days. This provided a relative comparison of travel speeds and survival during the migration season.

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 juvenile salmonids. In this report, we focus our analyses on the more numerous PIT-tagged yearling Chinook salmon and steelhead; however, detections of PIT-tagged coho salmon *O. kisutch*, sockeye salmon *O. nerka*, subyearling Chinook salmon, and coastal cutthroat trout *O. clarki clarki*, were also recorded.

Sample Period

Sampling with our surface pair trawl began on 7 March and continued through 19 July, coincident with the passage of PIT-tagged yearling Chinook salmon and steelhead from the Snake River transportation study. Not all days were sampled for an equal number of hours. At the beginning and end of the migration season, sampling was conducted with a single crew 2-5 d per week. From 23 April through 28 June, sampling was increased to two daily crews for an average of 12 h d^{-1}. Generally, the day crew began before daylight and sampled for 6 to 10 hours, and the night crew began in late afternoon and sampled until well after dark or until relieved by the day crew. Sampling was nearly continuous throughout the two-crew period except between 1400 and 1900 PDT, when it was interrupted for fueling and maintenance.

To determine the diel availability of yearling Chinook salmon and steelhead, we compiled weighted hatchery and wild detection data during the two-crew sampling period. A smoothed, interpolated value was used during the 5 h period between shift changes. No significant difference in diel availability was apparent between hatchery and wild rearing types; therefore, we weighted the detection data by total fish detected within each rearing category (PTAGIS designation wild or hatchery) and plotted hourly percentages of total detections by species.

Study Sites

We sampled with the standard cylindrical detection system (Ledgerwood et al. 2004) and a newly designed "matrix" pair trawl detection system from rkm 83, near Eagle Cliff, to rkm 61, near the west end of Puget Island (Figure 1). This is a freshwater reach characterized by frequent ship traffic, occasional severe weather, and river currents often exceeding 2.5 knots. 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 occurs in this reach during flood tides, particularly during years of medium-to-high river flow. Trawls were deployed adjacent to a 200-m-wide navigation channel, which is maintained at a depth of 14-m. The fixed location shoreline detection system was deployed on ebb tides along Jones Beach (rkm 75).

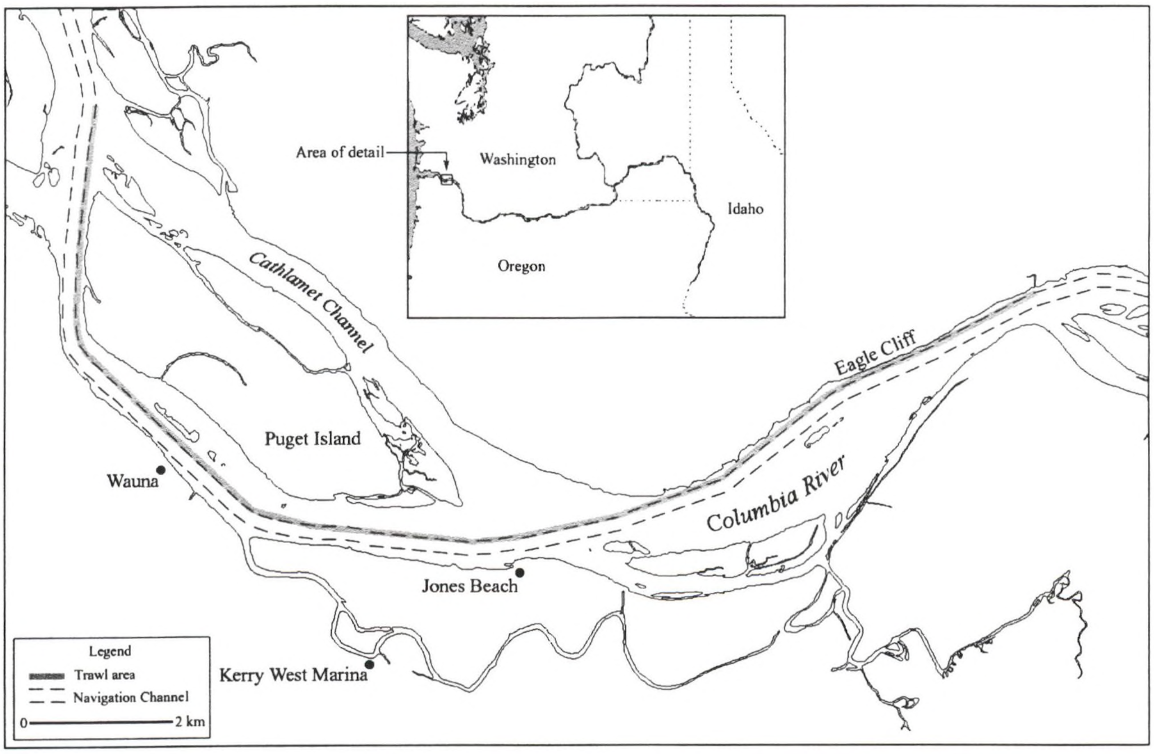

Figure 1. Trawl area adjacent to the ship navigation channel in the upper Columbia River estuary between rkm 61 and 83.

Trawls and Detection System Designs

Cylindrical Antenna Trawl System

The cylindrical antenna trawl components are described below, and their basic configuration remained fairly constant through the study period (Ledgerwood et al. 2004; Figure 2). 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 shackled to the wing section. The end of each wing was attached to the 14-m-long trawl body, followed by a 2.7-m-long cod-end, modified for antenna attachment.

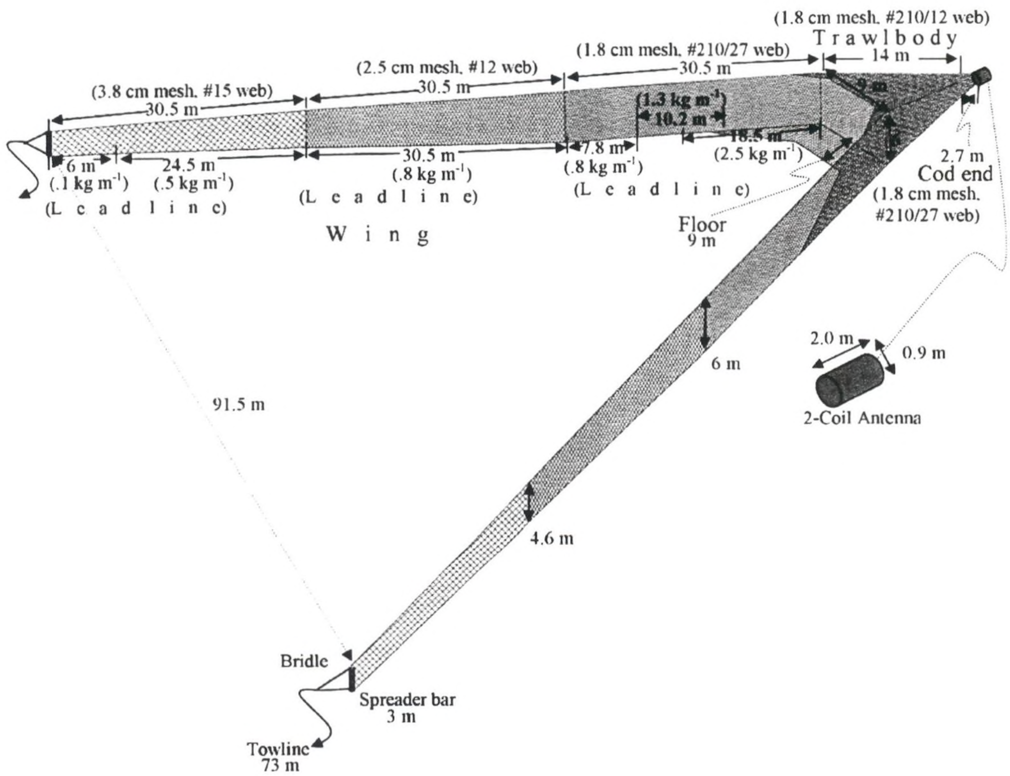

Figure 2. Sketch showing basic design of the cylindrical antenna surface pair trawl that was used to sample PIT-tagged juvenile salmonids in the Columbia River estuary (rkm 75), 2007.

The mouth of the trawl body opened between the wings and from the surface to a depth of 6 m; a floor extended 9 m forward from the mouth. Sample depth was about 4.6 m due to curvature in the side-walls under tow. The primary detection antenna used with the cylindrical antenna detection system measured 0.9 m in diameter and was centered at a depth of 1.8 m. Early tests of the larger 1.1-m diameter antenna used in 2006 revealed a reduction in detection efficiency when compared to the 0.9-m diameter antenna. The larger antenna also had sustained damage to its detection coils (it leaked) and was not utilized in 2007.

PIT-tag technology has improved through the years, allowing for longer read ranges. This enabled us to enlarge the fish-passage opening of the antenna, which improves fish (and debris) egress from the trawl (Ledgerwood et al. 2004). The larger opening also reduces drag and lift on the net, increasing the effective sample depth. During a typical deployment, the net is towed upstream facing into the current, with a distance of about 91.5 m between the trawl wings. Fish that enter between the wings are guided to the trawl body and exit through the antenna. During net retrieval, the antenna is removed and the net is inverted in the current to flush debris and release fish from between the trawl wings. The deployment/retrieval process requires about 30 minutes, during which time the vessels and net are adrift in tidal and river currents often exceeding 2.5 knots.

Matrix Antenna Trawl System

The matrix trawl system incorporated five antennas much larger than those in they cylindrical system, but used a pair-trawl net similar in size to those used in previous years (Figure 3). In 2007, the matrix detection antenna system consisted of a front and rear coil configuration joined by a 1.5-m-long webbed tunnel. The rear component consisted of two coils (1.1 × 2.8 m) affixed together and separated by a 15-cm gap (total dimension 2.6 × 3.0 m). The front component had three adjoining coils (0.75 × 2.8 m each). Front and rear components of the matrix antenna weighed approximately 113 kg in air and required an additional 113 kg of lead weight to properly submerge the system in the water column.

During deployment, buoys fixed to each component maintained them at a depth of 0.3-m from the top of the antennas to the water surface. A PIT-tag recording transceiver, wireless data transmission modem, and two 12-volt batteries were mounted on a small catamaran floated above the matrix antenna system.

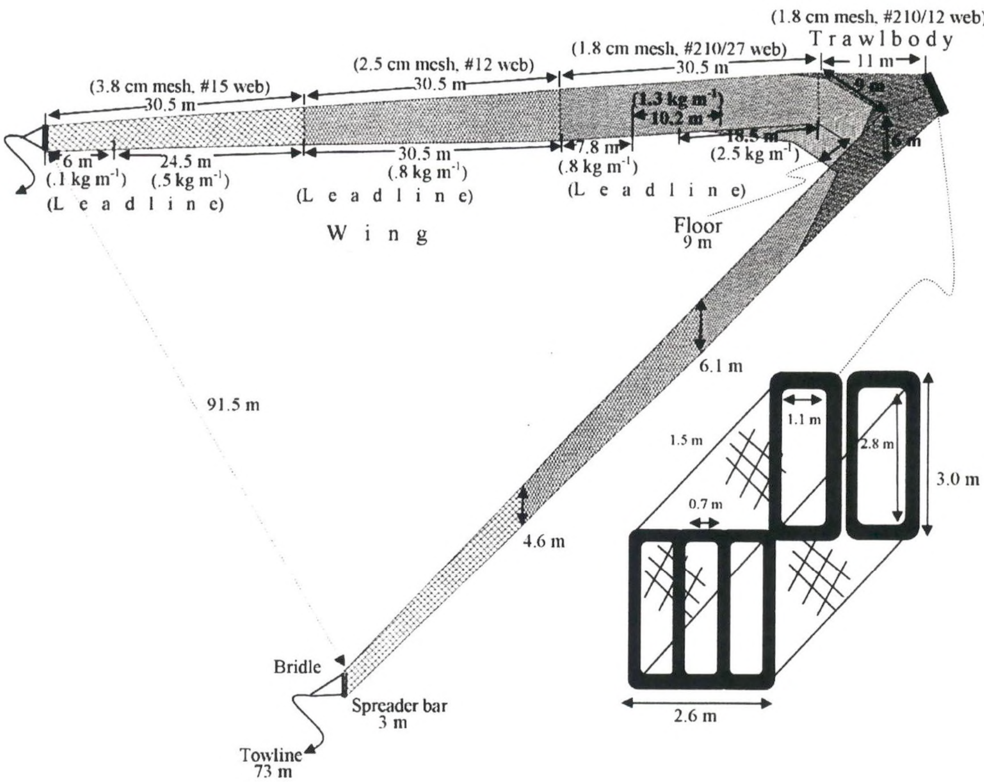

Figure 3. Basic design of the surface pair trawl that was used with the prototype "matrix" antenna system to sample PIT-tagged juvenile salmonids in the Columbia River estuary (rkm 75), 2007.

The transceiver was electronically connected by cables to the underwater antenna and relayed data and status reports to a computer mounted in a tow vessel via the wireless modem. Operation of the matrix system was similar to that described above for the cylindrical system, except the trawl was retrieved directly to one of the vessels (the vessel fitted with a net reel) without removing the antenna or inverting the trawl in the current.

Shoreline Detection System

The shoreline PIT-tag detection system was configured similar to the cylindrical and matrix sytems, with a detection antenna used in place of the cod-end of a modified pair trawl. The shoreline side of trawl net was 27.3-m long and was anchored to a truck-mounted winch, while the river side of the net was 15.2-m long and attached to a fixed anchor (Figure 4). The trawl body was 8.5-m long with a 4.9-m^2 opening between the wings, and it tapered on the downstream side to its terminus, where a 2-coil matrix-style antenna was attached. The antenna had a fish-passage opening 2.6-m wide by 3.0-m tall. Sample depth was about 3.5 m and was controlled by positioning the offshore anchor with falling tide level. The antenna was supported on a buoy similar to that of the other trawls.

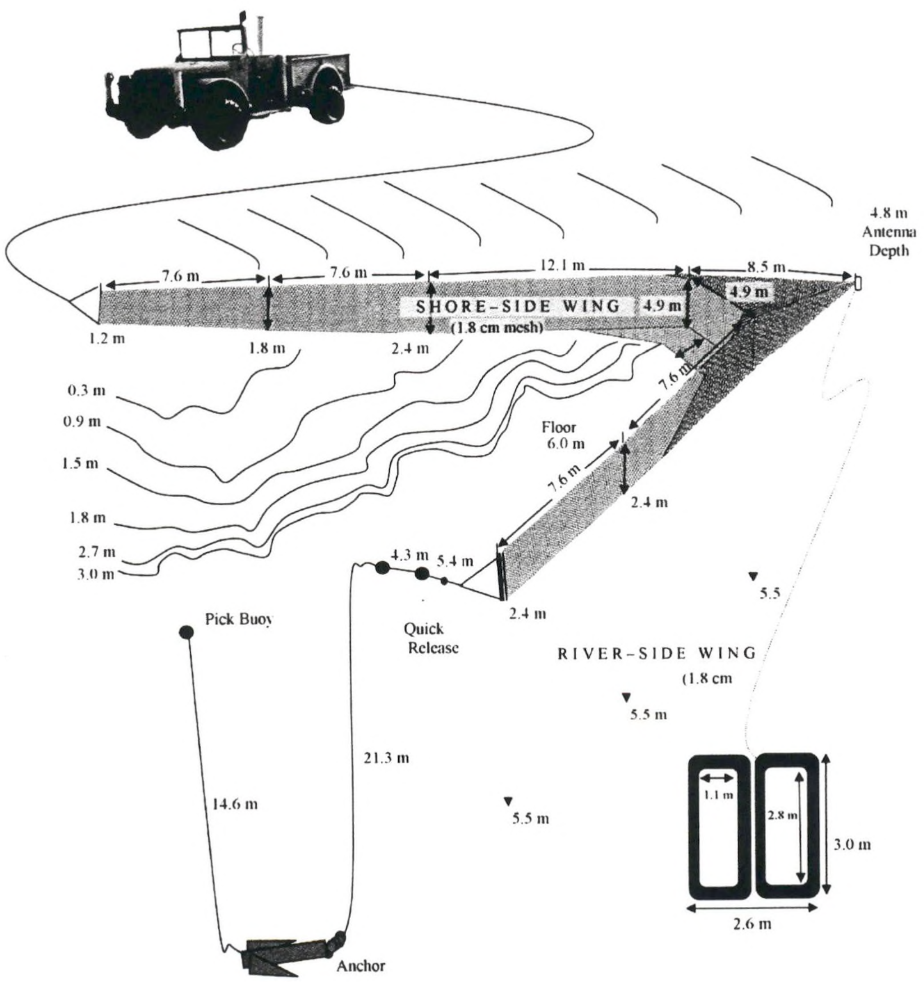

Figure 4. Design for the PIT-tag detection system used along the shoreline parallel to the shipping channel in the Columbia River estuary (rkm 75), 2007.

Generally, we deployed the shoreline system at high tide and sampled during ebb currents. Current velocities varied from 0.0 to about 1.5 knots at maximum ebb. A video camera was mounted within the antenna and used to monitor fish passage. We developed a method to "flush" the net using a line attached to the tip of the river-side wing. The line was drawn toward shore to close the wings, which encouraged fish to exit the trawl and also helped to clear the trawl of debris.

Electronic Equipment and Operation

For operation of the two-coil cylindrical antenna, we used essentially the same electronic components and procedures as in 2001-2006, with the exception of the transceivers and software. We continued to use a single FS1001M transceiver, which is capable of monitoring up to six detection antennas simultaneously. A 10-m pontoon barge, the *RV* Electric Barge, was towed behind the trawl exit, and carried the gasoline generator used to power all electronic equipment. The transceiver and associated electronics were mounted in the cabin of the barge, and cables led underwater to tuner ports, one on each of the two detection coils. A video camera mounted inside the antenna tunnel was used to monitor fish passage on a VCR/TV housed in the barge. The two-coil cylindrical antenna unit weighed 200 kg and was 2.1-m long with an 86-cm-diameter fish passage opening (Figure 5).

During operation, the date, time, tag code, coil identification number, and GPS location for each detection was automatically recorded using MiniMon PIT-tag monitoring software (available at no cost from PTAGIS website; PSMFC 2009). For each sampling cruise, written logs were maintained noting the time and duration of net deployment, the start and end of each net-flushing period, estimated detections during each net-flushing period, approximate location of each detection (rkm), and any incidence of impinged fish.

Electronic components for the matrix trawl and shoreline detection systems were contained in a water-tight instrument box (0.8 × 0.5 × 0.3 m) mounted on a 1.9-m pontoon raft. Two 12-volt batteries were used to power the transceiver and antennas. The two-coil antenna used for the rear component of the matrix system described above was also used for the shoreline system. Detection data and electronic status reports from the transceiver were transmitted wirelessly to a computer, located on one of the tow vessels for the cylindrical system and on a vehicle on shore for the shoreline system. Global-positioning-system (GPS) locations were automatically stored with each detection record and every 15 minutes using Minimon software.

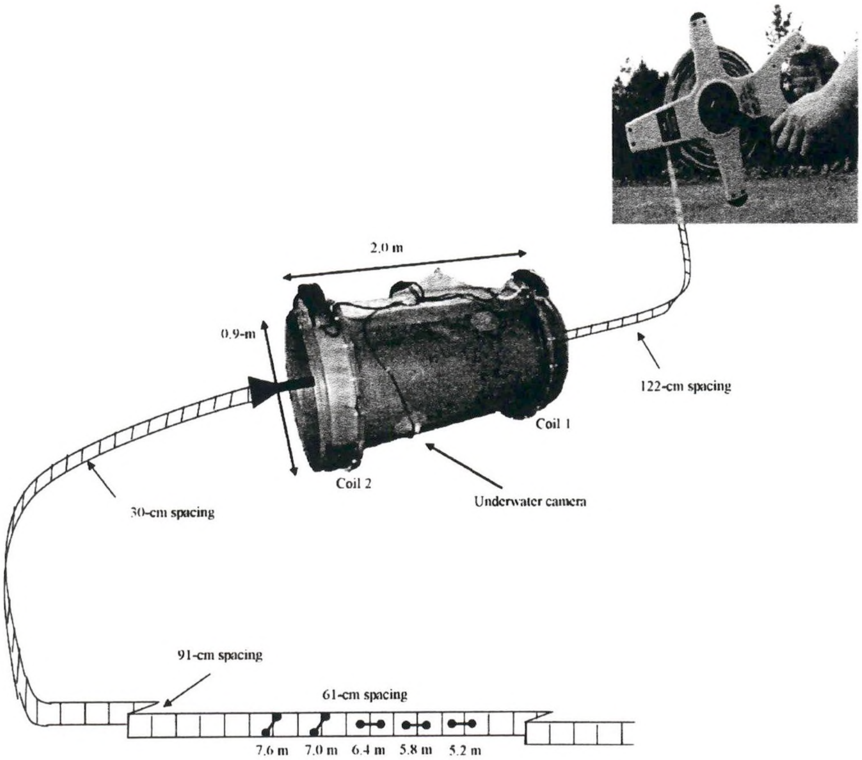

Figure 5. Funnel testing system depicting test tag laden vinyl tape measure, threaded through a PVC pipe positioned in the center of the two-coil cylindrical antenna. PIT-tags were oriented at 0 and 45 degrees to the direction of travel and spaced 30, 61, 91, and 122 cm apart.

PIT-tag detection data files were uploaded periodically (about weekly) to PTAGIS using standard methods described in the *PIT-tag Specification Document* (Stein et al. 2004). The specification document, PTAGIS operating software, and user manuals are available via the Internet (PSMFC 2007). 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 2007). 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 PTAGIS release information within our database to reflect the date, time, and river kilometer of release from transport barges.

Detection Efficiency Evaluation

In earlier years, tests of detection efficiency (tag reading) required the release of test fish into the trawl mouth (Ledgerwood et al. 2005). In 2007, we used a procedure that did not require test fish. A 2.5-cm-diameter PVC pipe with a small plastic funnel on each end was positioned through the center of the detection antenna and extended at least 0.5 m past both ends. Fifty PIT tags at known intervals and orientations were attached to a vinyl-coated tape measure (Figure 5; Appendix Table 1), which was passed through the pipe. This method was used for the cylindrical, matrix, and shoreline detection antennas.

Detection efficiency at the center of the antenna was evaluated for each system, and was expected to be positively correlated with improved alignment, orientation, and proximity to the electronic field. With each new trawl system design, we attempted to concurrently maximize the fish-passage opening and detection efficiency. For these tests, we positioned tags on the tape at densities and orientations such that not all tags would be read. Thus the tests did not reflect actual reading efficiency for PIT-tagged fish. Fish generally pass through the antennas with better orientation and in areas of the electronic field more optimal for detection.

The relative consistency of tag detections on the tape also helped to validate electronic tuning 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. The start time of each pass was recorded in a logbook, and detections were recorded using MiniMon software. Efficiency was calculated as the total number of unique tags decoded during each pass divided by the total number of tags passed through the antenna. The cylindrical antenna detection system was tested about weekly, while the matrix and shoreline detection systems were evaluated periodically during deployment.

Antenna Detection Efficiency

Advances in PIT-tag and transceiver technology enabled us to develop the matrix antenna and a cylindrical antenna with a larger fish-passage opening. However, during deployment in 2006, the larger cylindrical antenna performed poorly, and it eventually developed a leak. Therefore, for sampling in 2007, we resumed use of the smaller cylindrical antenna used during 2000-2005. In the meantime, we continued development and testing of the matrix antenna system. Detection efficiencies of both systems were compared to those of previous antenna designs. This provided a gauge of overall efficiency for the different antenna designs and helped to identify possible design weaknesses requiring modification or electronic tuning.

Impacts to Fish

We used video to monitor debris accumulation in the antenna and in the cod end of the net. Other sections of net were monitored visually, and accumulated debris was removed from all net sections as necessary to avoid potential injury to fish. When debris accumulated, we reduced tow speed and pulled the antenna to the surface to remove entrained material from the cod end. During conditions of extreme debris loading, we disconnected the electronics and inverted the entire net for cleaning.

Because of its configuration with the pair trawl net (Figure 3), the matrix trawl system was retrieved directly onto a tow vessel without inverting the trawl for debris removal. This was a potential drawback of the matrix trawl design, since the occasional accumulation of significant quantities of debris could impact fish passing through the trawl body and antenna. However, the larger antennas used with the matrix design allowed large debris to flow through the trawl body and tunnel. This resulted in a generally lower accumulation of debris in the matrix system than in the cylindrical antenna system, but did not eliminate the problem altogether. Therefore, debris eventually had to be removed from the matrix system by hand, either during the retrieval process, which required longer drifts, or at the dock. For both the matrix and cylindrical systems, we recorded impinged or trapped fish during debris removal, net retrieval, and net deployment periods. These fish were recorded as mortalities in the operation log books.

Data Analyses

Diel Detection Rates

To assess the diel presence of yearling Chinook salmon and steelhead in the study area, we examined detection data for each 24-h period during two-crew sampling. A smoothed, interpolated value was used for the afternoon period between shifts, when sample effort was halted. We found no significant differences in diel presence associated with rearing type for either species. Therefore, we weighted the detection data by total fish within each rearing type category (hatchery or wild).

Numbers of yearling Chinook salmon and steelhead detected per hour of daylight vs. darkness were evaluated using one-way ANOVA-unstacked (Zar 1999). The total number of detections and the minutes of deployment within each hour were separated into daylight and darkness hour categories. Preliminary analyses and hourly detection rates were pooled for wild and hatchery rearing types of each species for each category.

These mean hourly detection rates were compared statistically, and diel detection curves were compiled for yearling Chinook salmon and steelhead weighted by the number of minutes within each hour that the detector was operating. There were insufficient detections of other species for meaningful analyses.

Travel Time

Based on estuary detections, we plotted travel-time distributions for the following two subsets of yearling Chinook salmon and steelhead marked and released at Lower Granite Dam: inriver migrants previously detected at Bonneville Dam, and transported fish released just downstream from Bonneville Dam. We prepared similar plots for transported and inriver migrant subyearling Chinook salmon released in late June and July. Plots of travel time also indicated the seasonal presence in the estuary for the respective fish groups. 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 from a barge or detection at Bonneville Dam from date and time of detection at Jones Beach.

One-way ANOVA was used to evaluate differences in travel speed to Jones Beach between inriver migrants and transported fish. Daily median travel speed (km d^{-1}) was calculated by dividing days of travel time by kilometers traveled from release to detection in the estuary. Travel speed was compared by migration history for yearling Chinook salmon, steelhead, and subyearling Chinook. Daily average discharge rates at Bonneville Dam ($m^3 s^{-1}$) were plotted during the respective periods of presence in the estuary for comparison to travel speeds.

Detection Rates and Migration History

We used logistic regression analysis to compare estuary detection rates of transported vs. inriver migrant fish (Hosmer and Lemeshow 2000; Ryan et al. 2003). Inriver migrants were grouped by date of detection at Bonneville Dam and paired with transported fish released from a barge on the same day. Only PIT-tagged fish released at sites from upstream from McNary Dam were included for analysis. Barge releases occurring just after midnight were paired with detections at Bonneville Dam the previous day.

Fish transported early in the migration season were often released downstream from Bonneville Dam before sufficient numbers of inriver migrant fish had arrived at the dam for comparison. Recovery percentages for both inriver and transported fish groups are shown for the entire season, but daily groups were not used for analysis unless both groups were present and were detected during intensive two-crew sampling periods.

We used the same logistic regression analysis to compare estuarine detection rates between fish transported from different locations. To provide sufficient sample sizes, we compared fish transported from Lower Granite Dam to those from Little Goose and Lower Monumental Dams combined. Components of the logistic regression model were treatment as a factor and date and date-squared as covariates. The model estimated the log odds of the detection rate of *i* daily cohorts (i.e., $\ln[p_i/(1-p_i)]$) as a linear function of the components, assuming a binomial distribution for the errors.

Daily detection rates were then estimated as:

$$p_i = \frac{e^{\beta_0 + \beta_1 day_i + \beta X_i}}{1 + e^{\beta_0 + \beta_1 day_i + \beta X_i}}$$

where β is the coefficient of the respective components (i.e., β_0 for the intercept, β_1 for day *i*, and β for the set "X_i" of day-squared and/or interaction terms). A stepwise procedure was used to determine the appropriate model.

First, the model containing interactions between treatment and date and date-squared was fitted. Next we determined the amount of overdispersion in the data, or variance in the observed data relative to the variance assumed in the binomial distribution (Ramsey and Schafer 1997). Overdispersion was estimated as "σ", the square root of the model deviance statistic divided by the degrees of freedom. If σ was > 1.0, we adjusted the standard errors of the model coefficients by multiplying by σ (Ramsey and Schafer 1997). This inversely adjusted the z statistic used to test the significance of the coefficients.

If each respective interaction term was not statistically significant (likelihood ratio test α >0.05), it was removed and a reduced model fitted. The model was further reduced depending on the significance [of interactions] between treatment and date and/or date-squared. The final model was the most-reduced from this process.

Various diagnostic plots were examined to assess the appropriateness of the models. Extreme or highly influential data points were identified and included or excluded on an individual basis, depending on the data situation.

The daily barged and inriver groups had similar distributions in the sampling area and presumably pass the sample area at similar times. Thus we assume these groups were 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 (at or near Bonneville Dam) to the estuary.

To examine the assumption that barged and inriver-migrant groups passed the sample area with similar diel timing, we examined hourly detections of yearling Chinook salmon and steelhead (detections of other species were insufficient for this analysis). We divided total seasonal detections for each group into interval hours based on time of detection. Diel detection curves were prepared based on the average number of fish detected each hour weighted by the number of minutes within each hour that the detectors were energized. Differences in the average hourly detection rate between transported and inriver groups were then plotted by species. Data from study years 2000 to 2006 were plotted to give a visual overview of differences between and among years.

Downstream Passage Survival

Detection data from the estuary are essential to estimates of juvenile salmonid survival 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 (CJS model; 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

Cylindrical Antenna System Detections

In 2007, we detected 19,186 PIT-tagged juvenile salmonids of various species, runs, and rearing types using the cylindrical antenna trawl detection system at Jones Beach (Appendix Table 2). Of these total detections, 78% were Chinook salmon, 18% were steelhead, and the remaining 4% were other salmonid species (Table 1). From detections of all species combined, 17% were wild fish, 81% were hatchery fish, and 2% were of unknown origin. River basin source and migration histories for PIT-tagged fish detected in the estuary are shown in Figure 6.

Table 1. Species composition and rearing-type history for PIT-tagged fish detected with the cylindrical antenna system in the upper Columbia River estuary near rkm 75 in 2007.

	Cylindrical antenna system detections (n)			
	Rear Type			
Species/run	Hatchery	Wild	Unknown	Total
Spring/summer Chinook salmon	12,358	1,854	107	14,319
Fall Chinook salmon	515	31	78	624
Coho salmon	270	0	20	290
Steelhead	2,165	1,321	6	3,492
Sockeye salmon	214	32	0	246
Sea-run cutthroat trout	0	0	0	0
No release info	0	0	215	215
Grand total	15,522	3,238	426	19,186

We sampled with the cylindrical antenna detection system for 1,059 h in 2007 and detected 19,186 fish. In 2006, we sampled for 961 h hours and detected 12,361 fish (Figure 7). The higher detection rate in 2007 vs. 2006 (18 fish/h vs. 13 fish/h) occurred despite the release of about 26% fewer PIT-tagged fish in 2007 (according to PTAGIS). Many variables have influenced detection numbers in the estuary among years. For example, during two-crew sampling in 2007, mean flow volumes were about 28% lower than during two-crew sampling in 2006 (6,934 vs. 9,661 $m^3 s^{-1}$; Figure 8). Lower flows tend to slow fish travel speed and thus extend the period of availability for sampling. Sampling in the estuary since 1998 at has revealed a strong correlation between high flows and lower annual detection rates of PIT-tagged fish.

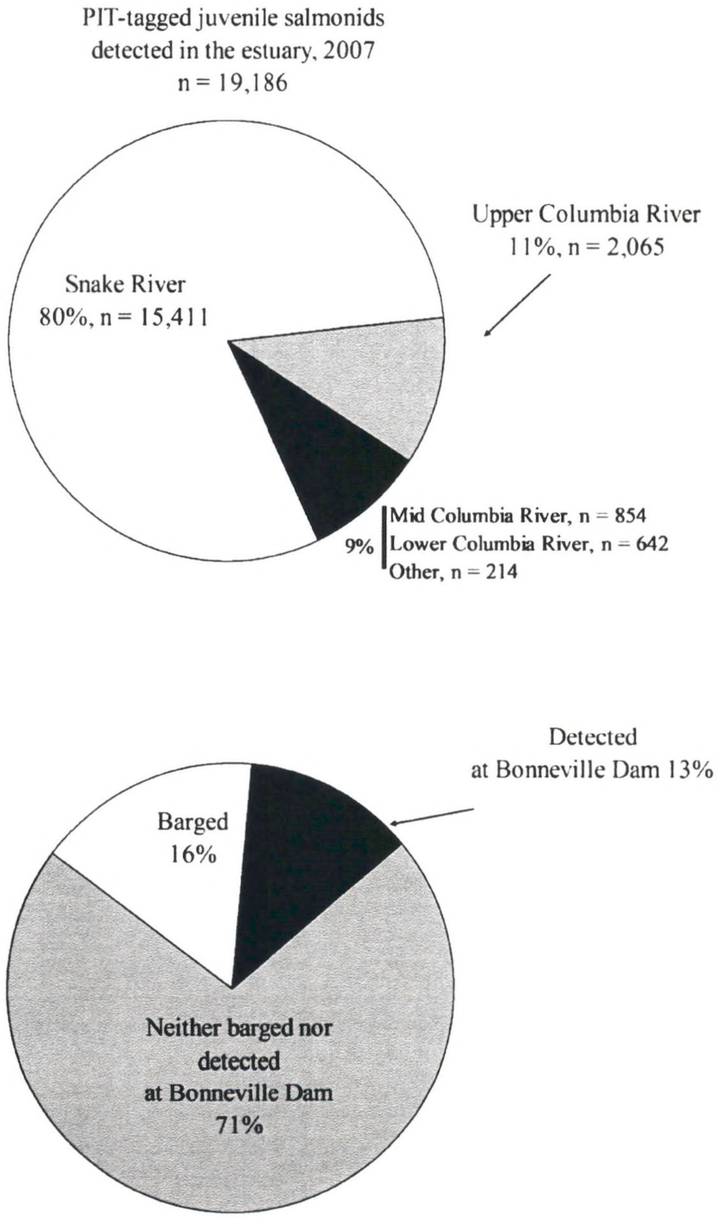

Figure 6. River basin sources and migration histories of PIT-tagged fish detected in the Columbia River estuary near rkm 75, 2007. For fish released to the Columbia River, upper-river fish were those released upstream from McNary Dam; mid-river fish were those released below McNary Dam, and lower-river fish were relased below Bonneville Dam. Only fish Snake River fish and those passing McNary Dam could be collected for transport.

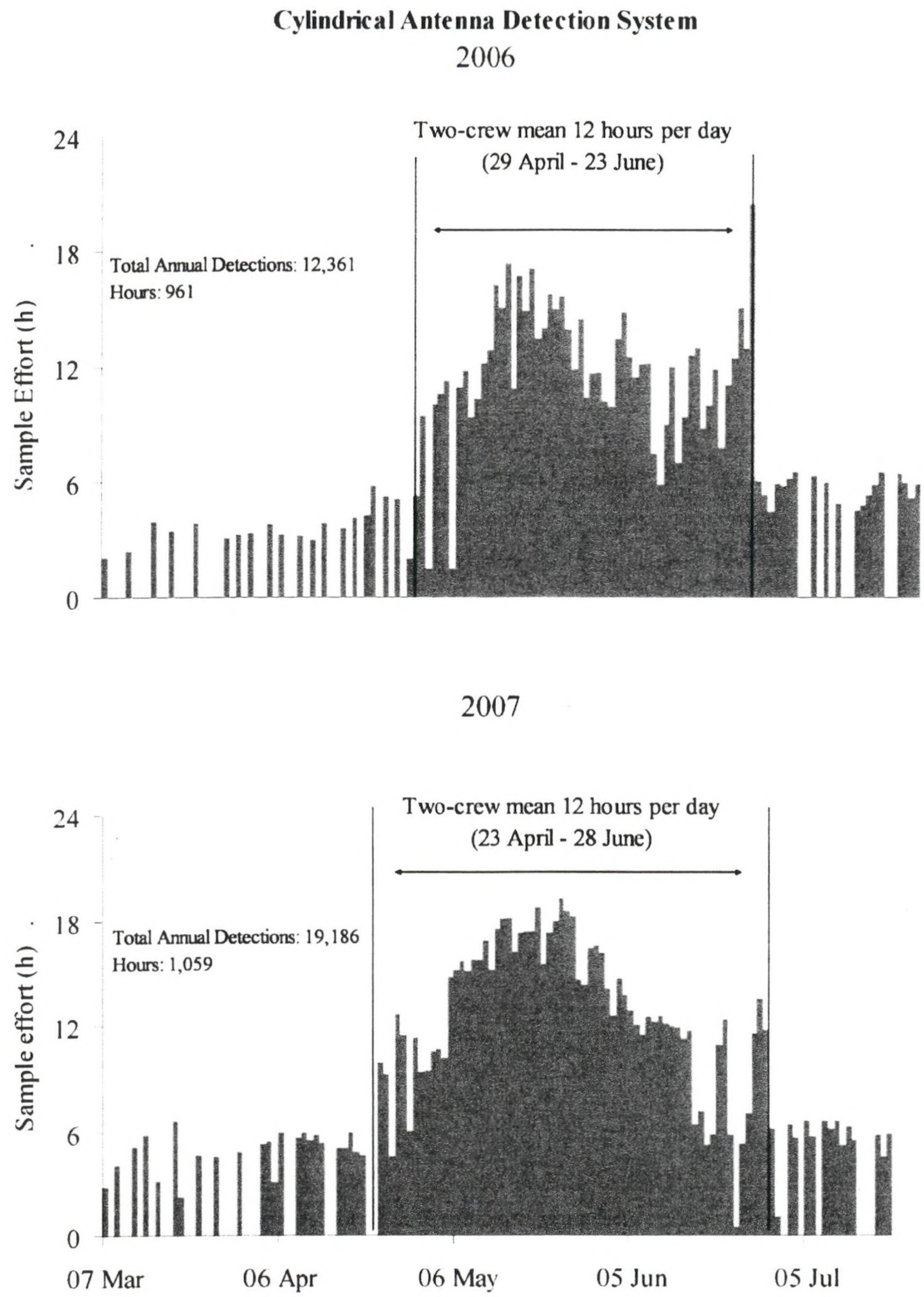

Figure 7. Daily sample effort using the cylindrical antenna PIT-tag detection system near river kilometer 75, 2006-2007.

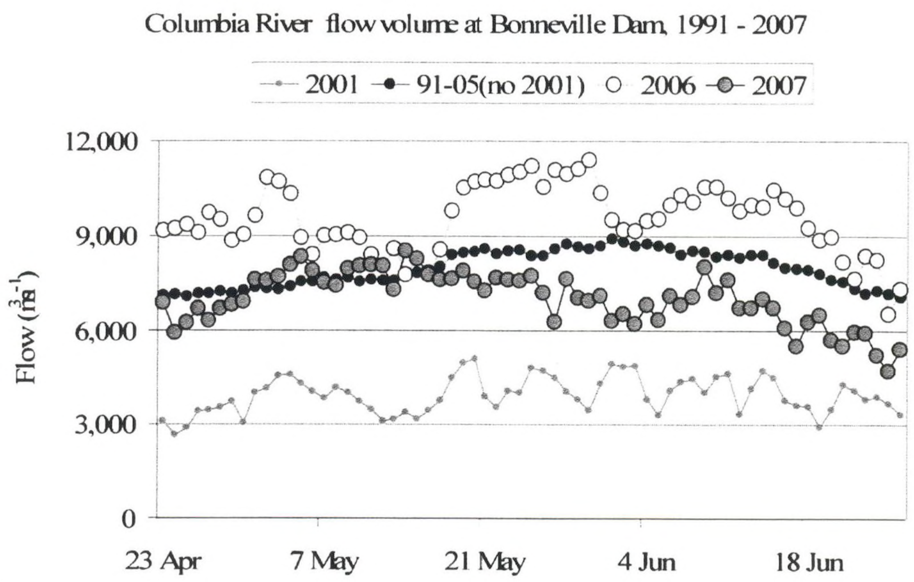

Figure 8. Columbia River flows at Bonneville Dam during the two-crew sample periods 2006 and 2007, as compared to the average flow from 1991 to 2000. Drought-year flows for 2001 are also shown for comparison.

Matrix Trawl System Detections

In 2007, we sampled with a prototype 2-coil matrix antenna system for approximately one week near the peak of the spring migration and again for approximately one week late in the season. During the first sampling period in late May-early June, we deployed the 2-coil matrix system simultaneously with the cylindrical system . Both systems were operated during a period of relatively high densities of PIT-tagged fish in the sample area. We then compared detections on both systems during the same 35.9-h period, during which 233 fish were detected with the 2-coil matrix antenna and 730 with the cylindrical antenna system (Table 2 and Appendix Table 3). A total of 19 individual fish were detected on both systems.

The lower detection rate of the prototype 2-coil matrix system was partly due to electromagnetic interference (EMI). High levels of EMI were recorded the in status reports generated by the transceivers, and noise levels were high enough to prevent the system from reading test tags deployed on a stick. Periodically, EMI would drop, and detection rates of the matrix system would dramatically increase, surpassing those of the smaller cylindrical antenna. The smaller antenna was seemingly unaffected by the noise source recorded so prominently on the matrix antenna. Lack of a rear detection component was also a likely factor in reduced overall efficiency of the matrix system.

Table 2. Daily detections and sampling effort using a 2-coil matrix antenna system and the cylindrical system near rkm 75, 2007. Nineteen fish were detected on both trawls.

		Total detections (n)	
Date	Effort (h)	Matrix system (2-coil)	Cylindrical system (0.9 m dia)
22 May	3.92	47	185
23 May	5.28	50	228
24 May	5.47	66	159
30 May	5.68	36	69
4 Jun	5	12	26
5 Jun	5.25	7	20
6 Jun	5.3	15	43
Totals	35.9	233	730

The pair trawl net used during both sampling periods with the matrix antenna was identical in size and dimensions to the net used with the 0.9-m diameter cylindrical antenna. However, the trawl body of the matrix system was about 3 m shorter than that of the cylindrical system because the rear portion of original trawl body was cut to fit the larger fish passage opening. The shorter trawl body made it noticeably more difficult to maintain proper alignment of the matrix antenna with the wings of the trawl during deployment. In addition, because of the larger size of the matrix antenna and the logistics involved in deploying the system, much of the focus during sampling was on development of safe handling practices, transceiver tuning, and verification of detection efficiency.

On 4 June, during a 3-h tandem sampling period, the matrix system traveled 0.3 knots h^{-1} faster than the cylindrical system (average speed 0.2 knots h^{-1}) using similar engine power (1,100 rpm) on the 12.0-m tow vessels. However, since we had only three 12-m tow vessels, we utilized two additional smaller vessels in tandem to tow one side of the matrix trawl. The 12-m vessel set the pace (1100 RPM) and the smaller vessels matched that speed. In addition to these complexities, speed differences were difficult to evaluate with certainty due to tidal effects, currents, and cross channels in the sample area.

In mid-July, construction of a 5-coil matrix antenna system was completed. The new system consisted of the original 2-coil antenna, which was used as the front component, and a new 3-coil antenna used as the rear component. Both components measured 2.6 by 3.0 m (Figure 3) and were separated by a net mesh tunnel. We tested the 5-coil system during daylight hours between 12 and 18 July.

Due to a vessel breakdown, simultaneous sampling of the 5-coil matrix and cylindrical antenna system was not possible except on 13 July. Therefore, we sampled with each system on alternate days within the same 7-day period. These sampling cruises occurred late in the migration season, when abundance in the estuary of PIT-tagged fish was generally low. With the 5-coil matrix system, we sampled for a total of 16.4 h and detected 70 fish, and with the cylindrical system, we sampled for 16.1 h and detected 12 fish (Table 3). These late season detections were primarily subyearling Chinook salmon. Results showed that the matrix system detected over five times more fish than the cylindrical system, and after extensive electronics tuning, very little environmental noise was observed.

Table 3. Daily detections and sample effort using a 5-coil matrix system (2 coils in front and 3 coils in rear) and the cylindrical system in mid July near rkm 75, 2007.

	Sampling effort (h)		Total detections (n)	
Date	Matrix system (5-coil)	Cylindrical system (0.9 m dia)	Matrix system (5-coil)	Cylindrical system (0.9 m dia)
12 Jul	2.2	NA	9	NA
13 Jul	2.8	5.6	3	7
14 Jul	7.9	NA	26	NA
16 Jul	6.3	NA	32	NA
17 Jul	NA	5.9	NA	1
18 Jul	NA	4.7	NA	4
Totals	16.4	16.1	70	12

Shoreline System Detections

We deployed a modified PIT-tag sampling system along the shoreline at rkm 75 on six ebb tides between 13 March and 19 April. We sampled with the shoreline system for a total of 43 h. Target fish were juvenile salmonids migrating in the shallow near-shore waters of the estuary, which are inaccessible to the larger trawl system. The shoreline system was composed of a 2-coil matrix antenna (2.6 × 3.0 m) fitted to a modified trawl net. We believed the larger opening of the matrix antenna would pass more water and reduced the fish avoidance encountered with the shoreline system in previous years. However, the 2007 shoreline system was also plagued with intermittent high EMI, and funnel testing on 19 April revealed a very low test tag detection rate. No fish were detected using this system (Table 4).

Table 4. Daily detections and sample effort using a 2-coil matrix antenna along the shoreline at rkm 75, 2007.

Date	Effort (h)	Detections (n)
13 Mar	2.07	0
15 Mar	4.73	0
20 Mar	3.33	0
22 Mar	4.37	0
28 Mar	5.28	0
29 Mar	5.30	0
5 Apr	4.78	0
10 Apr	4.73	0
17 Apr	2.73	0
19 Apr	5.67	0
Totals	43.00	0

Electronic Performance and Efficiency Evaluations

Detection Efficiency

As found in previous years, test tags oriented perpendicular to the electronic field were read at higher rates than those placed at an angle to the field. Efficiencies were also positively correlated with spacing between tags, regardless of orientation. It is important to note that often, differences in detection efficiency were observable only when the test-tag tape was passed through the center of the antenna. When passed near the edge of antenna (the area of optimal detection and where most fish are likely to pass), differences in detection efficiency between angles of orientation were negligible.

According to PTAGIS, about 39% of fish PIT-tagged and released into the Columbia River Basin for migration in 2007 were tagged with SST tags, which have longer read ranges than the older ST tags. About 36% of trawl system detections in 2007 were SST tags and the rest were ST tags. The matrix antennas, with their larger fish-passage openings, were designed to utilize the increased read range of the SST tag. Since few hours of sampling were conducted with the prototype matrix systems, we evaluated detection efficiency only for the cylindrical system. Moreover, based on the percentages of SST vs. ST tags from our detections and from PTAGIS, transition to the newer SST tag was not yet complete. Therefore, detection efficiency tests were conducted using only ST tags.

The 0.9-m-diameter cylindrical antenna read about 43% of test-tags spaced 30-cm apart and held perpendicular to the electronic field, but read less than 32% of test tags oriented at 45° to the electronic field (Figure 9). When spacing between tags was increased to 61 cm, detection efficiency increased to nearly 85% for perpendicular tags and 95% for tags at 45° angles. When spacing between tags was increased to 91 and 122 cm, detection efficiencies increased to between 93 and 98%, regardless of tag orientation. When tags were passed through the cylindrical system antenna within approximately 20 cm of the wall (side), rather than through the center, the average detection rate was 96%, regardless of spacing and orientation.

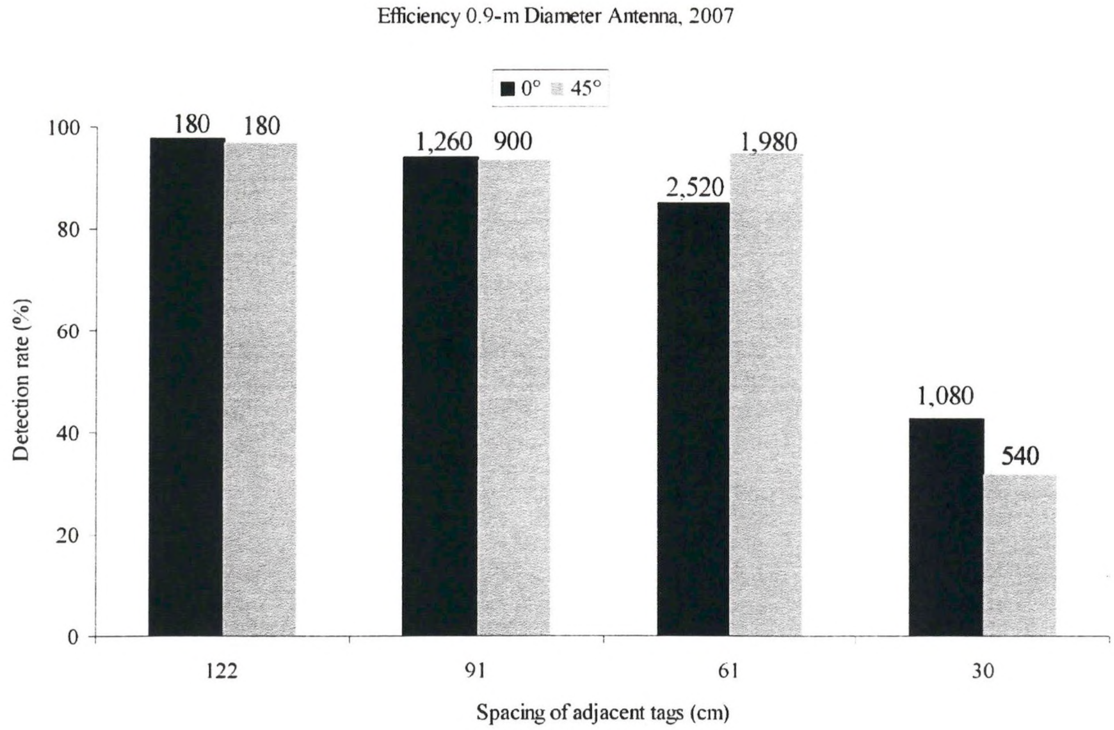

Figure 9. Read efficiency of the cylindrical antenna (0.9-m dia) tested using 50 ST PIT-tags attached to vinyl tape measures, 2007. Various spacing between tags and angles of orientation to the electronic field were used. Tags were passed through the antenna repeatedly on different dates (total potential tags listed above the bars). Results are detections of unique codes per pass for the front and rear coils combined.

Antenna Efficiency

Reading efficiencies of each antenna and individual coil were evaluated periodically during sample cruises through the season. The 0.9-m-diameter cylindrical antenna used throughout most of 2007 had a higher mean detection rate (63%) than the 1.1-m diameter cylindrical antenna used in 2006 (54%; Ledgerwood et al. 2007). Antenna efficiency of the 2 coil matrix antenna systems was lower than that of either cylindrical antenna system. Mean antenna efficiency was 32% for the 2-coil matrix system and 69% for the 3-coil matrix system (higher than the 1.1-m diameter antenna). Testing of both matrix systems was often complicated by unexplained EMI (Table 5). 19,470

Table 5. Average detection efficiencies of four PIT-tag antenna designs used in 2006 and 2007. In 2006 efficiencies were determined by passing 50 test tags at various spacing and orientations on a vinyl tape through the center of each antenna while in 2007, using the same spacing and orientation designs, test tags were placed through the center as well as near the side of each antenna.

	2006		2007		
Antenna system (dimensions)	Total tags (N)	Mean antenna efficiency (%)	Total tags (N)	Mean antenna efficiency (center %)	Maximum antenna efficiency (side %)
Cylindrical (0.9-m diameter)	10,900	73	4,200	81	96
Cylindrical (1.1-m diameter)	22,200	63	6,000	54	91
2-coil matrix (1.1 × 2.8 m)	5,450	31	6,000	32	63
3-coil matrix (0.7 × 2.8 m)	*	*	3,300	69	79

* In 2006, only the 2-coil matrix system was used.

Detection rates of individual coils for each antenna were evaluated to provide an understanding of antenna status and performance We observed early in the season that the detection rate of the 1.1-m-diameter antenna originally planned for use in 2007 was significantly lower than measured in 2006 (54 vs. 63%). On 4 April, we determined the integrity of the antenna had been compromised by water leakage. After this date and for the remainder of the season, we used the older, 0.9-m diameter cylindrical antenna system (the antenna used during 2001-2005).

We also evaluated daily performance of the 0.9-m diameter cylindrical system by comparing the total number of fish detected to the number detected the front and rear coils (14 and 12%, respectively) (Figure 10).

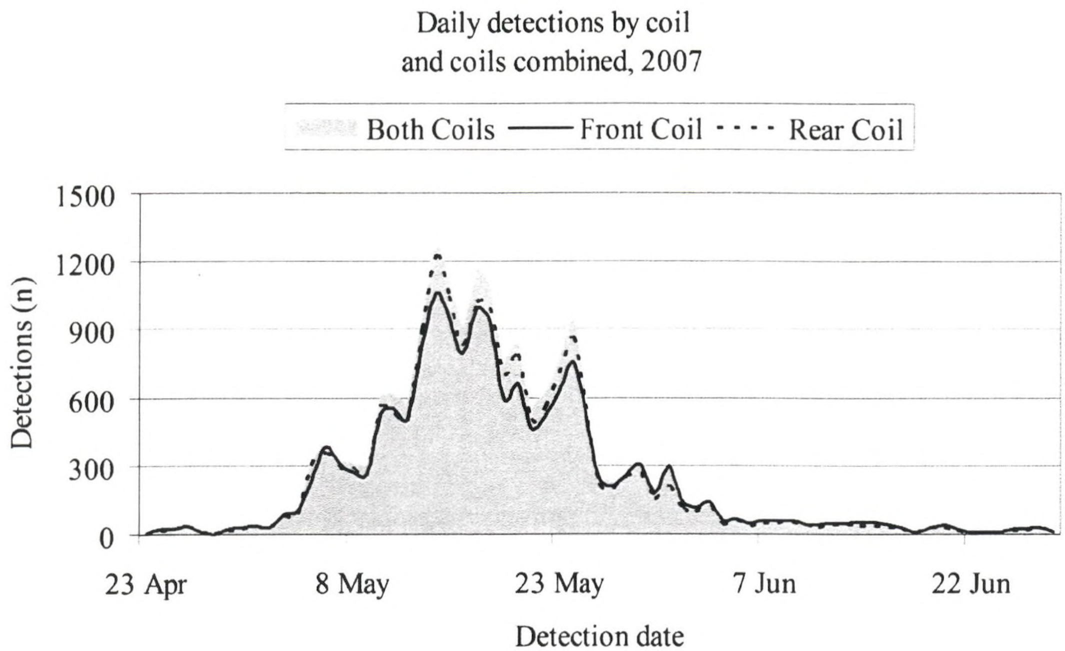

Figure 10. Daily detections of juvenile salmonids by coil, using the cylindrical (0.9-m diameter) antenna system during the two-crew sample period, 2007.

Impacts to Fish

During sampling with the cylindrical detection system, we observed 106 juvenile salmonids either impinged, injured, or dead in trawl inspections or retrievals. An additional 46 mortalities were observed with the matrix detection system (Appendix Table 4). Due to the net inversion process of the cylindrical system, it is possible that other fish were injured or killed but were not observed. Even though volitional passage through the antenna occurred while towing with the wings extended, we continued to bring the wings together every 17 minutes and detected most fish during these 7-min net-flushing periods.

In the cylindrical antenna system, some fish were detected repeatedly on either the front or rear coil. Fish detected on the front coil occasionally swam forward into the trawl and were detected on the front coil again as they moved back toward the antenna. Most fish detected on the front coil immediately passed through the antenna and were detected a few seconds later on the rear coil, at times repeatedly. Some of these fish probably swam forward in the trawl body after initial detection and later returned and passed through the antenna. Multiple detections with the cylindrical system were fewer in 2006 (1.1-m dia antenna) than in either 2005 or 2007 (0.9-m dia antenna; Table 6). Overall, delay time was also shortest with the larger antenna used in 2006 (Figure 11).

Table 6. Trawl system passage metrics for the cylindrical antenna design used in 2007 compared to previous years.

	Trawl system passage metrics		
	2005	2006	2007
Cylindrical antenna diameter (m)	0.9	1.1	0.9
Fish with 10 or more detections (n)	168	22	105
Fish exiting within 11 sec of first detection (%)	78	70	67
Median exit time (sec)	4	2	5

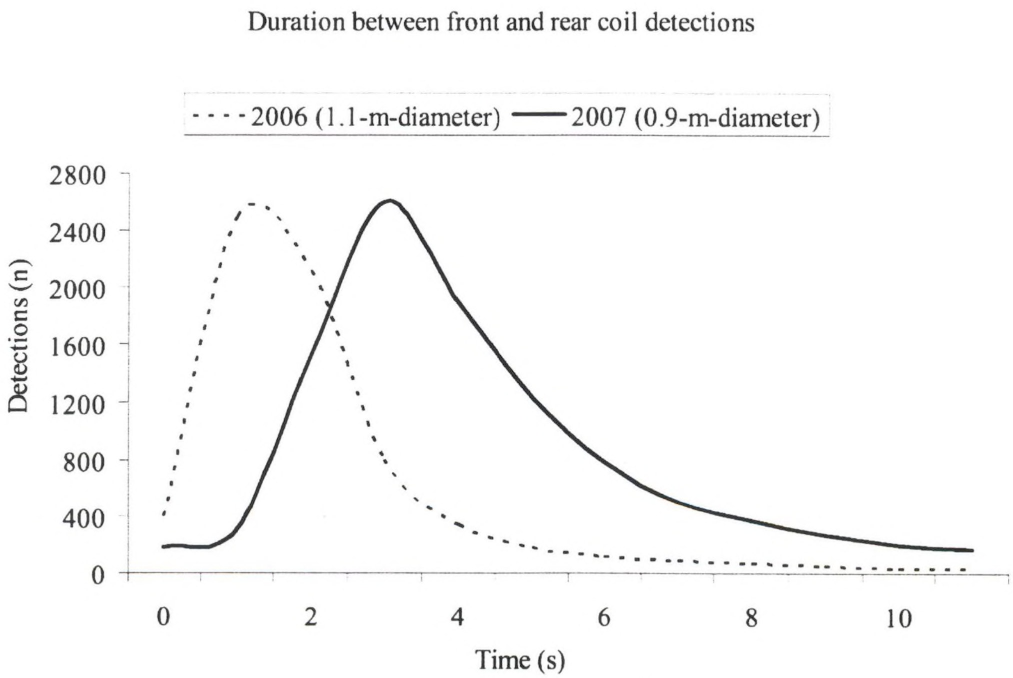

Figure 11. Total number of detections and corresponding time lapse between first and last detection of PIT-tagged fish passing through the 0.9-m vs. 1.1-m diameter antennas in less than 11 seconds. Figure represents 78 and 67% of annual detections in 2006 and 2007, respectively.

Diel Detection Patterns

During the two-crew sampling period (23 April- 28 June), we detected 14,397 yearling Chinook salmon and 3,460 steelhead. Total detections during two-crew sampling in 2007 were compared to those from intensive sampling in previous years. We pooled average diel detections distributions from 2003 through 2006 and compared them to the average diel distribution in 2007 (Figure 12). During two-crew sampling in 2007, the detection system recorded data for an average of 12 h d^{-1} (Appendix Table 5).

Hourly detection rates were significantly higher during nighttime (2100 to 0500 PDT) than during daytime hours for yearling Chinook salmon of both hatchery (24 vs. 10 fish h^{-1}, $P = 0.001$) and wild origin (3 vs. 1 fish h^{-1}, $P = 0.000$). However, hourly detections rates did not differ significantly between darkness and daylight hours for either hatchery (2 vs. 3 fish h^{-1}, $P = 0.887$) or wild steelhead (1 vs. 2 fish h^{-1}, $P = 0.268$).

We examined the hourly distribution of trawl detections from 2003 to 2007 and found no significant differences between those of hatchery and wild fish. Therefore, we pooled hatchery and wild fish detection data for analysis. Results for yearling Chinook and steelhead are presented in Figure 12. Data from other salmonid species were insufficient for analsysis. Continuous diel sampling was either limited or not conducted during 2000-2002; therefore the data from these years was excluded from analysis. Typically, Chinook salmon have been more numerous during darkness hours, often significantly so, and steelhead more numerous during daylight hours, though rarely significantly.

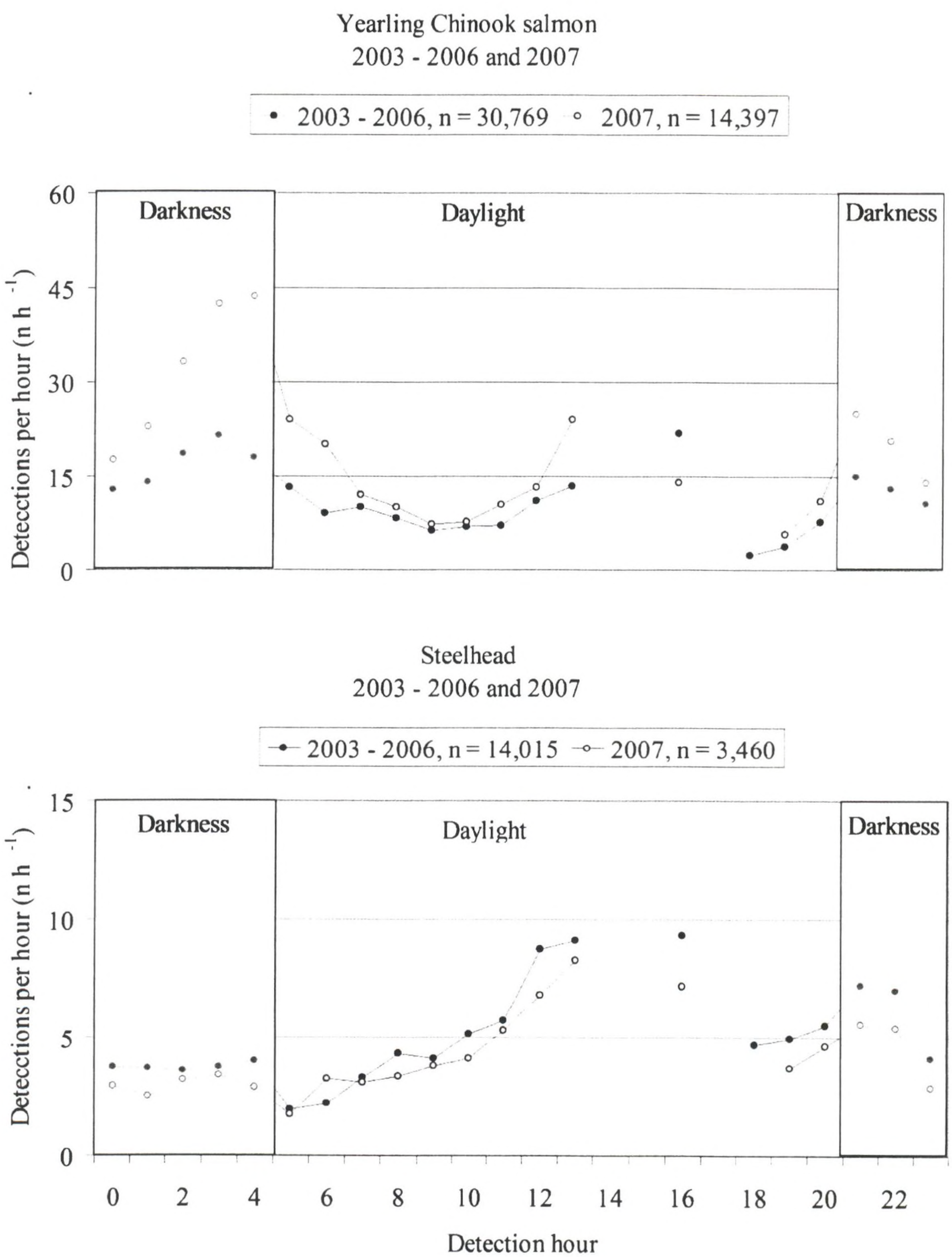

Figure 12. Average hourly detection rates of yearling Chinook salmon and steelhead during the two crew sampling periods of 2003 through 2006 versus 2007 using the large trawl system in the upper estuary.

Timing and Migration History

Yearling Chinook Salmon and Steelhead

Median travel times to the estuary from the tailrace of Lower Granite Dam, detection at Bonneville Dam, and from barge release sites below Bonneville Dam are shown in Table 7 for yearling Chinook salmon and steelhead. Median travel time from Lower Granite Dam to the estuary was greater in 2007 than in 2006 for both yearling Chinook salmon (15.7 vs. 14.7 d) and steelhead (15.6 vs. 12.5 d). Overall, travel times for yearling Chinook salmon and steelhead from Lower Granite Dam in 2007 were similar to previous years since 2000, with the exception of the low-flow drought year of 2001, when median travel times were more than 30 d for both species.

For yearling Chinook salmon, median travel time from detection at Bonneville Dam to the estuary was the same in 2006 and 2007 (1.7 d in both years). For juvenile steelhead detected at Bonneville Dam, travel time to the estuary was slightly slower in 2007 than in 2006 (1.7 vs. 1.6 d). For fish released from barges just downstream from Bonneville Dam, median travel time to the estuary was also slower in 2007 than 2006 (2.2 vs. 2.1 d for yearling Chinook; 1.7 vs. 1.6 d for steelhead).

We also compared daily differences in travel speed to the estuary by migration history (transported vs. inriver) and river flow (Figure 13). Median travel speed to the estuary was significantly slower for yearling Chinook salmon released from barges (69 km d^{-1}) than for those detected at Bonneville Dam on the same date (92 km d^{-1}; $P = 0.000$). This difference was similar to observations from previous study years. Median travel time to the estuary was significantly faster for juvenile steelhead detected at Bonneville Dam (94 km d^{-1}) than for steelhead released from barges on the same date (89 km d^{-1}; $P = 0.000$). Interactions between date (of barge release/detection at Bonneville), flow, and migration history were found in some comparisons.

Table 7. Median travel time in days for yearling Chinook salmon and steelhead detected and released inriver at Lower Granite Dam, detected at Bonneville Dam, or released from a transportation barge just downstream from Bonneville Dam, to the upper estuary (rkm 75). Mean flow volume from mid-April through the end of June (approximate spring migration period) at Bonneville Dam listed, 2000-2007.

	Median time (d) to trawl-system detection in the upper Columbia River estuary (rkm 75)												
	Detection at Lower Granite Dam (rkm 695)				Detection at Bonneville Dam (rkm 234)				Release from transportation barge (rkm 225)				
	Yearling Chinook salmon		Steelhead		Yearling Chinook salmon		Steelhead		Yearling Chinook salmon		Steelhead		
Year	Travel time (d)	Sample (n)	Travel time (d)	Sample (n)	Travel time (d)	Sample (n)	Travel time (d)	Sample (n)	Travel time (d)	Sample (n)	Travel time (d)	Sample (n)	Flow ($m^3 s^{-1}$)
2000	17.4	681	17.1	833	1.7	479	1.7	296	1.9	495	1.6	301	7,415
2001	32.9	680	30.1	44	2.3	792	2.5	59	2.9	1,329	2.3	244	3,877
2002	18.2	538	17.8	93	1.8	1,137	1.7	156	2.0	1,958	1.6	296	8,071
2003	17.0	563	16.5	95	1.8	1,721	1.7	567	2.1	2,382	1.7	435	7,120
2004	16.6	867	16.6	153	1.9	672	2.0	110	2.2	2,997	1.9	333	6,663
2005	17.3	1,183	16.9	278	1.8	81	2.0	471	2.2	2,910	1.9	400	5,776
2006	14.7	628	12.5	110	1.7	888	1.6	131	2.1	1,315	1.6	170	9,435
2007	15.7	1,196	15.6	117	1.7	1,510	1.7	362	2.2	1,096	1.7	143	6,858

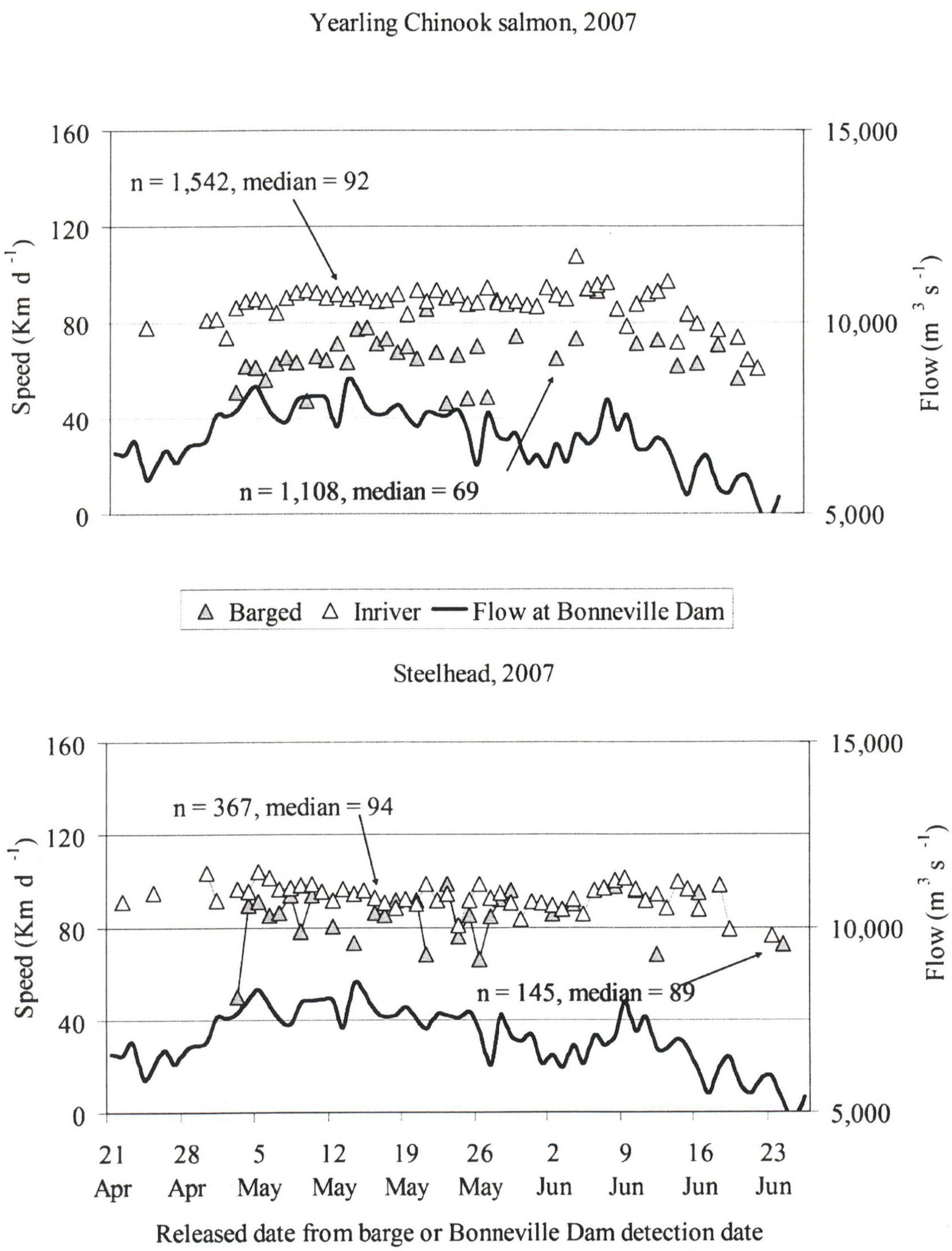

Figure 13. Daily mean travel speed of yearling Chinook salmon (top) and steelhead (bottom) to the estuary following detection at Bonneville Dam or release from a barge, 2007. Detections from 0.9-m dia cylindrical antenna trawl system.

Subyearling Fall Chinook Salmon

We detected 336 fall Chinook salmon, all of which had been PIT-tagged and released after 30 April 2007 and were less than 120 mm fork-length at tagging. Most fall Chinook salmon released prior to 30 April were yearlings and greater than 120 mm. We detected 11 transported and 325 inriver migrant fall Chinook salmon between May and mid-July (Figure 14). The largest proportion of fall Chinook detected (38%) had been released in the upper Columbia River. Twenty-six percent had originated in the lower Columbia River, 24% in the Snake River, and 11% in the middle Columbia River.

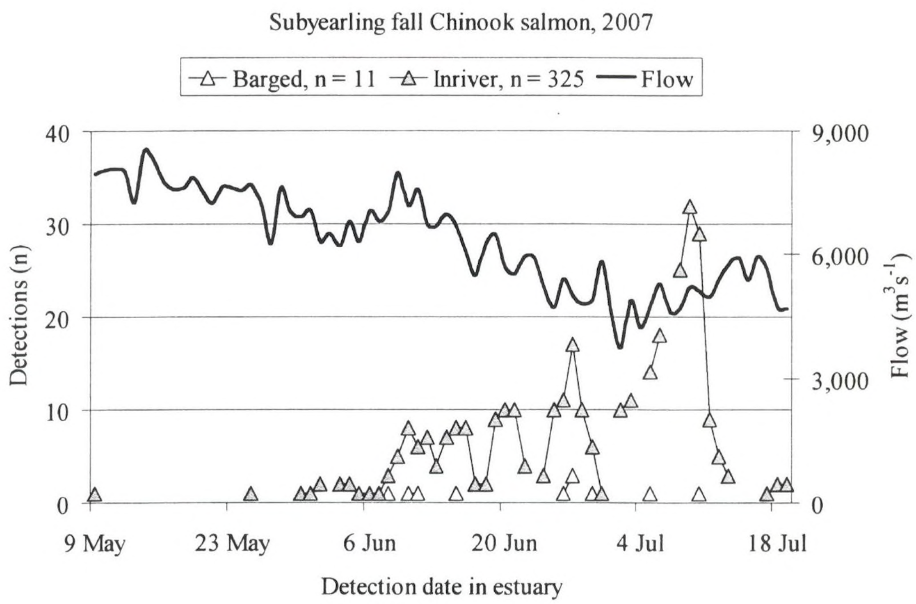

Figure 14. Temporal detection distribution in the estuary at rkm 75 compared to river flow volume for subyearling Chinook salmon released from barges vs. inriver migrants, cylindrical system, 2007.

Daily average travel speed of PIT-tagged fall Chinook salmon released from barges or left to migrate inriver decreased with river flow (Figure 15). Median travel speed for transported fall Chinook from the barge release site to the estuary was as 60 km d^{-1}. Median travel speed for inriver fall Chinook from detection at Bonneville Dam to the estuary was 73 km d^{-1}. However, due to small sample sizes in both migration history groups, we could not make any definite conclusions based on these results.

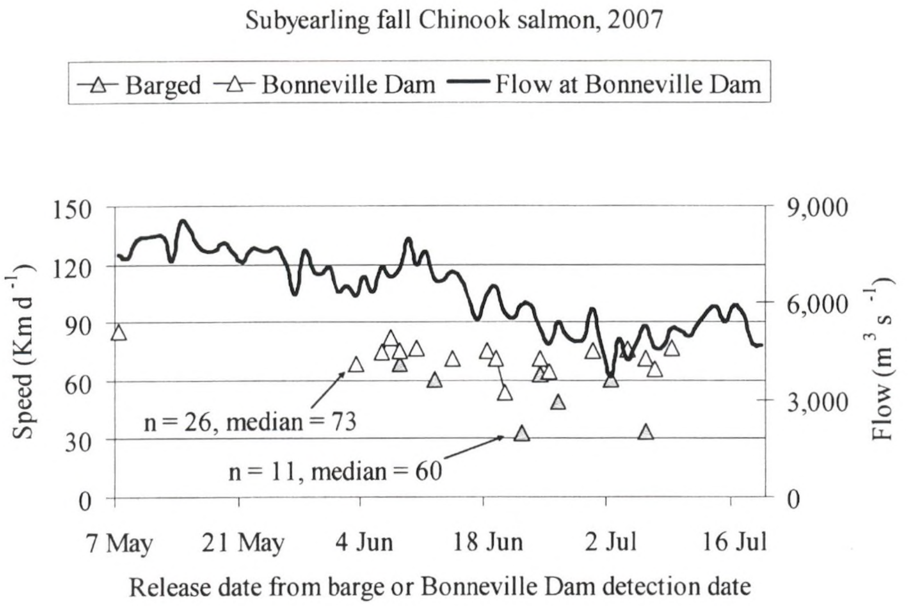

Figure 15. Daily mean travel speed and river flow volume of subyearling Chinook salmon released from barges vs. those detected passing Bonneville Dam and subsequently detected in the cylindrical system rkm 75, 2007.

A portion of Snake River subyearling fall Chinook salmon that were released in 2006 did not migrate downstream that year, but instead overwintered in the river basin and migrated in 2007. We detected 27 of these fish in the upper estuary between 3 and 15 May. None of these fish had been transported, and all of them originated from the Dworshak National Fish Hatchery. Twenty-six had been released from the Big Canyon Creek Acclimation Facility on the Clearwater River, and one had been released into the Snake River 29 km above its confluence with the Clearwater River. Two of these 27 subyearlings were later detected on East Sand Island in the estuary (Caspian tern and cormorant colonies). Two others were detected migrating upstream in late 2008 at Bonneville Dam, and one of these two was later detected at Lower Granite Dam.

Transportation Evaluation

Comparisons of transported and inriver migrant fish included river-run fish diverted at transport dams, fish tagged at Lower Granite Dam for NMFS transport studies, and fish tagged for other studies. From these groups, a total of 64,846 yearling Chinook salmon and 47,894 steelhead were transported and released above the trawl sample area (rkm 75). Of these transported fish, we detected 1,886 yearling Chinook salmon and 1,183 steelhead using the cylindrical trawl system (Appendix Tables 6-7). Of the Snake and Columbia River basin fish that completed migration in the river, 49,423 yearling Chinook and 13,618 steelhead were detected at Bonneville Dam. Of those, we detected 1,678 yearling Chinook salmon and 472 steelhead (Appendix Table 8).

Prior to completion of the corner collector monitoring system at Bonneville Dam, PIT tag detections were available only from juveniles that passed via the juvenile collection facility. In 2006, after the corner collector bypass was fitted with PIT-tag monitors, an estimated 42% of the 73,842 PIT-tagged migrants passing via corner collector were detected. In 2007, the proportion was even higher, with an estimated 60% of 76,996 PIT-tagged migrants detected. Additional fish were detected in the juvenile bypass facility in both years.

In 2007, 98% of the barged juvenile salmonids and 89% of those detected at Bonneville Dam were at or near rkm 75 during the two-crew sample period (23 April-28 June). Detections of fish transported fish during the first 2 d were excluded from analysis to allow time for inriver fish to travel to the sample area. During the two-crew period, we detected 3.0% of barged juvenile Chinook salmon available and 3.6% of those previously detected at Bonneville Dam. For steelhead during the same period, we detected 2.5% of the transported fish and 3.9% of fish detected at Bonneville Dam (Table 8).

Table 8. Trawl detection of PIT-tagged fish released from barges or previously detected at Bonneville Dam during intensive two-crew sample period (23 Apr-28 Jun). Release totals represent 91% of the annual totals; the remaining 9% were excluded from analysis, since we allowed 2-d lag time for inriver fish to travel to the sample area.

	Barged			Inriver		
	Released	Detected	%	Released	Detected	%
Chinook salmon	63,238	1,889	3.0	43,277	1,562	3.6
Steelhead	47,657	1,181	2.5	10,496	408	3.9

Detections of Transported vs. Inriver Migrants

Using logistic regression analysis, we compared the daily detection percentages of transported vs. inriver migrant fish previously detected at Bonneville Dam. Fish included in the analysis were only those detected during the two-crew daily sampling period. From the inriver fish detected at Bonneville Dam we used only those that originated at or upstream from the transportation dams. We also used logistic regression to model the daily detection rates of fish released from the same transport barge but loaded at different dams.

Regression analysis for yearling Chinook salmon showed no significant interaction between date and migration history ($P > 0.539$) (Figure 16, top panel) and none between the detection rates of barged vs. inriver migrants ($P = 0.196$). In fact, barged and inriver components appeared so similar that the two regression lines overlapped. There was, however, a significant change in detection rate through the migration season ($P < 0.001$). Estimated sampling efficiency was lower early in the two-crew sample period for barged and inriver yearling Chinook salmon (1.1%), increased by late-May (4.0%), and then dropped again by the end of the two-crew sample period (0.71%). The adjustment for overdispersion was 1.5.

Similar analysis for steelhead showed no significant interaction between date and migration history ($P = 0.094$); however, detection rates were significantly different dependant on migration history ($P = 0.001$). Date-squared was not a significant factor in the seasonal trend ($P = 0.124$). Detection rates for steelhead of both migration types increased steadily throughout the two-crew period, from 1.9 to 2.7% for transported fish and from 4.1 to 5.9% for inriver migrants (Figure 16, bottom). The adjustment for overdispersion was 1.93. As in 2005 and 2006, the daily detection data for steelhead was more variable than for yearling Chinook salmon, probably due to smaller sample numbers.

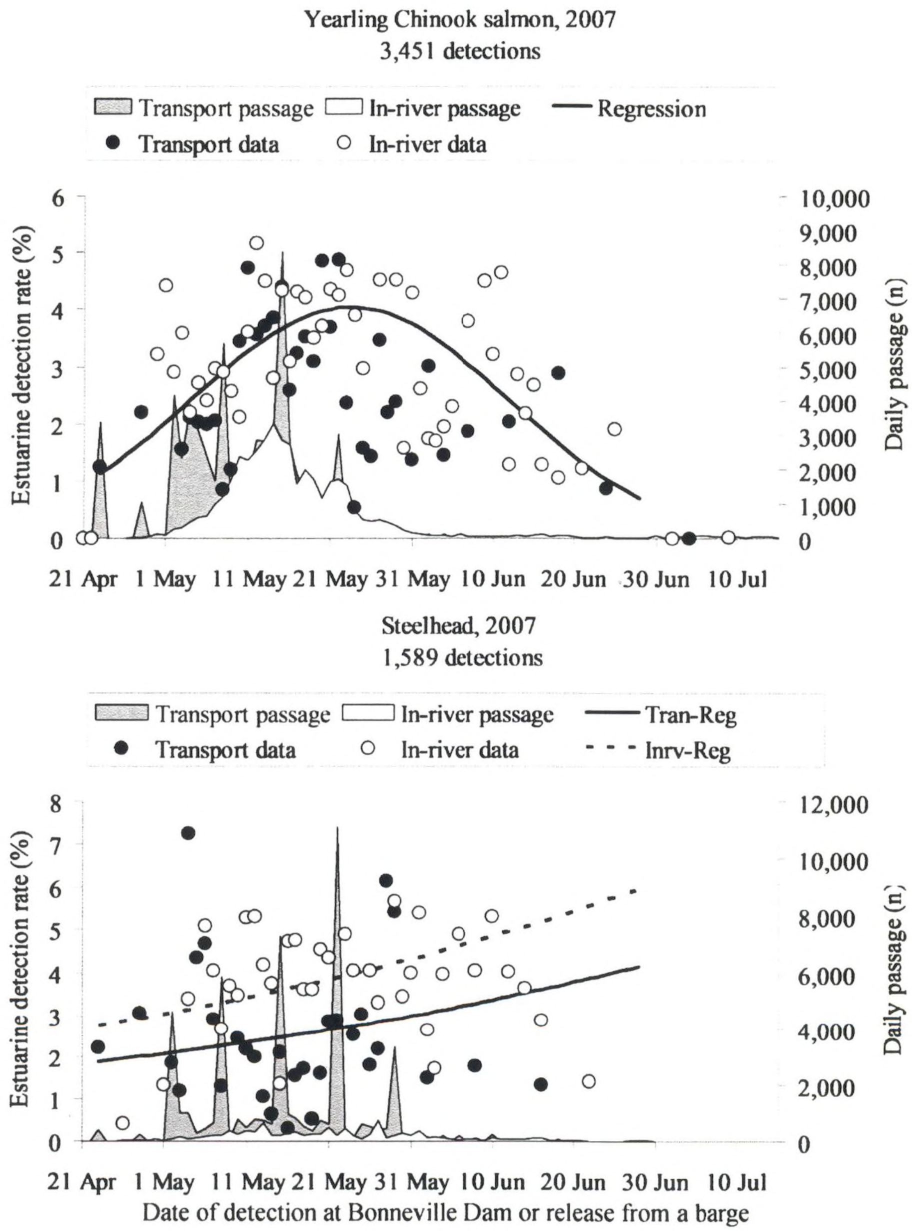

Figure 16. Logistic regression analysis of the daily detection percentage of transported and inriver migrant yearling Chinook salmon and steelhead detected at Bonneville Dam, 2007.

Mixing Assessment: Transported vs. Inriver Migrants

Comparisons of relative detection rates between transported and inriver migrant fish were based on the assumption that probabilities of detection in the estuary were equal between fish released from barges near Bonneville Dam and those detected in the bypass system at the dam on the same date. To test the validity of this assumption, we calculated the hourly differences in detection distributions between the two groups during the two-crew sample period for each year since 2000 (Figure 17).

The average hourly detection distributions for yearling Chinook salmon varied from 0 to 4% (average 2000-2007). There did not appear to be strong trends in the hourly differences for either group of yearling Chinook salmon. This supports a conclusion that the two groupings of fish were well mixed during their passage through the estuary. The extreme values in most years represented intervals with low sampling effort (shift change time periods) and perhaps low detection numbers for one group or another during the time of year that those interval hours were sampled. Variability was most extreme for 2001 (range, -9 to 7%), and for 2005, when most inriver fish (9%) were detected at 1400 and most barged fish (5%) at 2100.

For steelhead, average hourly differences in detections for the same 6-year period varied from 0 to 3%. While data from individual years indicated the possibility of a trend, when analyzed together, there did not appear to be strong trends in the differences for either group. This finding also supported the assumption that transported fish and those detected at Bonneville Dam were mixed during passage through the estuary. For example, sampling data from 2000 and 2006 suggested that higher percentages of barged steelhead were present during mid-day and less were present in the evenings, while 2001 data suggested the opposite. Ranges of difference were the highest than in 2000, 2001, and 2006 when sample sizes of steelhead were larger.

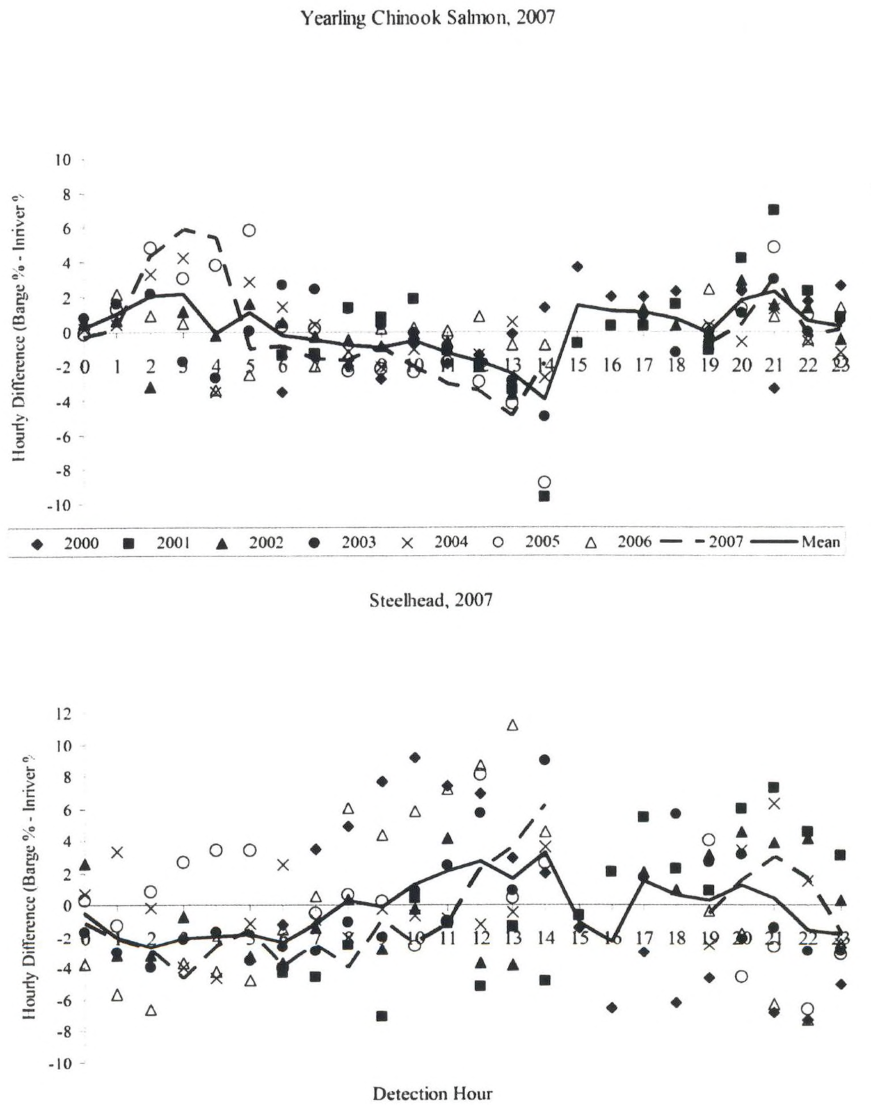

Figure 17. Hourly difference in estuarine detection percentages of transported fish vs. fish previously detected at Bonneville Dam during two-crew sampling periods, 2000-2007. The pooled mean difference is plotted. For each hour, a mean difference greater than zero indicates that a higher proportion of barged fish were detected, while a mean difference below zero indicates a higher proportion of inriver migrants were detected.

Transport Dam Assessment

There was a significant interaction between Snake River transport dam and barge release date for yearling Chinook salmon ($P = 0.003$; Figure 18, top). Detection rates for fish transported from Lower Granite Dam increased from 1.6% in April to 4.0% in May and then decline to zero by late June. For fish transported from Little Goose and Lower Monumental Dams combined, detection rates decreased steadily through the season from 4.2 to 1.8%. During early and late May, there was no difference between detection rates of these two transport treatment groups. The adjustment for overdispersion was 1.44.

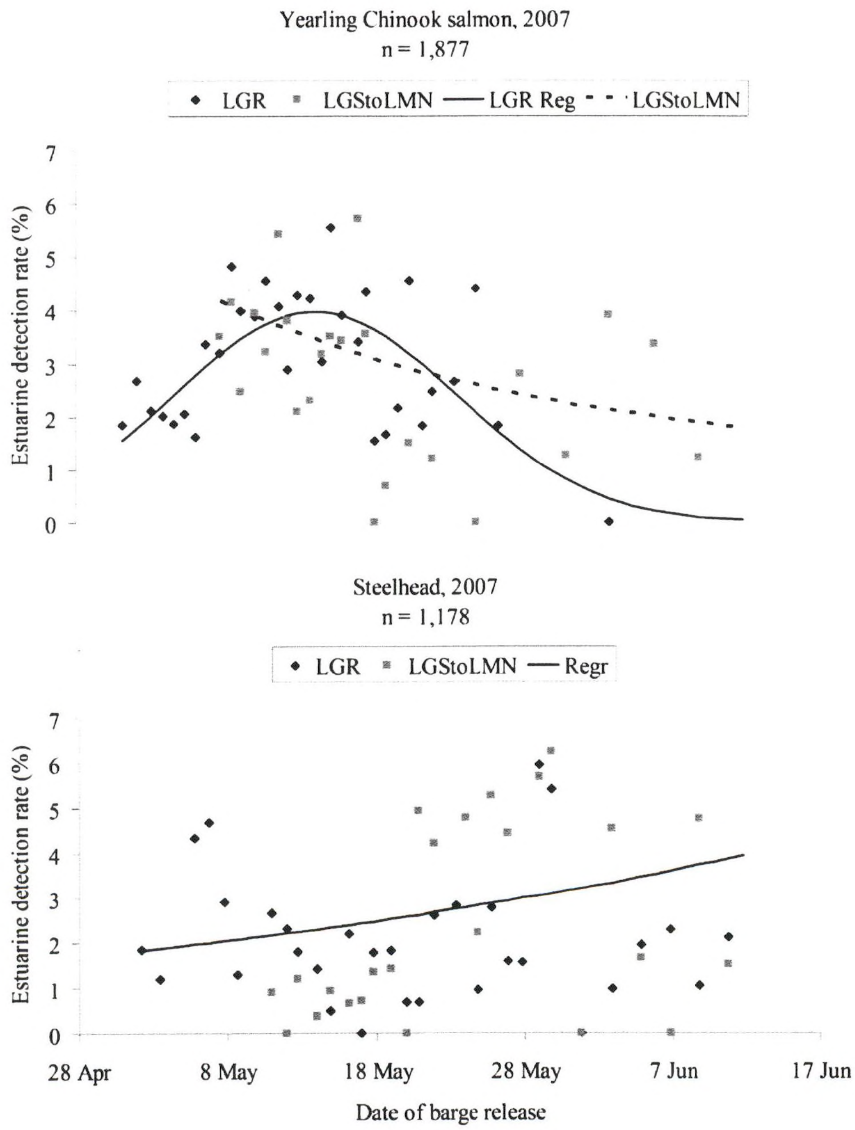

Figure 18. Daily detection rates of yearling Chinook salmon and steelhead released from barges loaded at Lower Granite Dam (LGR) or other downstream dams, Little Goose Dam (LGS) and Lower Monumental Dam (LMN), 2007.

There was no significant interaction in the estimated estuarine detection rate between Snake River transported and barge release date for steelhead ($P = 0.112$) (Figure 18, bottom). Nor was there a significant difference in detection rates between fish transported from Lower Granite Dam and those transported from Little Goose and Lower Monumental Dams combined ($P > 0.602$). There was, however, a significant difference in the detection rate of steelhead between days throughout the season ($P = 0.002$). During the two-crew period, the detection rates of steelhead from Lower Granite Dam as well as from Little Goose and Lower Monumental Dams combined increased from 1.8 to 4.0%. The adjustment for overdispersion was 2.21.

Survival of Inriver Migrants to the Tailrace of Bonneville Dam

Detections of yearling Chinook salmon and steelhead arriving at McNary Dam were pooled weekly, and survival probabilities of fish released in the Snake and Columbia Rivers were estimated from McNary to John Day, John Day to Bonneville, and McNary to Bonneville Dams (Table 9). Weighted annual survival estimates were compared for the years 1999-2007 for both Snake River and Columbia River basin stocks (Figure 19). In some years, there were insufficient PIT-tags released for one species or the other for a comparison between watersheds. However, there did not appear to be a general trend in survival between the two sources for either species.

Annual estimates for Snake River stocks of yearling Chinook salmon ranged from 50.1% in 2001 to 84.2% in 2006 (76.3% in 2007). Similar estimates for Columbia River stocks ranged from 62.2% in 2004 to 76.7% in 2003 (70.9% in 2007). Survival estimates for Snake River stocks of steelhead ranged from 25.0% in 2001 to 64.8% in 2006 (52.4% in 2007). Similar estimates for Columbia River stocks ranged from 39.2% in 2007 to 74.2% in 1999.

Fish loaded aboard trucks and barges at Lower Granite or other dams on the Snake River bypass a maximum of seven downstream dams. The effectiveness of fish transportation is evaluated in part by comparing adult return ratios of transported fish vs. inriver migrants. The annual benefit of transportation is sometimes related to river conditions experienced by fish left to migrate through the hydropower system. In 2006, seasonal average survival of inriver migrants from the tailrace of Lower Granite Dam to the tailrace of Bonneville Dam was 64.3% for yearling Chinook and 45.5% for Snake River steelhead. In 2007, the survival estimate for yearling Chinook salmon was 59.7% and 36.4% for steelhead (Table 10).

Table 9. Weekly average survival percentages from the tailrace of McNary Dam to the tailrace of Bonneville Dam for yearling Chinook salmon and steelhead, 2007. Total fish used in the survival estimates, weighted average survivals, and standard errors (SE) for each species and water basin are presented. Blank cells indicate sample sizes were too small for a one week estimate, and therefore the week prior is a two week pooled estimate.

		McNary to John Day Dam		John Day to Bonneville Dam		McNary to Bonneville Dam	
Date	N	%	SE	%	SE	%	SE
		Snake River yearling Chinook salmon					
20 Apr-26 Apr	1,344	95.5	7.6	76.3	26.8	72.9	24.9
27 Apr-03 May	11,709	87.2	1.8	94	11.3	82	9.7
04 May-10 May	37,880	96	1.5	87.7	5.7	84.1	5.3
11 May-17 May	28,473	92.1	1.8	86	6.9	79.2	6.2
18 May-24 May	16,429	90.6	2.1	60.9	5.7	55.2	5
25 May-31 May	2,310	71.2	6.8	87.5	41.4	62.3	28.8
01 Jun-07 Jun	695	72.8	11.2	111.6	105.8	81.3	76.1
08 Jun-14 Jun	607	65.5	12.4	45.2	23	29.6	14
Wt. Avg.	99,447	92	1.6	82.4	4.3	76.3	4.4
		Snake River steelhead					
20 Apr-26 Apr	541	174.9	55.7	34.5	32.5	60.3	53.4
27 Apr-03 May	893	98.6	16.7	46.4	17.7	45.7	15.7
04 May-10 May	2,242	100.4	10.8	71.1	16.8	71.3	15
11 May-17 May	1,781	98.5	18.6	41.9	12	41.3	8.9
18 May-24 May	1,136	70	15	65.2	25.1	45.7	14.7
25 May-31 May	464	41.7	20.4	65.8	50.3	27.4	16.1
Wt. Avg.	7,057	98.8	9.8	57.9	5.9	52.4	6.4
		Columbia River yearling Chinook salmon					
20 Apr-26 Apr	67	109.4	18.9	NA	NA	NA	NA
27 Apr-03 May	388						
04 May-10 May	727	89.1	5.6	111	34.8	98.9	30.4
11 May-17 May	1,512						
18 May-24 May	1,935	90.4	6.1	71.7	20.2	64.8	17.7
25 May-31 May	1,404						
01 Jun-07 Jun	586	71.7	10	60	37.1	43	25.9
08 Jun-14 Jun	179						
Wt. Avg.	6,798	89.1	3.3	86.2	14.5	76.1	13.8
		Columbia River steelhead					
04 May - 10 May	143	137.1	41.4	30	15.1	41.1	16.6
11 May - 17 May	668						
18 May - 24 May	949	79.1	13.8	58.8	20.4	46.5	14
25 May - 31 May	559						
01 Jun - 07 Jun	321	48.8	13.3	62.6	29.7	30.6	12
08 Jun - 14 Jun	322						
Wt. Avg.	2,962	82.1	17	53	9.1	40.8	4.7

Table 10. Estimated survival probabilities from the tailrace of Lower Granite Dam to the tailrace of Bonneville Dam for yearling Chinook salmon and steelhead, 1998-2007. SE is standard error; dashes indicate data were insufficient for analysis.

	Survival estimates			
	Yearling Chinook salmon		Steelhead	
Migration year	(%)	SE	(%)	SE
1998	53.8	4.6	62.8	5.4
1999	55.7	4.6	64.7	1.8
2000	48.6	9.3	66.8	3.4
2001	27. 9	1.6	31	0.3
2002	57.8	6	69.6	5
2003	53.2	2.3	57.7	1.1
2004	39.5	5	--*	--*
2005	57.7	6.9	--*	--*
2006	64.3	1.7	45.5	5.6
2007	59.7	3.5	36.4	4.5

* Sample size too small to estimate annual survival probability

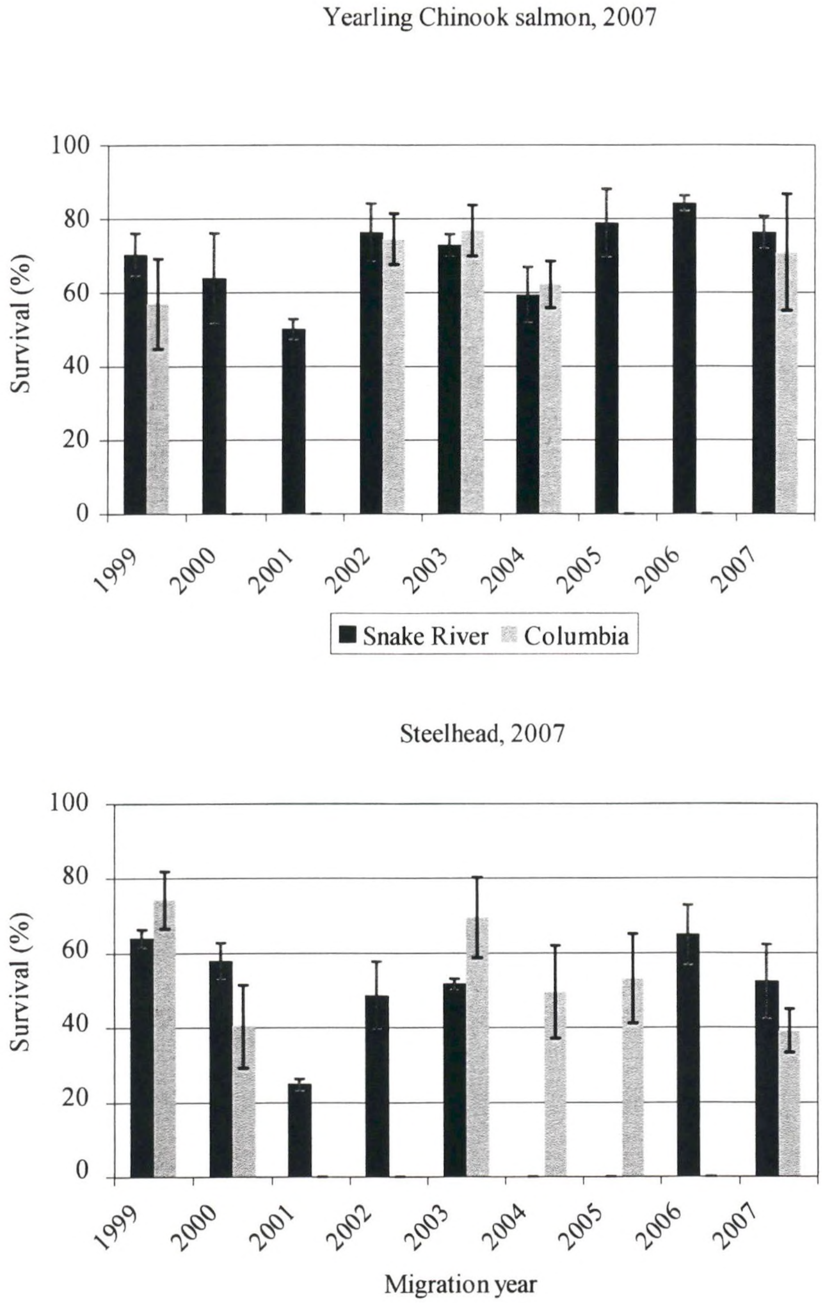

Figure 19. Weighted average annual survival and SE from the tailrace of McNary Dam to the tailrace of Bonneville Dam for Snake and Columbia River yearling Chinook salmon and steelhead, 1999-2007.

DISCUSSION

In 2007, we continued to provide detection data from the estuary trawl systems to agencies and individuals for studies of migration behavior and survival of juvenile salmonids. For the past several years, some 2 million PIT-tagged fish have been released annually into the Columbia River basin. Estuary trawl detections of these fish as they pass through the estuary has increased our understanding of salmon migration behavior and survival during the critical transition period from freshwater to saltwater. Detection data from 2007 ware also used for our own comparisons of seasonal and multi-year trends in survival to the estuary.

Trawl system detections also provide data for studies examining smolt-to-adult return ratios, which have shown substantial variation related to timing of the juvenile migration. For these studies, data from trawl detections helps separate freshwater effects from ocean effects when evaluating possible causes and timing of juvenile mortality. For example, large colonies of predacious birds occur on East Sand Island in the lower estuary and have a significant annual impact on migrating smolts (Collis et al. 2001; Ryan et al. 2001, 2003). Temporal comparisons can now be made between estuary detection rates of fish groups released from transport barges and their inriver migrating cohorts detected in the bypass system at Bonneville Dam. Similar comparisons are possible using PIT-tag data collected from abandoned bird colonies. Both sets of data contribute to better understanding of temporal variation in SARs and the benefits of management actions taken to enhance them.

In 2007, sampling was conducted using the 0.9-m-diameter cylindrical detection system used in 2006. Efficiency tests of the system during deployment at the beginning of the season revealed that this system was more efficient than the newer 1.1-m-diameter cylindrical system used in 2006. The larger system was originally designed to take advantage of the longer read ranges of the newer SST PIT-tags. However, early season testing revealed damage (a leak) to one of the coils. Therefore, we reverted to the 0.9-m antenna from previous years and focused further development efforts on the much larger matrix design.

The matrix design was intended to adapt the trawl detection system to utilize advances in PIT tag technology, improve system detection efficiency, and reduce impacts to fish. For example, in previous years, divers inspecting the trawl body and wing areas of the nets and reported that fish rarely swam close to the webbing, but rather, tended to linger near the entrance to the trawl body and antenna. The larger fish-passage opening of the matrix trawl system helped fish debris pass quickly and safely through the system.

As antennas increase in size, the power necessary to project the detection field across a larger area also increases the potential for tag collision (Downing et al. 2003). For trawl detection systems, tag collision can substantially reduce detection efficiency, especially during periods of high fish density, such as during net flushing. However, a greater detection range also allows for a larger fish-passage opening through the antennas. This larger opening, and the resulting increase in water volume passing through the trawl, reduced the reluctance of fish to exit the trawl. For example, the mean duration from first to last detection (front to rear coil) for fish in the cylindrical antennas increased from 2.0 seconds in 2006 (1.1-m dia) to 5.0 seconds in 2007 (0.9-m dia).

We conducted simultaneous sampling of the cylindrical and 2-coil prototype matrix system in late May-early June. During a total of nearly 36 hours of sampling with both systems, the prototype matrix system was less than half as effective at detecting PIT-tagged fish as the cylindrical system. The cause of this low efficiency was ambient EMI, which was recorded by the matrix system transceivers through much of the testing period. No such interference appeared to affect the smaller cylindrical antenna during the same test period. During the brief periods of low interference, matrix system efficiency increased, and perhaps even surpassed efficiency of the cylindrical system.

Other than EMI, factors effecting PIT-tag detection efficiency include the volume of water being filtered by the antenna and an antenna design allowing for redundant reading of passing fish (front-coil and rear-coil reads). Our preliminary tests with the matrix showed we travel nearly twice as fast through the water as the cylindrical system, but the original matrix design lacked a set of rear-coils eliminating any chance of detecting a PIT-tagged fish missed on the front coils. The increase in trawl speed was expected given the matrix system's much larger fish passage opening and shorter trawl body under similar tow power.

A second coil in the rear of the antenna system is an important design feature, since it not only provides a second chance to detect tagged fish missed by the front coil, but can help indicate detuning or other problems with detection system function. For example, a higher proportion of detections on the rear than on the front coil can indicated a potential problem with the front coil. Conversely, a much higher proportion of detections on the front coil can signal a potential problem on the rear coil.

If detection efficiencies are sufficiently high, then detections on the front and rear coils can indicate patterns of fish movement through the system. Normally, the front coil will have more total detections and the rear coil more unique detections. The reason for this is that some fish come near enough to the front coil to be detected, but then moved forward into the trawl body. They then either approach the front coil again or escape the trawl entirely, in which case they were never within reading range of the rear coil.

By mid-July, the 5-coil matrix antenna system was complete, and this new system incorporated the front/rear antenna design. The original 2-coil prototype matrix served as the front component, and a 3-coil matrix served as the rear coil component. During alternate cruises comparing the cylindrical and 5-coil matrix systems, 16.1 h of sampling yielded 12 detections with the cylindrical system and 16.4 h yielded 70 fish with the matrix system. We concluded that at least during periods of low fish densities, the matrix antenna system was more efficient at collecting and detecting PIT-tagged fish due to its larger fish passage opening and somewhat faster towing speed.

Noteworthy is the fact that levels of electronic interference that compromised the earlier prototype matrix system were not observed during July. Electronics technicians are evaluating the interference events observed during late May and early June, in addition to similar noise events observed other large antenna arrays during the same time. Although this interference has occurred infrequently, it can potentially have a widespread effect on PIT-tag antenna arrays throughout the region. It is possible that the same EMI source that troubled the prototype matrix system also affected the shoreline system, and this may in part explain its lack of detections in spite of successful deployment. We sampled for 43 hrs on ebb tides with the shoreline system during the same period of EMI, but detected no fish.

We intend to construct another 3-coil antenna component to replace the 2-coil component in the antenna to create a 6-coil matrix for future use. We plan to again conduct simultaneous sampling comparing detection rates of the cylindrical system and the new 6-coil matrix system during May, when densities of PIT-tagged fish in the estuary are high. If detection rates of the matrix system are improved over the cylindrical system and reliable, we will transition to the matrix system exclusively in 2008.

Our sampling cruises coincided with the presence in the lower river and estuary of nearly 89% of all inriver migrating fish and 98% of all barge transported fish that had been PIT tagged and released in 2007. The majority of these fish had migrated inriver PIT tagged and released in the Snake and Columbia River basins. During our 2-crew sample period, we detected 3.6% of all yearling Chinook salmon and 3.9% of all steelhead previously detected in the juvenile bypass system or corner collector at Bonneville Dam. These e detection rates much higher than those observed in 2006 (2.0% of yearling Chinook and 1.8% of steelhead.

We also detected 3.0% of yearling Chinook salmon and 2.5% of steelhead transported and released just downstream from Bonneville Dam in the estuary, and these rates were also improved over 2006 (1.4% and 1.1%, respectively). We speculate that, as in previous years, the lower flow volumes in 2007 compared to 2006 resulted in fish passing through the sample area more slowly than during the latter year, thus allowing more sample hours. Additionally, in 2007, debris loads were reduced which allowed us to maximize sampling effort and avoid shorter or cancelled shifts for net repair/swaps.

Overall travel speed for all fish groups was slower in 2007 than in 2006 and can be directly attributed to the decrease in river flow volume. In 2007, flows during our two-crew sample period averaged 6,858 $m^3 s^{-1}$ compared to 9,435$m^3 s^{-1}$ in 2006 (a 27% reduction in flow). Travel speed of fish, both daily and seasonally, has strong correlation with flow. Relative daily travel speed to the estuary was significantly slower for yearling Chinook salmon following release from barges near Bonneville Dam (median 69 km d^{-1}) than for those detected at Bonneville Dam on the same date (median 92 km d^{-1}). These differences were similar to previous years' results. Similarly, steelhead released from barges traveled significantly slower to the estuary than steelhead detected passing Bonneville Dam on the same date (medians 89 and 94 km d^{-1}, respectively).

The single-release method of estimating survival probabilities for inriver migrants to the tailrace of Bonneville Dam is dependent on subsequent detections of fish previously detected at Bonneville Dam in the estuary. Therefore, 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).

In 2004 and 2005, the numbers of fish detected at Bonneville Dam declined sharply due to operation of the corner-collector bypass. Since the corner collector was fitted with monitors in 2006, detections of PIT-tagged fish at Bonneville Dam have increased considerably. Of the total number of detections at Bonneville Dam, the proportion from corner collector monitors was 42% in 2006 (n = 73,842), and 60% in 2007 (n = 76,996). These additional detection data have improved the precision of survival estimates to the tailrace of Bonneville Dam.

Higher survival probabilities through the entire federal hydropower system were recorded for yearling Chinook salmon in 2006 (64.3%) and 2007 (59.4%). These high estimates can be attributed in part to the higher-than-average flow volumes in those years. Survival probability estimates have been much lower during years with extremely low flows, such as 2001 (27.9%) and 2004 (39.5%). For steelhead, survival estimates through the hydropower system in 2006 and 2007 were about mid-range compared to previous years. In 2004 and 2005, steelhead detections at Bonneville Dam were too few to estimate survival probability. In the drought year of 2001, steelhead survival was estimated at just over 4% (most fish were transported in that year).

Our detection numbers were generally higher during darkness for Chinook salmon and during daylight for steelhead. A similar difference in diel detection distributions between these species has been noted in previous years. Afternoon shut-downs for shift changes and fueling no doubt reduced overall detection numbers for steelhead. Previous purse seine sampling in this river reach has indicated peak catches for steelhead between 1400 and 1600 h (Ledgerwood et al. 1991).

Since 2000, trawl detection data have indicated no strong diel trends or differences in detection rates between transported fish and inriver migrants detected at Bonneville Dam. Therefore, for analysis, we assumed that when transported and inriver migrant groups were released/detected on a given day both were present in the estuary with a similar distribution and subject to the same sampling procedures and river conditions. This assumption was also used in the analysis comparing fish released from the same barge, but loaded at different dams. Comparison of daily detection rates for fish released from barges with selected fish detected passing Bonneville Dam should properly reflect differences in daily survival to the estuary.

In 2007, there was a significant difference in detection rates throughout the migration season. For yearling Chinook salmon, estimated sampling efficiency was lower early in the two-crew sample period for both transported and inriver fish. Sampling efficiency then increased into late May, but dropped again by the end of the two-crew sample period. For steelhead, inriver migrants detected at Bonneville Dam were detected again in the estuary at a significantly higher rate than transported fish. Estuary detection rates increased steadily throughout the sample period for both transported and inriver migrant steelhead.

We suspect that much of the variability observed in daily detection rates of transported fish was associated with specifics of barge loading such as species composition, loading densities, and loading sites. For yearling Chinook salmon, we compared daily detection rates for fish loaded at various dams and released from the same barge downstream from Bonneville Dam. These comparisons showed seasonal differences among dams. For example, for fish loaded and transported from Lower Granite Dam, detection rates increased in April and May and then declined through late June. For yearling Chinook loaded at Little Goose and Lower Monumental Dam combined, detection rates decreased steadily through the season. However, from early to late May, there was no difference in detection rates of yearling Chinook salmon by barge loading site. Thus we assumed similar survival rates to the estuary among these loading sites. There were no significant differences or temporal trends between detections of steelhead loaded at Lower Granite Dam compared to those loaded at downstream transportation facilities.

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APPENDIX

Appendix Table 1. Position, orientation, and tag code of each PIT tag attached to a vinyl tape to evaluate antenna performance in 2007.

Position on tape (ft)	Orientation (°)	Distance from previous tag (ft)[a]	PIT-tag code[b]	Position on tape (ft)	Orientation (°)	Distance from previous tag (ft)[a]	PIT-tag code[b]
17	0	0	3D9.1BF22F5437	72	0	2	3D9.1BF1F7268D
19	0	2	3D9.1BF1A73554	73	0	1	3D9.1BF1A972D5
21	0	2	3D9.1BF1A723D6	75	0	2	3D9.1BF1A6B38B
23	45	2	3D9.1BF1A6BBD5	77	0	2	3D9.1BF1F81389
25	45	2	3D9.1BF1F8B9A4	81	0	4	3D9.1BF1A98D9E
28	0	3	3D9.1BF1A6BE89	83	0	2	3D9.1BF1A7885E
31	0	3	3D9.1BF1F7DDEA	85	0	2	3D9.1BF1A73F1E
34	0	3	3D9.1BF1A1E4AF	88	45	3	3D9.1BF1A9B578
37	45	3	3D9.1BF1CF5597	89	45	1	3D9.1BF1A9919F
40	45	3	3D9.1BF1E73089	91	45	2	3D9.1BF1A78FC4
43	45	3	3D9.1BF1F81373	92	45	1	3D9.1BF1A76D70
45	0	2	3D9.1BF1F7D25F	94	45	2	3D9.1BF1A9C00C
47	0	2	3D9.1BF1F7DC5C	96	45	2	3D9.1BF1CF51C6
49	0	2	3D9.1BF1F7D8EA	100	45	4	3D9.1BF1A9C20F
50	0	1	3D9.1BF1A71E13	102	45	2	3D9.1BF1F7C65E
51	0	1	3D9.1BF1A1CD75	104	45	2	3D9.1BF1A77453
52	0	1	3D9.1BF1F7CDF7	106	0	2	3D9.1BF1A6C70C
55	0	3	3D9.1BF1F8F242	108	0	2	3D9.1BF1A1D513
58	0	3	3D9.1BF1A7A629	110	0	2	3D9.1BF1A6C4CF
59	0	1	3D9.1BF1F85701	112	0	2	3D9.1BF1A98396
62	0	3	3D9.1BF1A72BFD	114	45	2	3D9.1BF1A1D0F8
63	0	1	3D9.1BF1F8CAB0	116	45	2	3D9.1BF22BF651
66	0	3	3D9.1BF1F8BBEB	118	45	2	3D9.1BF1F8DA09
69	45	3	3D9.1BF1F7CD88	120	45	2	3D9.1BF22A8198
70	45	1	3D9.1BF1A9ADDC	125	0	5	3D9.1BF1A9953C

[a] Distance from previous tag as measured in the direction from 17 to 125 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, 2007.

Date	Total time underway (h)	PIT-tag detections (N)					
		Unknown	Chinook	Coho salmon	Steelhead	Sockeye	Total
07 Mar	2.90	0	0	0	0	0	0
08 Mar	0.00	--	--	--	--	--	--
09 Mar	4.13	0	0	0	0	0	0
10 Mar	0.00	--	--	--	--	--	--
11 Mar	0.00	--	--	--	--	--	--
12 Mar	5.17	0	0	0	0	0	0
13 Mar	0.00	--	--	--	--	--	--
14 Mar	5.85	0	0	0	0	0	0
15 Mar	0.00	--	--	--	--	--	--
16 Mar	3.28	0	1	0	0	0	1
17 Mar	0.00	--	--	--	--	--	--
18 Mar	0.00	--	--	--	--	--	--
19 Mar	6.58	0	1	0	0	0	1
20 Mar	2.25	0	0	0	0	0	0
21 Mar	0.00	--	--	--	--	--	--
22 Mar	0.00	--	--	--	--	--	--
23 Mar	4.67	0	0	0	0	0	0
24 Mar	0.00	--	--	--	--	--	--
25 Mar	0.00	--	--	--	--	--	--
26 Mar	4.55	0	0	0	0	0	0
27 Mar	0.00	--	--	--	--	--	--
28 Mar	0.00	--	--	--	--	--	--
29 Mar	0.00	--	--	--	--	--	--
30 Mar	4.88	0	2	0	0	0	2
31 Mar	0.00	--	--	--	--	--	--
01 Apr	0.00	--	--	--	--	--	--
02 Apr	0.00	--	--	--	--	--	--
03 Apr	5.33	0	0	0	0	0	0
04 Apr	5.47	0	0	0	0	0	0
05 Apr	3.22	0	0	0	0	0	0
06 Apr	5.98	0	0	0	0	0	0
07 Apr	0.00	--	--	--	--	--	--
08 Apr	0.00	--	--	--	--	--	--
09 Apr	5.65	0	1	0	0	0	1
10 Apr	5.97	0	0	0	0	0	0
11 Apr	5.53	0	0	0	0	0	0
12 Apr	5.78	0	1	0	0	0	1
13 Apr	5.42	0	0	0	0	0	0
14 Apr	0.00	--	--	--	--	--	--
15 Apr	0.00	--	--	--	--	--	--
16 Apr	5.07	0	5	0	6	0	11
17 Apr	5.10	0	1	0	0	0	1
18 Apr	5.93	0	0	0	3	0	3
19 Apr	4.88	1	1	0	2	0	4
20 Apr	4.68	0	0	0	2	0	2

Appendix Table 2. Continued.

Date	Total time underway (h)	PIT-tag detections (N)					
		Unknown	Chinook	Coho salmon	Steelhead	Sockeye	Total
21 Apr	0.00	--	--	--	--	--	--
22 Apr	0.00	--	--	--	--	--	--
23 Apr	9.87	0	4	0	1	0	5
24 Apr	9.25	1	10	0	14	0	25
25 Apr	4.58	0	28	0	1	0	29
26 Apr	12.63	0	35	0	5	0	40
27 Apr	11.48	0	8	0	5	0	13
28 Apr	6.03	0	2	0	3	0	5
29 Apr	11.32	0	13	0	12	0	25
30 Apr	9.38	0	23	0	7	0	30
01 May	9.45	0	32	0	8	0	40
02 May	10.52	1	30	0	3	0	34
03 May	10.68	1	28	0	69	0	98
04 May	10.15	5	78	0	27	0	110
05 May	14.77	2	273	4	46	1	326
06 May	15.22	2	308	1	100	0	411
07 May	15.73	2	274	3	48	0	327
08 May	15.12	0	266	1	56	0	323
09 May	15.78	5	273	2	22	0	302
10 May	15.78	3	519	4	98	0	624
11 May	16.88	3	526	1	92	0	622
12 May	15.17	18	468	2	84	0	572
13 May	17.53	49	812	2	108	0	971
14 May	18.08	6	1,215	5	97	5	1,328
15 May	18.22	3	1,013	1	106	12	1,135
16 May	16.23	4	814	1	77	10	906
17 May	17.28	8	969	4	202	4	1,187
18 May	17.35	7	959	7	118	11	1,102
19 May	17.42	14	640	9	93	16	772
20 May	18.75	38	746	7	62	9	862
21 May	15.52	5	487	4	50	14	560
22 May	17.32	3	509	7	85	18	622
23 May	17.95	2	658	4	95	16	775
24 May	19.30	3	633	6	345	14	1,001
25 May	18.52	1	477	7	162	10	657
26 May	18.23	1	171	4	75	8	259
27 May	14.62	0	149	10	67	8	234
28 May	14.35	3	159	6	93	14	275
29 May	16.43	0	188	13	119	11	331
30 May	16.57	0	125	9	54	13	201
31 May	16.13	1	68	3	235	2	309
01 Jun	14.08	1	62	13	76	4	156
02 Jun	12.62	1	48	14	59	2	124
03 Jun	14.68		53	19	66	7	145
04 Jun	13.72	0	29	8	21	5	63
05 Jun	12.88	1	28	10	28	6	73

Appendix Table 2. Continued.

Date	Total time underway (h)	PIT-tag detections (N)					
		Unknown	Chinook	Coho salmon	Steelhead	Sockeye	Total
06 Jun	12.07	1	15	5	26	5	52
07 Jun	11.48	0	29	5	26	1	61
08 Jun	12.48	0	31	10	20	4	65
09 Jun	12.23	1	34	7	19	3	64
10 Jun	12.55	0	21	6	19	1	47
11 Jun	12.13	0	17	4	19	2	42
12 Jun	12.00	3	21	10	16	1	51
13 Jun	11.93	1	17	6	23	1	48
14 Jun	11.30	3	20	16	14	1	54
15 Jun	11.68	0	26	9	22	1	58
16 Jun	6.40	0	24	2	14	1	41
17 Jun	7.12	0	10	6	15	2	33
18 Jun	5.23	0	5	0	6	1	12
19 Jun	5.82	0	24	3	7	0	34
20 Jun	10.90	0	28	0	12	1	41
21 Jun	12.35	0	16	2	5	1	24
22 Jun	5.80	0	8	0	2	0	10
23 Jun	0.48	0	0	0	0	0	0
24 Jun	5.28	0	12	2	1	0	15
25 Jun	7.03	0	20	1	5	0	26
26 Jun	11.60	0	22	0	3	0	25
27 Jun	13.53	0	31	0	3	0	34
28 Jun	11.78	0	13	0	2	0	15
29 Jun	6.17	0	10	2	0	0	12
30 Jun	1.07	0	2	0	0	0	2
01 Jul	0.00	--	--	--	--	--	--
02 Jul	6.38	9	12	1	0	0	22
03 Jul	5.65	0	18	0	0	0	18
04 Jul	0.00	--	--	--	--	--	--
05 Jul	6.62	0	26	0	1	0	27
06 Jul	5.75	0	24	0	1	0	25
07 Jul	0.00	--	--	--	--	--	--
08 Jul	6.58	0	47	2	1	0	50
09 Jul	6.18	0	40	0	0	0	40
10 Jul	6.63	0	58	0	3	0	61
11 Jul	5.22	0	20	0	0	0	20
12 Jul	6.33	0	7	0	0	0	7
13 Jul	5.55	2	5	0	0	0	7
14 Jul	0.00	--	--	--	--	--	--
15 Jul	0.00	--	--	--	--	--	--
16 Jul	0.00	--	--	--	--	--	--
17 Jul	5.85	0	1	0	0	0	1
18 Jul	4.60	0	4	0	0	0	4
19 Jul	5.87	0	2	0	0	0	2
Totals	1059.52	215	14,943	290	3,492	246	19,186

Appendix Table 3. Daily total sample time and detections for each salmonid species using the matrix detection system at Jones Beach, 2007.

Date	Total time underway (h)	PIT-tag detections (N)					
		Unknown	Chinook salmon	Coho salmon	Sockeye	Steelhead	Total
22 May	3.92	0	13	0	0	34	47
23 May	5.28	0	23	1	1	25	50
24 May	5.47	0	22	1	3	40	66
30 May	5.68	1	8	2	0	25	36
4 Jun	5.00	0	4	2	2	4	12
5 Jun	5.25	0	0	1	2	4	7
6 Jun	5.30	0	0	1	4	10	15
18 Jun	2.78	0	0	0	0	0	0
19 Jun	1.85	0	0	0	0	0	0
12 Jul	2.22	0	9	0	0	0	9
13 Jul	3.10	2	1	0	0	0	3
14 Jul	7.92	4	20	0	1	1	26
16 Jul	6.25	2	30	0	0	0	32
Totals	60.02	9	130	8	13	143	303

Appendix Table 4. Combined daily total of impinged fish on the large trawl, shoreline sampler and Matrix system, in the upper and lower Columbia River estuary, 2007.

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

Appendix Table 4. Continued.

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

Appendix Table 4. Continued.

Date	Chinook salmon Yearling	Chinook salmon Subyearling	Coho salmon	Steelhead	Sockeye salmon
11-Jun	0	0	0	0	0
12-Jun	0	0	0	0	0
13-Jun	0	0	0	0	0
14-Jun	0	0	0	0	0
15-Jun	0	0	0	0	0
16-Jun	0	0	0	0	0
17-Jun	0	0	0	0	0
18-Jun	0	0	0	0	0
19-Jun	0	0	0	0	0
20-Jun	0	0	0	0	0
21-Jun	2	0	0	1	0
22-Jun	1	0	0	0	0
23-Jun	0	0	0	0	0
24-Jun	0	0	0	0	0
25-Jun	0	0	0	0	0
26-Jun	0	0	0	0	0
27-Jun	1	0	0	0	0
28-Jun	0	0	0	0	0
29-Jun	0	0	0	0	0
30-Jun	--	--	--	--	--
1-Jul	--	--	--	--	--
2-Jul	0	0	0	0	0
3-Jul	0	0	0	0	0
4-Jul	--	--	--	--	--
5-Jul	0	0	0	0	0
6-Jul	0	0	0	0	0
7-Jul	--	--	--	--	--
8-Jul	0	0	0	0	0
9-Jul	0	0	0	0	0
10-Jul	0	0	0	0	0
11-Jul	0	0	0	0	0
12-Jul	0	0	0	0	0
13-Jul	0	0	0	0	0
14-Jul	5	0	0	1	0
15-Jul	--	--	--	--	--
16-Jul	0	0	0	0	0
17-Jul	0	0	0	0	0
18-Jul	1	0	0	0	0
19-Jul	0	0	0	0	0
Total	122	1	3	26	0

Appendix Table 5. Diel sampling of yearling Chinook salmon and steelhead using a PIT-tag detector surface pair-trawl at Jones Beach (Columbia River kilometer 75), 2007. Two-crew effort, between 23 April and 28 June, was rounded to the nearest tenth and presented as a decimal hour.

		Yearling Chinook salmon				Steelhead			
Diel	Effort	n		n/h		n		n/h	
hour	(h)	Hatchery	Wild	Hatchery	Wild	Hatchery	Wild	Hatchery	Wild
0	52.6	780	138	14.8	2.6	101	52	1.9	1.0
1	44.9	894	123	19.9	2.7	72	39	1.6	0.9
2	27.9	812	110	29.1	3.9	62	27	2.2	1.0
3	22.0	811	119	36.9	5.4	55	19	2.5	0.9
4	21.8	828	120	38.0	5.5	38	24	1.7	1.1
5	29.9	641	75	21.4	2.5	33	19	1.1	0.6
6	44.7	773	117	17.3	2.6	75	69	1.7	1.5
7	56.0	581	85	10.4	1.5	98	73	1.7	1.3
8	60.7	523	87	8.6	1.4	127	76	2.1	1.3
9	59.8	371	60	6.2	1.0	136	92	2.3	1.5
10	61.4	411	58	6.7	0.9	150	103	2.4	1.7
11	50.1	450	71	9.0	1.4	152	112	3.0	2.2
12	33.3	380	56	11.4	1.7	110	119	3.3	3.6
13	18.8	406	43	21.6	2.3	85	71	4.5	3.8
14	0.0	145	14	23.6	2.3	35	17	5.7	2.8
15	0.0	16	1	5.6	0.4	22	4	7.8	1.4
16	13.2	3	0	0.0	0.0	14	1	0.0	0.0
17	0.0	0	0	0.0	0.0	0	0	0.0	0.0
18	0.0	1	4	0.3	1.3	1	1	0.3	0.3
19	26.6	119	31	4.5	1.2	68	30	2.6	1.1
20	56.3	508	113	9.0	2.0	143	118	2.5	2.1
21	59.9	1,311	185	21.9	3.1	222	112	3.7	1.9
22	59.5	1,104	123	18.5	2.1	236	84	4.0	1.4
23	57.2	701	95	12.3	1.7	115	48	2.0	0.8
Total	856.3	12,569	1,828			2,150	1,310		

Appendix Table 6. Total estuary trawl detections of PIT-tagged yearling Chinook salmon loaded on barges at each of four transport dams, 2007. Transport dates 14 Apr-11 Aug; trawl operation 7 Mar-19 Jul, intensive sampling 23 Apr-28 Jun.

	Yearling Chinook loaded at each dam (n)				Total	Percent detected from each dam (%)				Total detected	
Detection date and time	Lower Granite	Little Goose	Lower Monumental	McNary	loaded (n)	Lower Granite	Little Goose	Lower Monumental	McNary	(n)	(%)
14 Apr 00:45	1,393	0	0	0	1,393	0.50	--	--	--	7	0.5
23 Apr 00:53	3,393	0	0	0	3,393	1.56	--	--	--	53	1.6
28 Apr 03:20	1,088	0	0	0	1,088	2.21	--	--	--	24	2.2
02 May 04:15	4,203	0	0	0	4,203	1.86	--	--	--	78	1.9
03 May 10:46	2,352	0	0	0	2,352	2.68	--	--	--	63	2.7
04 May 17:55	3,905	0	0	0	3,905	2.13	--	--	--	83	2.1
05 May 19:45	3,112	0	0	0	3,112	2.02	--	--	--	63	2.0
06 May 18:30	2,403	0	0	0	2,403	1.87	--	--	--	45	1.9
07 May 18:50	1,707	0	0	0	1,707	2.05	--	--	--	35	2.1
08 May 17:00	5,715	0	0	0	5,715	1.63	--	--	--	93	1.6
09 May 15:50	655	0	0	0	655	3.36	--	--	--	22	3.4
10 May 22:10	877	656	0	0	1,533	3.19	3.51	--	--	51	3.3
11 May 23:25	1,454	217	0	0	1,671	4.81	4.15	--	--	79	4.7
12 May 18:10	2,579	283	0	0	2,862	3.99	2.47	--	--	110	3.8
14 May 00:50	1,572	770	500	0	2,842	3.88	3.77	4.20	--	111	3.9
14 May 23:15	1,585	816	865	0	3,266	4.54	3.19	3.24	--	126	3.9
16 May 04:50	6,421	1,139	813	0	8,373	4.06	5.00	6.03	--	367	4.4
16 May 23:40	590	973	1,182	0	2,745	2.88	3.60	3.98	--	99	3.6
17 May 19:15	1,006	348	562	0	1,916	4.27	2.30	1.96	--	62	3.2
18 May 23:30	783	221	212	0	1,216	4.21	2.71	1.89	--	43	3.5
20 May 01:15	462	243	165	0	870	3.03	3.29	3.03	--	27	3.1
20 May 20:10	612	185	129	0	926	5.56	3.24	3.88	--	45	4.9
21 May 20:20	513	151	200	0	864	3.90	3.31	3.50	--	32	3.7
23 May 08:30	2,781	132	148	0	3,061	3.42	7.58	4.05	--	111	3.6
23 May 23:55	138	19	150	0	307	4.35	5.26	3.33	--	12	3.9
24 May 19:00	65	77	41	0	183	1.54	0.00	0.00	--	1	0.5
25 May 18:30	242	38	36	0	316	1.65	0.00	2.78	--	5	1.6
26 May 20:05	139	36	35	0	210	2.16	0.00	0.00	--	3	1.4
27 May 19:55	132	21	20	0	173	4.55	0.00	0.00	--	6	3.5
28 May 23:25	110	21	5	0	136	1.82	0.00	20.00	--	3	2.2

Appendix Table 6. Continued.

Detection date and time	Yearling Chinook loaded at each dam (n)				Total loaded (n)	Percent detected from each dam (%)				Total detected	
	Lower Granite	Little Goose	Lower Monumental	McNary		Lower Granite	Little Goose	Lower Monumental	McNary	(n)	(%)
29 May 19:50	243	16	13	0	272	2.47	0.00	0.00	--	6	2.2
31 May 19:40	75	49	5	0	129	2.67	2.04	0.00	--	3	2.3
02 Jun 19:30	91	38	4	0	133	4.40	0.00	0.00	--	4	3.0
04 Jun 19:00	110	28	0	0	138	1.82	0.00	--	--	2	1.4
06 Jun 19:25	37	44	0	0	81	0.00	4.55	--	--	2	2.5
08 Jun 21:25	16	45	18	0	79	0.00	2.22	0.00	--	1	1.3
10 Jun 21:05	15	36	1	0	52	0.00	0.00	0.00	--	0	0.0
12 Jun 19:50	2	26	16	0	44	0.00	0.00	6.25	--	1	2.3
14 Jun 17:40	8	25	19	0	52	0.00	8.00	0.00	--	2	3.8
16 Jun 20:50	5	30	3	0	38	0.00	0.00	33.33	--	1	2.6
18 Jun 19:40	7	33	1	0	41	0.00	6.06	0.00	--	2	4.9
20 Jun 20:25	5	55	0	0	60	0.00	1.82	--	--	1	1.7
22 Jun 19:10	6	25	0	0	31	0.00	4.00	--	--	1	3.2
24 Jun 20:35	1	30	0	0	31	0.00	0.00	--	--	0	0.0
26 Jun 20:00	4	26	0	0	30	0.00	0.00	--	--	0	0.0
28 Jun 21:05	3	21	0	0	24	0.00	0.00	--	--	0	0.0
30 Jun 20:45	4	11	0	0	15	0.00	0.00	--	--	0	0.0
02 Jul 20:05	3	34	0	0	37	0.00	0.00	--	--	0	0.0
04 Jul 19:05	2	19	0	0	21	0.00	5.26	--	--	1	4.8
06 Jul 03:00	0	37	2	0	39	--	0.00	0.00	--	0	0.0
08 Jul 20:40	0	17	4	0	21	--	0.00	0.00	--	0	0.0
10 Jul 20:10	2	54	2	0	58	0.00	0.00	0.00	--	0	0.0
12 Jul 19:35	2	7	1	0	10	0.00	0.00	0.00	--	0	0.0
14 Jul 20:00	3	4	0	0	7	0.00	0.00	--	--	0	0.0
18 Jul 19:45	1	0	1	0	2	0.00	--	0.00	--	0	0.0
20 Jul 21:15	0	0	1	0	1	--	--	0.00	--	0	0.0
22 Jul 20:20	1	0	1	0	2	0.00	--	0.00	--	0	0.0
01 Aug 21:00	1	0	0	0	1	0.00	--	--	--	0	0.0
11 Aug 20:25	1	0	0	0	1	0.00	--	--	--	0	0.0
Totals	52,635	7,056	5,155	0	64,846	2.76	3.42	3.72	--	1,886	2.9

Appendix Table 7. Total estuary trawl detections of PIT-tagged juvenile steelhead loaded on barges at each of four transport dams, 2007. Transport dates 22 Apr-14 Jul; trawl operation 9 Mar-1 Nov, no sampling 21 Jul-4 Sep; intensive sampling 23 Apr-28 Jun.

Detection date and time	Steelhead loaded at each dam (n) Lower Granite	Little Goose	Lower Monumental	McNary	Total loaded (n)	Percent detected from each dam (%) Lower Granite	Little Goose	Lower Monumental	McNary	Total detected (n)	(%)
14 Apr 00:45	188	0	0	0	188	2.1	--	--	--	4	2.1
23 Apr 00:53	405	0	0	0	405	2.2	--	--	--	9	2.2
28 Apr 03:20	262	0	0	0	262	3.1	--	--	--	8	3.1
02 May 04:15	4,644	0	0	0	4,644	1.9	--	--	--	86	1.9
03 May 10:46	1,006	0	0	0	1,006	1.2	--	--	--	12	1.2
04 May 17:55	1,005	0	0	0	1,005	7.3	--	--	--	73	7.3
05 May 19:45	276	0	0	0	276	4.3	--	--	--	12	4.3
06 May 18:30	469	0	0	0	469	4.7	--	--	--	22	4.7
07 May 18:50	654	0	0	0	654	2.9	--	--	--	19	2.9
08 May 17:00	5,852	0	0	0	5,852	1.3	--	--	--	76	1.3
09 May 15:50	78	0	0	0	78	5.1	--	--	--	4	5.1
10 May 22:10	676	110	0	0	786	2.4	0.9	--	--	17	2.2
11 May 23:25	476	30	0	0	506	2.3	0.0	--	--	11	2.2
12 May 18:10	719	84	0	0	803	1.8	1.2	--	--	14	1.7
14 May 00:50	493	174	98	0	765	1.4	0.0	1.0	--	8	1.0
14 May 23:15	409	107	111	0	627	0.5	0.0	1.8	--	4	0.6
16 May 04:50	6,644	260	352	0	7,256	2.2	0.0	1.1	--	150	2.1
16 May 23:40	111	365	482	0	958	0.0	1.2	0.6	--	6	0.6
17 May 19:15	394	81	368	0	843	1.8	1.2	1.4	--	13	1.5
18 May 23:30	383	55	86	0	524	1.8	3.6	0.0	--	9	1.7
20 May 01:15	292	35	57	0	384	0.7	0.0	0.0	--	2	0.5
20 May 20:10	582	53	109	0	744	0.7	1.9	6.4	--	12	1.6
21 May 20:20	538	40	55	0	633	2.6	0.0	7.3	--	18	2.8
23 May 08:30	11,036	57	48	0	11,141	2.8	8.8	6.3	--	320	2.9
23 May 23:55	71	2	81	0	154	0.0	0.0	1.2	--	1	0.6
24 May 19:00	33	30	60	0	123	3.0	3.3	1.7	--	3	2.4
25 May 18:30	575	17	40	0	632	2.8	0.0	7.5	--	19	3.0
26 May 20:05	507	12	33	0	552	1.6	8.3	3.0	--	10	1.8
27 May 19:55	322	58	30	0	410	1.6	3.4	6.7	--	9	2.2
28 May 23:25	437	27	8	0	472	5.9	11.1	0.0	--	29	6.1

Appendix Table 7. Continued.

Detection date and time	Steelhead loaded at each dam (n) Lower Granite	Little Goose	Lower Monumental	McNary	Total loaded (n)	Percent detected from each dam (%) Lower Granite	Little Goose	Lower Monumental	McNary	Total detected (n)	(%)
29 May 19:50	3,326	18	14	0	3,358	5.4	0.0	14.3	--	182	5.4
31 May 19:40	24	62	22	0	108	0.0	0.0	0.0	--	0	0.0
02 Jun 19:30	103	30	14	0	147	1.0	6.7	0.0	--	3	2.0
04 Jun 19:00	154	51	9	0	214	1.9	2.0	0.0	--	4	1.9
06 Jun 19:25	131	56	7	0	194	2.3	0.0	0.0	--	3	1.5
08 Jun 21:25	95	16	5	0	116	1.1	6.3	0.0	--	2	1.7
10 Jun 21:05	188	64	2	0	254	2.1	1.6	0.0	--	5	2.0
12 Jun 19:50	6	22	3	0	31	0.0	4.5	33.3	--	2	6.5
14 Jun 17:40	13	15	7	0	35	0.0	0.0	0.0	--	0	0.0
16 Jun 20:50	96	11	2	0	109	0.0	9.1	0.0	--	1	0.9
18 Jun 19:40	54	11	0	0	65	0.0	0.0	--	--	0	0.0
20 Jun 20:25	32	8	0	0	40	0.0	0.0	--	--	0	0.0
22 Jun 19:10	1	7	0	0	8	0.0	0.0	--	--	0	0.0
24 Jun 20:35	0	8	0	0	8	--	12.5	--	--	1	12.5
26 Jun 20:00	0	2	0	0	2	--	0.0	--	--	0	0.0
28 Jun 21:05	0	4	0	0	4	--	0.0	--	--	0	0.0
30 Jun 20:45	1	0	0	0	1	0.0	--	--	--	0	0.0
02 Jul 20:05	1	2	0	0	3	0.0	0.0	--	--	0	0.0
06 Jul 03:00	0	2	0	0	2	--	0.0	--	--	0	0.0
08 Jul 20:40	0	5	0	0	5	--	0.0	--	--	0	0.0
12 Jul 19:35	0	2	0	0	2	--	0.0	--	--	0	0.0
14 Jul 20:00	0	0	1	0	1	--	--	0.0	--	0	0.0
16 Jul 19:45	0	7	0	0	7	--	0.0	--	--	0	0.0
18 Jul 19:45	0	1	0	0	1	--	0.0	--	--	0	0.0
20 Jul 21:15	0	7	0	0	7	--	0.0	--	--	0	0.0
22 Jul 20:20	0	1	0	0	1	--	0.0	--	--	0	0.0
24 Jul 20:25	0	4	0	0	4	--	0.0	--	--	0	0.0
26 Jul 20:20	0	1	0	0	1	--	0.0	--	--	0	0.0
28 Jul 21:35	0	3	0	0	3	--	0.0	--	--	0	0.0
30 Jul 22:35	0	6	0	0	6	--	0.0	--	--	0	0.0
05 Aug 18:45	0	1	0	0	1	--	0.0	--	--	0	0.0
07 Aug 20:50	0	2	0	0	2	--	0.0	--	--	0	0.0
09 Aug 19:30	0	1	0	0	1	--	0.0	--	--	0	0.0
17 Aug 21:00	0	1	0	0	1	--	0.0	--	--	0	0.0
Totals	43,762	2,028	2,104	0	47,894	2.5	1.4	1.9	--	1,183	2.5

Appendix Table 8. Total detections in the Columbia River estuary of PIT-tagged juvenile Chinook salmon and steelhead previously detected at Bonneville Dam, 2007. Detection systems at Bonneville Dam operated 16 Feb-20 Oct; trawl operated 7 Mar–19 Jul, with intensive sampling 23 Apr-28 June.

Detection date at Bonneville Dam	Bonneville Dam detections		Jones Beach detections			
	Chinook salmon (n)	Steelhead (n)	Chinook salmon (n)	Steelhead (n)	Chinook salmon (%)	Steelhead (%)
16 Feb-6 Mar	14	0	0	--	0.0	0.0
07 Mar	0	0	--	--	--	--
08 Mar	2	0	0	--	0.0	--
09 Mar	6	0	0	--	0.0	--
10 Mar	5	0	0	--	0.0	--
11 Mar	22	0	1	--	4.55	--
12 Mar	19	0	0	--	0.0	--
13 Mar	7	0	0	--	0.0	--
14 Mar	3	0	0	--	0.0	--
15 Mar	4	0	0	--	0.0	--
16 Mar	4	0	0	--	0.0	--
17 Mar	4	0	0	--	0.0	--
18 Mar	1	0	0	--	0.0	--
19 Mar	0	0	--	--	--	--
20 Mar	0	0	--	--	--	--
21 Mar	1	1	0	--	0.0	--
22 Mar	3	0	0	--	0.0	--
23 Mar	1	0	0	--	0.0	--
24 Mar	4	0	0	--	0.0	--
25 Mar	2	0	0	--	0.0	--
26 Mar	1	0	0	--	0.0	--
27 Mar	1	1	0	0	0.0	0.0
28 Mar	3	1	0	0	0.0	0.0
29 Mar	3	0	0	--	0.0	--
30 Mar	4	0	0	--	0.0	--
31 Mar	2	0	0	--	0.0	--
01 Apr	4	0	0	--	0.0	--
02 Apr	1	0	0	--	0.0	--
03 Apr	6	1	0	0	0.0	0.0
04 Apr	4	1	0	0	0.0	0.0
05 Apr	6	1	0	0	0.0	0.0
06 Apr	12	1	0	0	0.0	0.0
07 Apr	10	0	0	--	0.0	--
08 Apr	11	3	0	0	0.0	0.0
09 Apr	7	1	0	0	0.0	0.0
10 Apr	6	3	0	0	0.0	0.0
11 Apr	6	2	0	0	0.0	0.0
12 Apr	8	0	0	--	0.0	--
13 Apr	46	1	0	0	0.0	0.0
14 Apr	91	3	2	1	2.20	33.33
15 Apr	126	0	2	--	1.59	--
16 Apr	66	4	1	0	1.52	0.0
17 Apr	69	5	2	0	2.90	0.0

Appendix Table 8. Continued.

Detection date at Bonneville Dam	Bonneville Dam detections		Jones Beach detections			
	Chinook salmon (n)	Steelhead (n)	Chinook salmon (n)	Steelhead (n)	Chinook salmon (%)	Steelhead (%)
18 Apr	58	11	1	0	1.72	0.0
19 Apr	52	12	1	0	1.92	0.0
20 Apr	65	10	1	0	1.54	0.0
21 Apr	79	5	0	0	0.0	0.0
22 Apr	61	20	0	1	0.0	5.00
23 Apr	73	31	0	1	0.0	3.23
24 Apr	63	37	1	2	1.59	5.41
25 Apr	76	29	0	2	0.0	6.90
26 Apr	70	52	0	1	0.0	1.92
27 Apr	93	78	4	1	4.30	1.28
28 Apr	96	82	1	0	1.04	0.0
29 Apr	157	82	0	1	0.0	1.22
30 Apr	307	104	7	3	2.28	2.88
01 May	275	71	8	1	2.91	1.41
02 May	510	110	13	1	2.55	0.91
03 May	542	188	16	5	2.95	2.66
04 May	732	110	16	3	2.19	2.73
05 May	831	145	20	4	2.41	2.76
06 May	820	196	19	8	2.32	4.08
07 May	1,164	252	37	9	3.18	3.57
08 May	1,348	250	36	5	2.67	2.00
09 May	1,861	452	51	17	2.74	3.76
10 May	2,518	349	54	14	2.14	4.01
11 May	2,381	467	85	21	3.57	4.50
12 May	2,836	392	150	20	5.29	5.10
13 May	2,978	759	133	30	4.47	3.95
14 May	3,417	243	98	7	2.87	2.88
15 May	2,934	291	125	6	4.26	2.06
16 May	2,756	402	87	16	3.16	3.98
17 May	1,608	423	69	17	4.29	4.02
18 May	2,011	289	85	10	4.23	3.46
19 May	1,933	304	72	9	3.72	2.96
20 May	1,191	299	43	9	3.61	3.01
21 May	1,686	621	70	19	4.15	3.06
22 May	1,721	304	70	17	4.07	5.59
23 May	1,577	552	75	19	4.76	3.44
24 May	846	285	33	10	3.90	3.51
25 May	570	84	17	1	2.98	1.19
26 May	537	318	20	15	3.72	4.72
27 May	548	875	29	30	5.29	3.43
28 May	499	182	31	9	6.21	4.95
29 May	389	282	8	12	2.06	4.26
30 May	253	349	4	12	1.58	3.44
31 May	184	264	8	12	4.35	4.55
01 Jun	151	459	4	22	2.65	4.79
02 Jun	321	153	9	5	2.80	3.27
03 Jun	116	224	1	4	0.86	1.79
04 Jun	101	193	2	4	1.98	2.07

Appendix Table 8. Continued.

Detection date at Bonneville Dam	Bonneville Dam detections		Jones Beach detections			
	Chinook salmon (n)	Steelhead (n)	Chinook salmon (n)	Steelhead (n)	Chinook salmon (%)	Steelhead (%)
05 Jun	86	209	2	6	2.33	2.87
06 Jun	129	142	3	6	2.33	4.23
07 Jun	83	121	5	6	6.02	4.96
08 Jun	80	78	5	1	6.25	1.28
09 Jun	54	72	1	2	1.85	2.78
10 Jun	78	137	3	9	3.85	6.57
11 Jun	71	109	4	2	5.63	1.83
12 Jun	72	80	1	4	1.39	5.00
13 Jun	88	104	3	4	3.41	3.85
14 Jun	80	90	2	2	2.50	2.22
15 Jun	96	134	3	6	3.13	4.48
16 Jun	166	134	2	1	1.20	0.75
17 Jun	78	47	2	0	2.56	0.0
18 Jun	116	59	1	2	0.86	3.39
19 Jun	91	37	0	1	0.0	2.70
20 Jun	63	35	1	0	1.59	0.0
21 Jun	54	46	1	0	1.85	0.0
22 Jun	50	25	1	0	2.00	0.0
23 Jun	57	23	3	3	5.26	13.04
24 Jun	70	13	2	0	2.86	0.0
25 Jun	32	10	1	0	3.13	0.0
26 Jun	28	18	0	0	0.0	0.0
27 Jun	40	21	0	0	0.0	0.0
28 Jun	48	23	0	0	0.0	0.0
29 Jun	49	26	0	0	0.0	0.0
30 Jun	98	13	1	0	1.02	0.0
01 Jul	49	7	0	0	0.0	0.0
02 Jul	39	3	0	0	0.0	0.0
03 Jul	84	8	0	0	0.0	0.0
04 Jul	56	8	0	1	0.0	12.50
05 Jul	95	0	0	--	0.00	--
06 Jul	94	13	4	0	4.26	0.0
07 Jul	69	7	0	0	0.0	0.0
08 Jul	53	10	3	0	5.66	0.0
09 Jul	58	4	2	0	3.45	0.0
10 Jul	54	0	0	--	0.00	--
11 Jul	39	1	0	0	0.00	0.00
12 Jul	83	4	0	0	0.00	0.00
13 Jul	54	4	0	0	0.00	0.00
14 Jul	257	3	0	0	0.00	0.00
15 Jul	39	3	0	0	0.00	0.00
16 Jul	31	3	0	0	0.00	0.00
17 Jul	36	1	0	0	0.00	0.00
18 Jul	12	0	0	--	0.00	--
19 Jul	15	0	0	--	0.00	--
20 Jul-20 Oct	259	14	0	0	0.0	0.0
Totals	49,423	13,618	1,678	472	3.4	3.5