Development of Pair-Trawl Detection Systems for Monitoring PIT-Tagged Juvenile Salmonids in the Columbia River Estuary, 2007

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EXECUTIVE SUMMARY

In 2007, we sampled migrating juvenile salmonids *Oncorhynchus* spp. tagged with passive integrated transponder (PIT) tags using a surface pair trawl in the upper Columbia River estuary (rkm 61 to 83). The cod end of the trawl was replaced with a PIT-tag detection antenna with an 86-cm diameter fish-passage opening and two detection coils connected in series. The pair trawl was 105 m long with a 91.5-m opening between the wings and a sample depth of 4.9 m. Also during 2007 we continued development of a prototype "Matrix" antenna, which was a magnitude larger than previous antennas. The Matrix antenna consisted of 5 coils, with 2 in the front and 3 in the rear of the fish passage opening. The fish-passage opening was 2.5 m wide by 3.0 m tall and was attached to a standard pair trawl net.

Intermittent sampling with a single crew began on 7 March, and targeted yearling Chinook salmon *O. tshawytscha* and steelhead *O. mykiss*. Daily sampling using two crews began on 23 April and continued through 28 June; during this period we detected 3.5% of all juvenile salmonids previously detected at Bonneville Dam—a measure of sample efficiency. Sampling with a single crew continued through 19 July and targeted subyearling fall Chinook salmon. We detected 14,319 spring/summer Chinook salmon, 580 fall Chinook salmon, 290 coho salmon *O. kisutch*, 3,492 steelhead, and 246 sockeye salmon *O. nerka* in the upper estuary. Intermittent sampling with the Matrix system (55 hours) yielded an additional 304 detections.

Mean survival rates for non-transported yearling Chinook salmon and steelhead from Lower Granite Dam to Bonneville Dam was 59% (SE = 3.5%) and 39% (SE = 6.9%), respectively. Over 157,000 PIT-tagged salmonids were transported, and we detected 3,081 of these transported fish.

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INTRODUCTION

In 2007, we continued a multi-year study of juvenile salmonid *Oncorhynchus* spp. survival and timing in the Columbia River estuary (Ledgerwood et al. 2006, 2007; Magie et al. 2008). This study is funded by the Bonneville Power Administration (BPA) and U.S. Army Corps of Engineers (USACE). Here we report on survival and timing with regard to river of origin and migration history, which are specific objectives supported through BPA. Moreover, the BPA-funded portion of this study is a companion to an additional multi-year BPA study to estimate survival of juvenile salmonids through the entire Federal Columbia River Power System (FCRPS) from the reservoir of Lower Granite Dam on the Snake River to the tailrace of Bonneville Dam on the Columbia River (Faulkner et al. 2007, in press).

Detections of migrating fish implanted with passive integrated transponder (PIT) tags were utilized by both studies. PIT tags are generally implanted in juvenile salmonids captured in natal streams, hatcheries, or collector dams prior to or during migration (PSMFC 2007). Once tagged, these fish can be interrogated without further handling as they pass detectors. PIT-tag detection systems are presently located in the bypass systems at dams (Prentice et al. 1990a,b,c), in our pair trawl, and in some natal streams. The Columbia Basin PIT tag Information Systems (PTAGIS) is a regional database used to store and disseminate tagging and detection data. We used PTAGIS and recorded release and detection times and locations, as well as species, origin, and migration history of individual PIT-tagged study fish.

Methods for using PIT-tag detection data to estimate survival and travel time for spring migrating juvenile salmonids are described in detail by Faulkner et al. (in press). Briefly, PIT-tag data were collected as fish pass interrogation facilities at Lower Granite, Little Goose, Lower Monumental, and Ice Harbor Dams on the Snake River and McNary, John Day, and Bonneville Dams on the Columbia River. Survival estimates were calculated using a statistical model for tag-recapture data from single-release groups (the single-release model).

Here we describe the methodology for sampling PIT-tagged fish in the upper estuary between river kilometers (rkm) 61 and 83. We interrogated tags using surface pair-trawls fitted with specialized detection equipment in a free-flowing riverine environment (Ledgerwood et al. 2004). We describe the methodology and equipment required to sample in the estuary. This sampling downstream from Bonneville Dam (rkm 234), the lowermost dam in the FCRPS, was required to estimate survival from the tailrace of John Day Dam (rkm 347) to the tailrace of Bonneville Dam. Estuary sampling

also contributed substantial data required to complete the reach survival estimates from McNary Dam (rkm 470) to Bonneville Dam.

Nearly 1.5 million PIT-tagged juvenile salmonids were released into the Snake and Columbia River basins for migration in 2007 (PSMFC 2007). In addition to bypassing fish at dams, fishery managers have the option to transport and release fish downstream from Bonneville Dam. In 2007, 156,099 PIT-tagged fish were transported. The primary goals of our trawling effort in the estuary were to provide data to estimate survival probabilities of PIT-tagged fish that have migrated in-river through the hydropower system to the estuary (BPA objective) and to compare relative survival and temporal differences between transported and in-river migrants previously detected at Bonneville Dam (USACE objective). A secondary goal was to increase sample efficiency by continuing to develop and test new, larger antennas and related equipment intermittently using a prototype experimental system. We termed this prototype system the Matrix as it consisted of a multiplexing transceiver controlling from 5 to eventually 6 detection coils configured to provide a 2.6 m wide by 3.0 m tall fish passage opening from the trawl.

METHODS

Study Fish

In 2007, we continued to focus research on large groups of PIT-tagged fish migrating through the upper Columbia River estuary (rkm 75) from late April through late July. According to PTAGIS, these groups included 268,029 PIT-tagged fish released for a transportation study on the Snake River (Marsh et al. 2006) and nearly 14,943 PIT-tagged fish released for a comparative survival study (Berggren et al. 2006). Fish from other major and minor PIT-tagging studies were incidentally detected as well.

During the spring migration period, we targeted yearling migrants, including over 930,000 yearling Chinook salmon and over 300,000 steelhead that had been PIT-tagged and released into the Snake and upper and mid Columbia Rivers. These releases were either allowed to migrate in the rivers or transported from the Snake River basin. Transported fish were collected from facilities at Lower Granite, Little Goose, Lower Monumental and McNary Dams, and were released below Bonneville Dam.

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 the large trawl began in late April, and daily sampling continued through June, coincident with the passage of PIT-tagged yearling Chinook salmon and steelhead from the Snake River transportation study. Beginning on 23 April and extending through 28 June, sampling increased from a single daily sampling crew to two daily crews for an average of 12 h d^{-1}. Generally, the day crew began before daylight and sampled for 8 to 10 h, and the night crew began in late afternoon and sampled until well after dark or until relieved by the day crew.

Study Sites

We conducted large trawl operations from Eagle Cliff (rkm 83) to the west end of Puget Island (rkm 61; Figure 1). This is a freshwater reach characterized by frequent ship traffic, occasional severe weather, and river currents often exceeding 1.5 $m^3 s^{-1}$. Tides in this area are semi-diurnal, with about 7 h of ebb and 4.5 h of flood. During the spring freshet periods (April-June), little or no flow reversal has occurred at the study site during flood tides, particularly during years of medium to high river flow. The net was deployed adjacent to a 200-m-wide navigation channel which is maintained at a depth of 14 m.

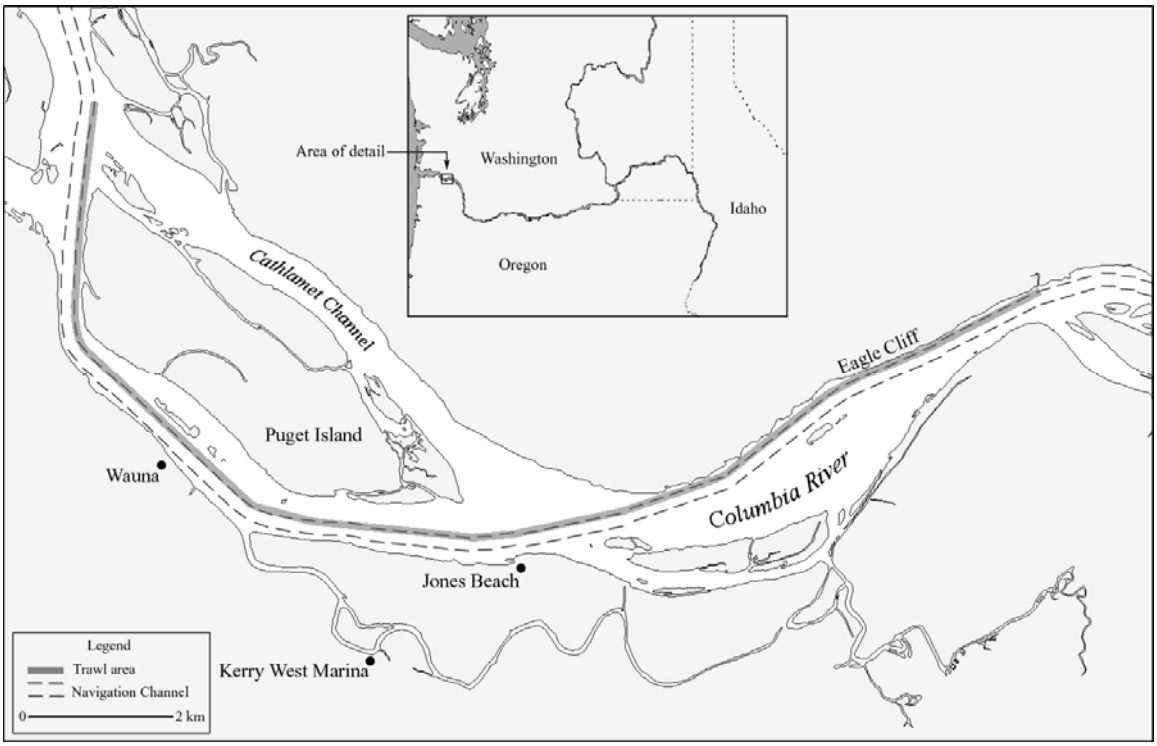

Figure 1. Trawling area adjacent to the ship navigation channel in the upper Columbia River estuary near rkm 75.

Trawls and System Designs

The large trawl components are described below, and their basic configuration remained fairly constant throughout 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 which was 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. 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.

The detection antenna measured 0.9 m in diameter and was centered at a depth of 1.8 m. Tag technology has improved over the years, enabling us to enlarge the fish-passage opening, which reduced drag and lift on the net. This increased the sample depth of the trawl to 4.6 m. During a typical deployment of the large trawl, the net is towed upstream, facing into the current.

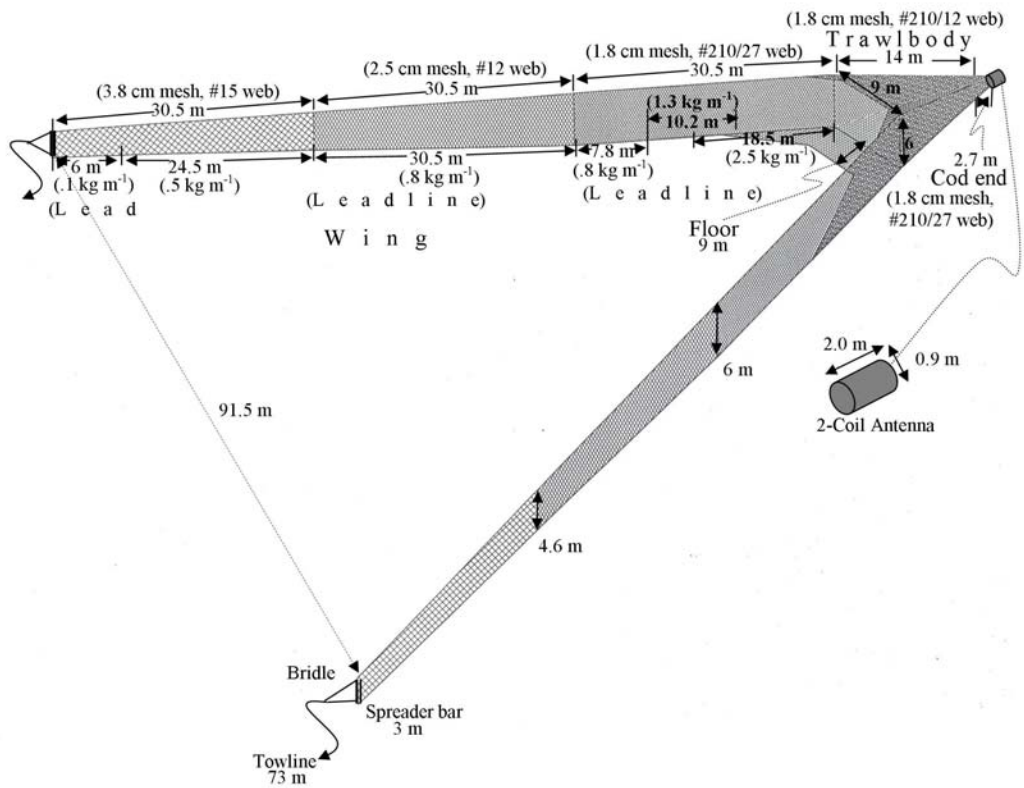

Figure 1. Design of the large surface pair trawl that was used to sample PIT-tagged juvenile salmonids in the Columbia River estuary (rkm 75).

Under tow we maintained a distance of 91.5 m between the wings, which resulted in an effective sample depth of 4.6 m (measured at the center of the floor lead line). Fish that enter between the wings are guided to the trawl body and exit through the antenna. During retrievals of the net, the antenna is removed and the net is inverted in the current to flush debris and release fish from between the small-mesh wings. The deployment/retrieval process of the large trawl requires about 30 min, during which time the vessels and net are adrift in tidal and river currents often exceeding 1.5 m s^{-1} (3 knots).

The Matrix antenna/trawl system (Figure 3) incorporated a much larger antenna affixed to a standard size pair-trawl (trawl with same dimensions as above). This antenna consisted of a two-coil component (1.1 × 2.8 m each) affixed together and separated by a 15-cm gap (total dimensions 2.6 × 3.0 m). Later, a second component was added, with three 0.75-m-wide coils, and joined to the first with a 1.5-m-long webbed fish passage tunnel.

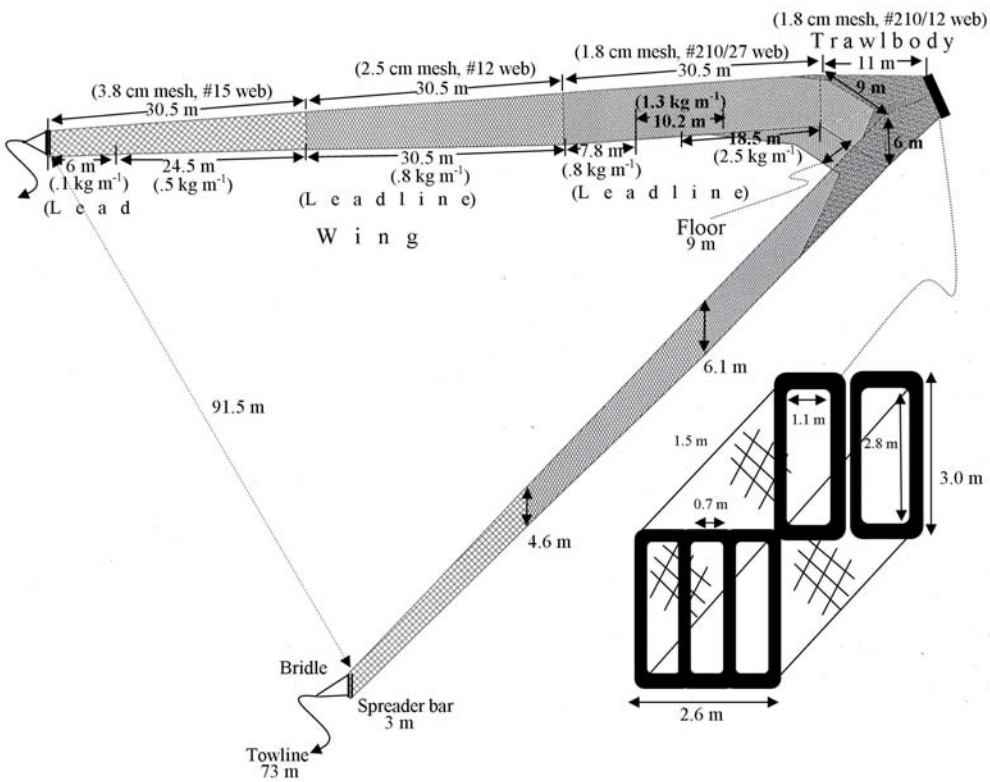

Figure 3. Design of the prototype "Matrix" surface pair trawl and antenna that was used to sample PIT-tagged juvenile salmonids in the Columbia River estuary (rkm 75), 2007.

Each component of the Matrix antenna weighed approximately 114 kg in air and required an additional 114 kg of lead weight to sink in the water column (452 kg total). A PIT-tag transceiver, similar to that used on the large trawl antenna system, was mounted on a small pontoon raft that was tethered at the rear of the trawl. Cables from the underwater antenna led to the raft, where a wireless modem transmitted PIT-tag detections and electronic status reports from the transceiver to a computer in a tow vessel.

Electronic Equipment and Operation

For the large trawl detection system, we used essentially the same electronic components and procedures as in earlier years with periodic upgrades to the electronic components. In 2007, we used Digital Angel model FS1001M transceivers and Minimon software available from PTAGIS. A 10-m-long pontoon barge was towed near the exit to the trawl, and a gasoline generator powered all electronic equipment. Associated PIT-tag detection electronics were mounted in the cabin of the barge, and cables led underwater to tuner ports, one on each of two detection antenna coils. A video camera mounted inside the antenna tunnel was used to monitor fish passage on a VCR/TV housed in the barge. The 200-kg antenna was 2.1 m long with a 0.9-m-diameter fish passage opening.

Once the antenna was operating, the Minimon software automatically recorded time, date, tag code, coil identification number, and GPS location. For each sampling cruise, written logs were maintained noting the time and duration of net deployment, total detections, the number of impinged fish, and the start and end of each net-flushing period.

Electronic components for the matrix trawl detection system were contained in a 0.8-m-long by 0.5-m-wide by 0.3-m-deep water-tight box mounted on a 1.9-m-long by 1.2-m-wide pontoon raft. A DC power source was used for both the Digital Angel model FS-1001M PIT-tag transceivers and the underwater antenna to interrogate fish. Data were then wirelessly transmitted to a computer onboard one of the tow vessels, and GPS position of the tow vessel was recorded along with date, time, tag code, and coil identification number.

PIT-tag detection data files were periodically (about weekly) uploaded to PTAGIS using standard methods described in the *PIT-tag Specification Document* (Stein et al. 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). Also, 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. The date and river kilometer of barge release were assigned to an independent subset of transported fish based on the last detection date recorded at the transport dam.

Detection Efficiency Tests

We used the same procedure for evaluating electronic performance of the various trawls and antenna systems, none of which required the release of test fish (Ledgerwood et al. 2005). A 2.5-cm-diameter PVC pipe with a small plastic funnel on each end was positioned through the center of each antenna. The pipe extended past each end of the antenna beyond the range of the electronic field (at least 0.5 m). We evaluated detection efficiency by attempting to detect 50 PIT-tags that were attached at known intervals and orientations to a vinyl coated tape measure passed through the antenna (Appendix Table 1).

Detection efficiency, the ability to read PIT-tags, was evaluated for each system at the center of the antenna (Figure 4) and was expected to be positively correlated with orientation, spacing, and proximity to the electronic field. With each new antenna design, we attempted to concurrently maximize the fish-passage opening and potential for detections. These tests were conducted in the weakest area of the antenna field, with tags dispersed and oriented in fixed positions along the vinyl tape-measure. Test results did not reflect actual reading efficiency for PIT-tagged fish because they generally pass in the more optimal areas of the antennas with their tags perpendicular to the electronic field.

We chose densities and orientations along the tape such that not all tags would be detected; the relative consistency of tag detection helped validate electronic tune and identify possible problems with the electronics. During tests, we suspended the antenna underwater and pulled the tape back and forth several times through the PVC pipe. The start time of each pass was recorded in a logbook, and we used standard PIT-tag software to record detections. Efficiency was calculated as the total number of unique tags decoded during each pass divided by the total tags passed through the antenna. The large trawl system was tested about weekly, while the matrix system was evaluated during experimental deployment.

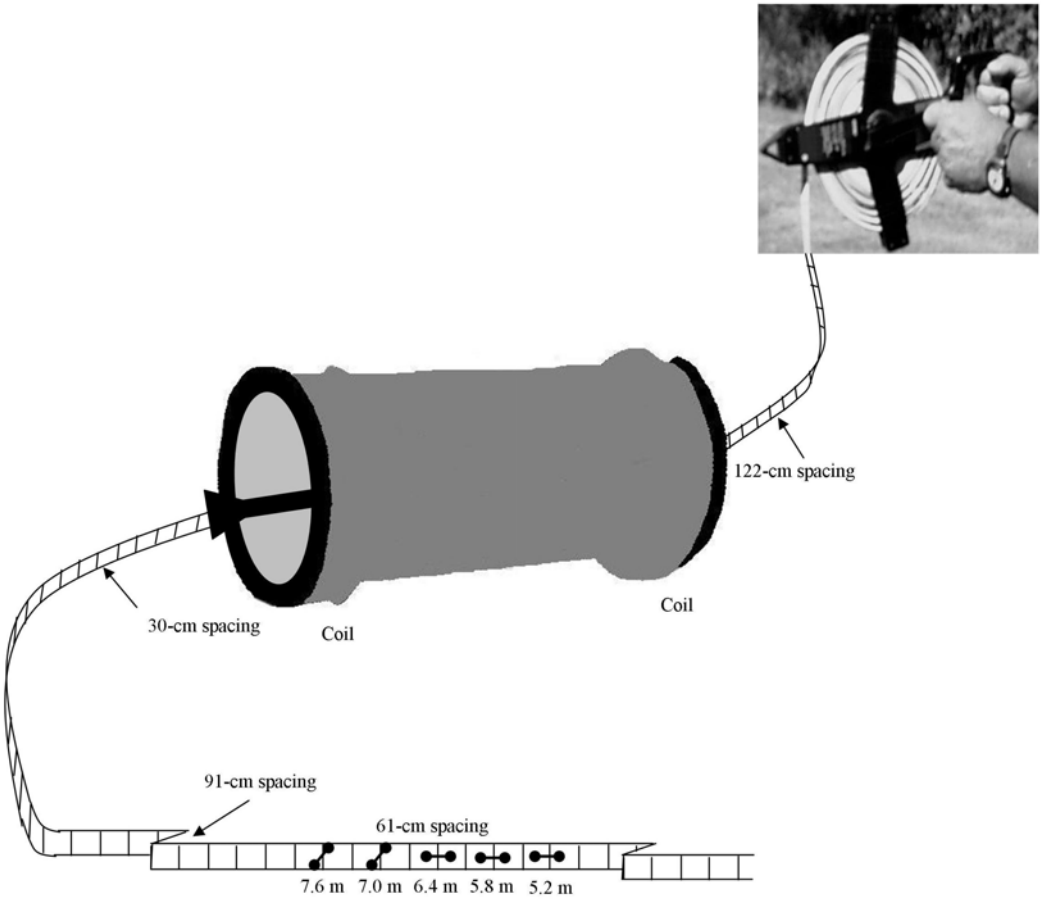

Figure 4. Funnel testing system depicting a vinyl tape measure fitted with test tags being passed through the center of the two-coil large trawl antenna, 2007. Tags attached to the tape were oriented at 0 and 45 degrees and spaced in combinations at 30, 61, 91 and 122 cm apart.

Impacts on Fish

During the day, we used an underwater video camera to monitor debris accumulation near the antenna and cod end of the net. Other sections of the net were monitored visually from the skiff and tow vessels, and accumulated debris was removed as necessary. The net-flushing procedures were also effective at breaking debris loads free from the net, which enabled the debris to pass out of the trawl through the antenna opening. We also adjusted sample operations upon indication of possible impacts to fish in the trawls. For example, when debris accumulated, we reduced tow speed and pulled the detection antenna to the surface to remove material from the cod end using a zipper opening located just forward of the antenna. When debris accumulation was extremely heavy in the standard trawl, we disconnected the electronics and inverted the entire net for cleaning, then reattached the antenna to continue sampling. We also inverted the entire net prior to each retrieval of the standard trawl.

Retrieval of the trawl of the Matrix/trawl system differed from that of the standard trawl system in that it required retrieval directly onto a tow vessel without having to detach the antenna and invert the trawl. One drawback of this design was the occasional accumulation of significant quantities of debris, which is emptied from the net during the inversion process of the standard trawl system. The larger fish-passage opening of the Matrix antenna was more efficient at passing debris, but occasionally accumulations of debris had to be removed by hand. This could be done either during the retrieval process, which required longer drifts, or back at the dock. During debris-removal activities and net-retrieval and redeployment procedures for either trawl system, we recorded impinged or trapped fish as mortalities in operations log books.

Statistical Analyses

Detection data from the estuary are essential to estimate survival of juvenile salmonids to Bonneville Dam, the last dam encountered by seaward migrants (Muir et al. 2001; Williams et al. 2001; Zabel et al. 2002). The probability of survival through an individual river reach was estimated from PIT-tag detection data using a multiple-recapture model for single release groups (CJS model) (Cormack 1964; Jolly 1965; Seber 1965; Skalski et al. 1998). This model requires detection probability estimates at the lowest downstream detection site (i.e., Bonneville Dam), and these estimates are calculated using detections downstream from the dam obtained with our trawl. Complete methodologies and analyses of these data for all river reaches were presented in the companion study by Faulkner et al. (in press).

RESULTS AND DISCUSSION

Large Trawl System Detections

In 2007, we detected 19,186 PIT-tagged juvenile salmonids using the large trawl system at Jones Beach. Fish detected were of various species, runs, and rearing types (Table 1). For example, 78% of our detections were Chinook salmon, 18% were steelhead, and the remaining 4% were other salmonid species. Of these same detections, 17% were wild, 81% were hatchery, and 2% had no release information available. River basin source and migration history for PIT-tagged fish detected in the estuary are shown in Figure 5. Annual differences in PIT-tagging strategies, hydrosystem operations, and proportions of fish transported each year contributed to variations in the proportions from each source. This complicates multiyear comparisons among sources, species, and run or rearing types; however, proportions in 2007 were nearly identical to those observed in 2006.

Table 1. Species composition and rearing-type history for PIT-tagged fish detected in the large trawl near river kilometer 75, 2007.

	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

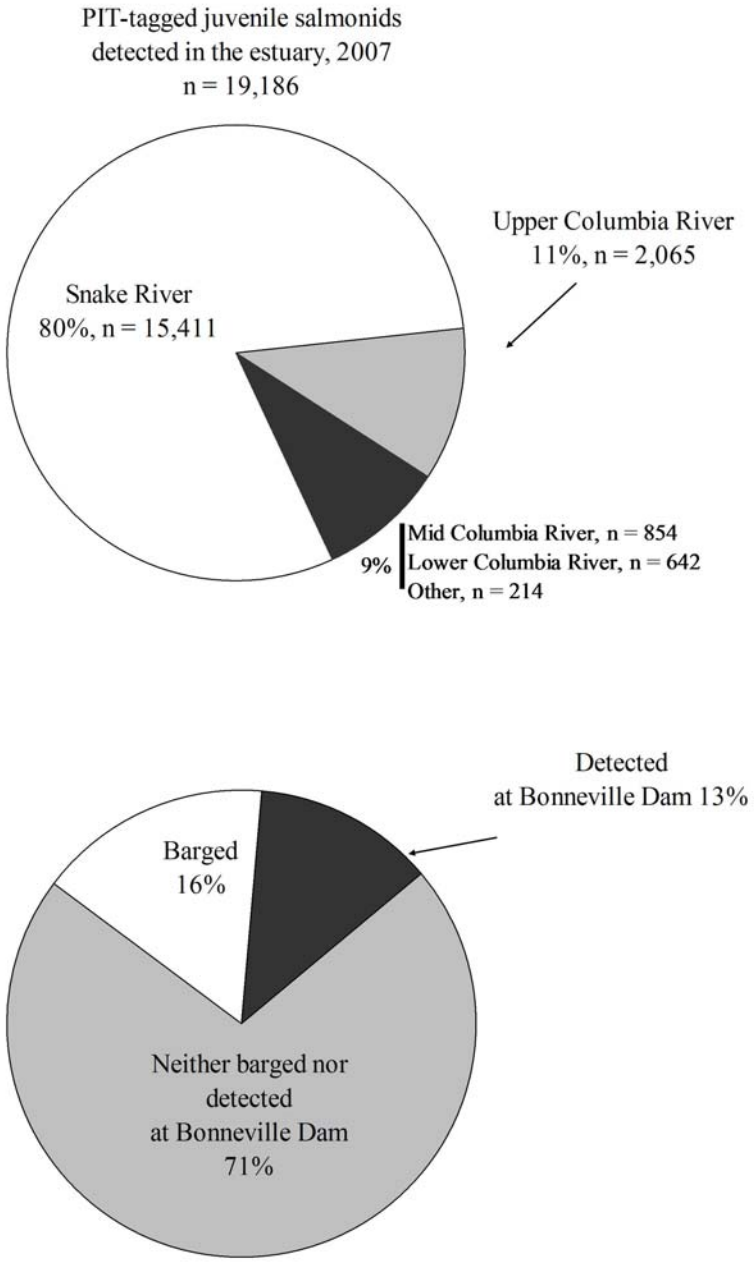

Figure 5. River basin sources and migration histories of PIT-tagged fish detected in the estuary (rkm 75), 2007.

During 2007, the large trawl system was operated for 1,059 h, resulting in 19,186 detections. In contrast, the trawl was operated for 961 h in 2006, with 12,361 detections (Figure 6). According to the PTAGIS database, there were about 26% fewer PIT-tagged fish released into the river basin during 2007 than in 2006; however, we detected nearly 7,000 more fish this year compared to last. Still, there are many variables associated with annual detection numbers in the estuary. For example, mean flow volumes in the Columbia River from mid-April through the end of June were 6,858 $m^3 s^{-1}$ in 2007 and 9,435 $m^3 s^{-1}$ in 2006 (Figure 7).

We speculate that, as in previous years, the lower flow volumes in 2007 resulted in fish groups being more concentrated and passing through the sample area more slowly than in 2006. This would have increased sample efficiency and detection numbers during the 2007 study year.

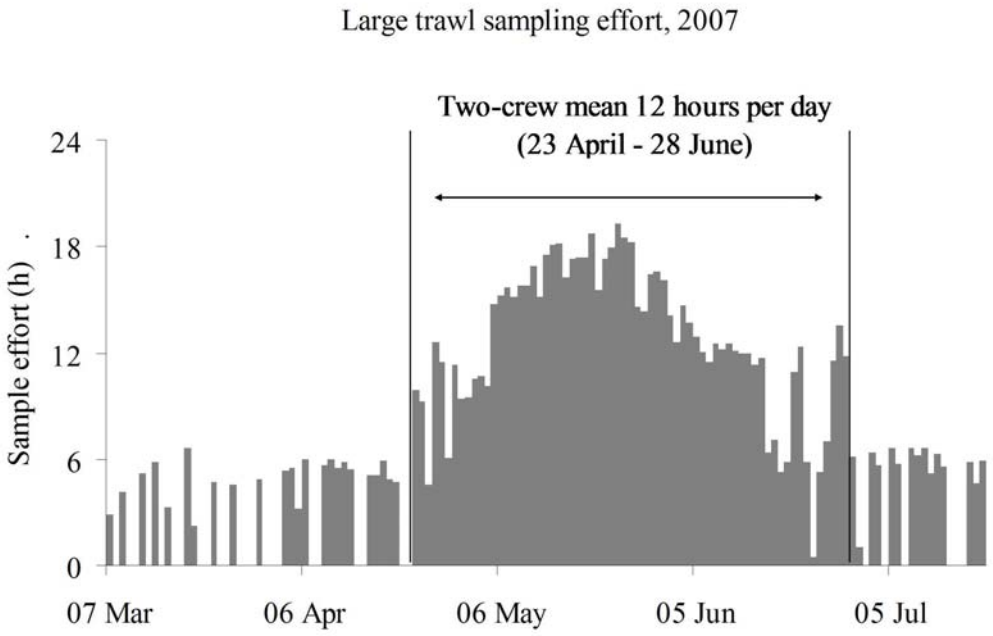

Figure 6. Daily sampling hours using the large trawl PIT-tag detection system in the upper Columbia River estuary (rkm 75), 2007.

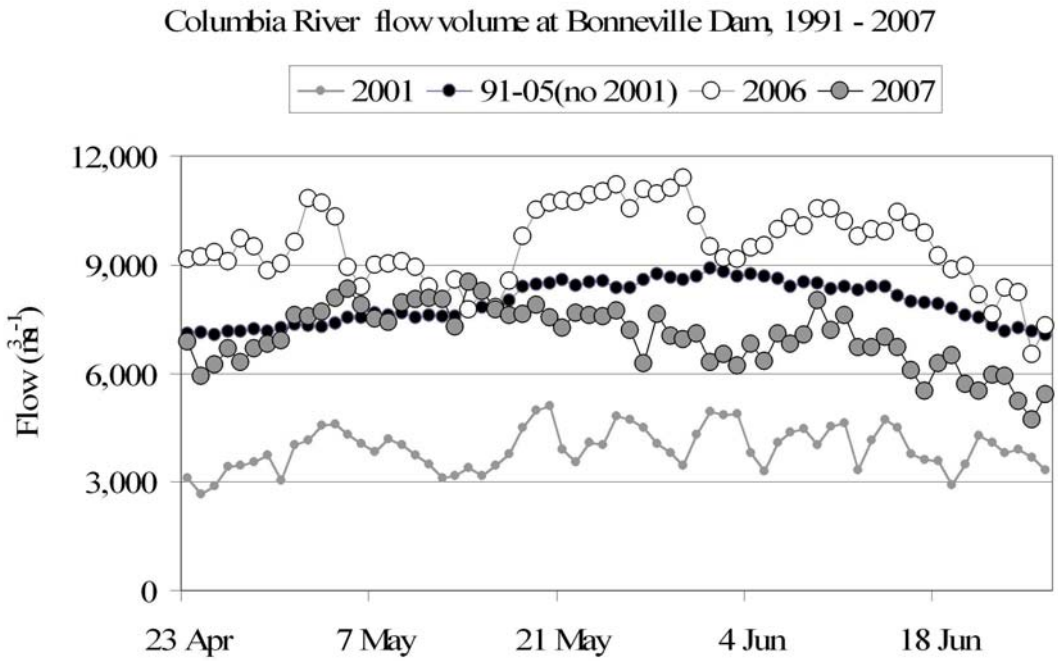

Figure 7. Columbia River flows at Bonneville Dam during the two-crew periods 2006 and 2007, as compared to the average flow from 1991 to 2000. Drought-year flows for 2001 are also shown for comparison.

Matrix Trawl System Detections

In 2007, we sampled with the prototype Matrix antenna system at rkm 75 during the peak of the spring migration and again late in the season. The pair trawl net used with the Matrix antenna was identical in size and dimension as that used with the standard 0.9-m diameter antenna. Because of the larger size of the Matrix antenna and the logistics involved in deploying the system, much effort during sampling with the system was focused on handling practices and electronic tuning.

Initially, we deployed a 2-coil Matrix during late May and June (35.9 h with 223 detections; Table 2). In mid-July, after most yearling fish had passed, we deployed a 5-coil Matrix system consisting of the original 2-coil component in front and a new 3-coil component in the rear. Both components had fish passage openings of the same size for trawl attachment, but the 3-coil component was divided into thirds. We sampled with the 5-coil Matrix for 16.4 h and detected 70 fish, primarily subyearling Chinook salmon (Table 3). During this same period, we sampled with the standard system for 16.1 h and detected only 12 fish. During simultaneous sampling,[1] a total of 19 individuals were recorded on both systems.

On 4 June, during a simultaneous 3-h sample period using both systems, we used similar engine power (1100 RPM) on the 10.0-m tow vessels, and the Matrix system traveled 0.3 knots faster through the water than the standard trawl system (average speed 0.2 knots). It is important to note that speed differences were difficult evaluate due to factors such as tidal effects, currents, and cross channels in the sampling reach. Although both systems were deployed at the same time, and were initially in close proximity to one another, they separated through time, with the Matrix system pulling away from the standard system. Therefore they were subjected to different degrees of influence from these geo-specific factors.

As mentioned above, we added a 3-coil component to the Matrix antenna system in early July. We tested this 5-coil Matrix system during daylight hours between 12 and 18 July. However, except for the simultaneous sampling conducted on 13 July, simultaneous sampling of the new Matrix system and standard trawl system was not possible due to a vessel breakdown. Therefore, sampling of the two systems occurred on different days within a period when the availability of PIT-tagged fish in the estuary was generally low. Results showed that the Matrix system detected over 5 times more fish than the standard trawl system. We believe that continued development of larger more efficient PIT-tag detection equipment for our trawls, will further increase sample efficiency and improve precision of the survival estimates.

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1 During simultaneous sampling, 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.

Table 2. Daily detections and sampling effort using a 2-coil Matrix antenna system near rkm 75, 2007.

Date	Effort (h)	Chinook salmon (n)	Sockeye (n)	Steelhead (n)	Coho salmon (n)	Unknown (n)	Total detections (N)
22 May	3.9	13	0	34	0	0	47
23 May	5.3	23	1	25	1	0	50
24 May	5.5	22	3	40	1	0	66
30 May	5.7	8	0	25	2	1	36
4 Jun	5.0	4	2	4	2	0	12
5 Jun	5.3	0	2	4	1	0	7
6 Jun	5.3	0	4	10	1	0	15
Totals	35.9	70	12	142	8	2	223

Table 3. Daily detections and sample effort using a 5-coil Matrix antenna system (2 coils in front and 3 coils in rear) near rkm 75, 2007.

Date	Matrix effort (h)	Large trawl (h)	Matrix detections (n)	Large trawl detections (n)
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

Detection Efficiency

Test tags that were oriented perpendicular to the electronic field were detected at higher rates than those placed at an angle in most instances. Efficiencies were also positively correlated with spacing between tags, regardless of orientation. It is important to note that differences in detection efficiency were observable primarily when the test tape was passed through the center of the antennas rather than when the tape was passed near the edges (the optimal area within the electronic field and where most fish pass). Therefore, these in situ evaluations of read efficiency were rigorous tests of antenna performance.

The antenna used with the standard (large) trawl system read only about 43% of test tags when the tape was passed through the center of the antenna and tags were spaced 30 cm apart and oriented perpendicular to the electronic field. When tags were oriented at 45 degrees to the electronic field, the standard antenna read less than 32% of the test tags (Figure 8). When spacing between tags was increased to 61 cm, detection efficiency with the standard antenna increased to nearly 85% for perpendicular tags and 95% for tags at a 45-degree angle. However, it is unclear why tags at a 45-degree angle were detected better than those held perpendicular to the field when tag spacing was 61 cm.

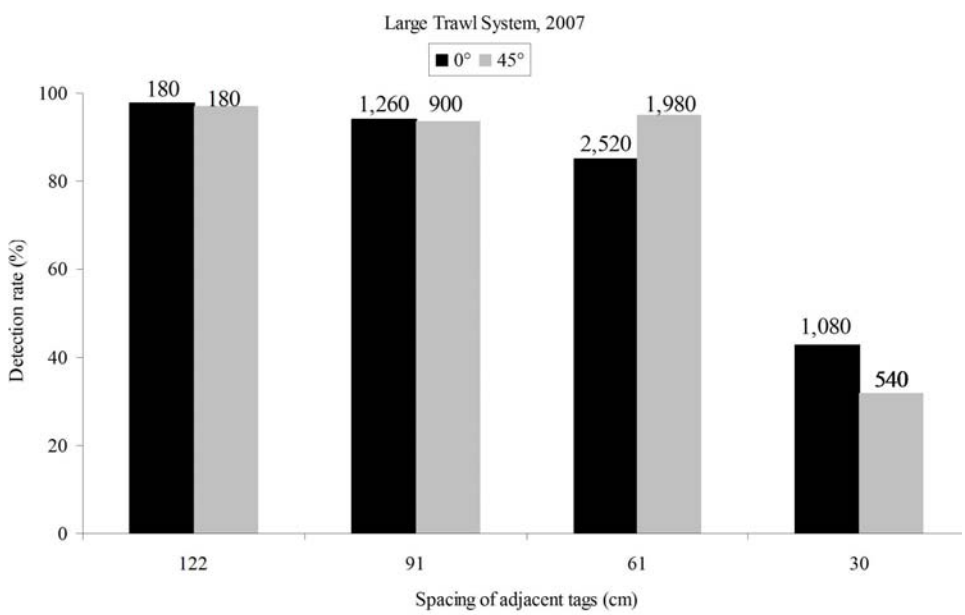

Figure 8. Average detection efficiency determined by using 50 ST-style PIT-tags attached to vinyl tape measures in 2007. Various spacing between tags and orientation to the electronic field were used, and all tape configurations were identical. Tags were passed through the antenna (0.9-m-diameter) center repeatedly on 14 different dates (total potential tags listed above the bars).

When spacing between tags was increased to 91 and 122 cm, detection efficiencies increased to between 93 and 98%, regardless of tag orientation. Seasonal average detection efficiency for all test tags passed through the 0.9-m-diameter antenna was 81% (Table 4). Finally, when the test apparatus was positioned about 20 cm from the antenna wall, rather than through the center, detection rates averaged 96%, regardless of spacing and orientation.

Table 4. Average detection efficiencies of four PIT-tag antenna designs was compared by passing 50 test tags at various spacing and orientations on a vinyl tape through the center or near the side of each antenna, 2007.

Antenna (dimensions)	Total tags (N)	Mean antenna efficiency (center %)	Maximum antenna efficiency (side %)
Large (0.9-m-diameter)	4,200	81	96
Large (1.1-m-diameter)	6,000	54	91
Matrix (1.1-m- × 2.8-m-perimeter)	6,000	32	63
Matrix (0.7-m- × 2.8-m-perimeter)	3,300	69	79

Detection efficiencies of individual coils for each antenna were evaluated in situ periodically (about weekly) through the season using test tags. We observed early in the season that the detection rate of the 1.1-m-diameter antenna planned for use in 2007, was significantly lower than measured in 2006 (54% in 2007 vs. 72% in 2006). On 4 April, it was determined the integrity of the antenna had been compromised (water leakage), and thus we switched to the backup antenna, which was 0.9-m in diameter, for the remainder of the season. Overall, the 0.9-m-diameter antenna read 81% of the test tags passed through the center on weekly test dates (n= 8,640 test tags on 14 test dates).

Detection efficiency of the matrix antenna was lower than that of the conventional antennas: 2-coil Matrix, each 1.1m-wide, averaged 32%; 3-coil Matrix, each 0.7-m-wide, averaged 69%. However, these tests of the Matrix antenna components were probably compromised due to the intermittent and unexplained electronic interference.

We also evaluated detection efficiency by comparing the daily proportions of fish detected on the front and rear coils of the 0.9-m-diameter antenna (Figure 9). The daily average detection efficiency for fish detected only on the front coil was 88%. Detection on the front coil only was possibly due to fish being missed by the rear coil or to fish escaping the net by swimming forward. Detection efficiency for fish detected on the rear coil only was similar, at 86%. The two-coil system provides redundancy for detecting tagged fish passing through the antenna, and this is particularly valuable during periods when high numbers of PIT-tagged fish are passing. When numbers of unique records of PIT-tagged fish recorded on the front and rear coils were radically different, we suspected problems with the electronics. In general, we attempted to use the coil that performed best as the rear coil. Orientation of fish to the electronic field was thought to be better at the rear of the fish-passage opening, since past results indicated that fish orientation may improve during passage through the opening.

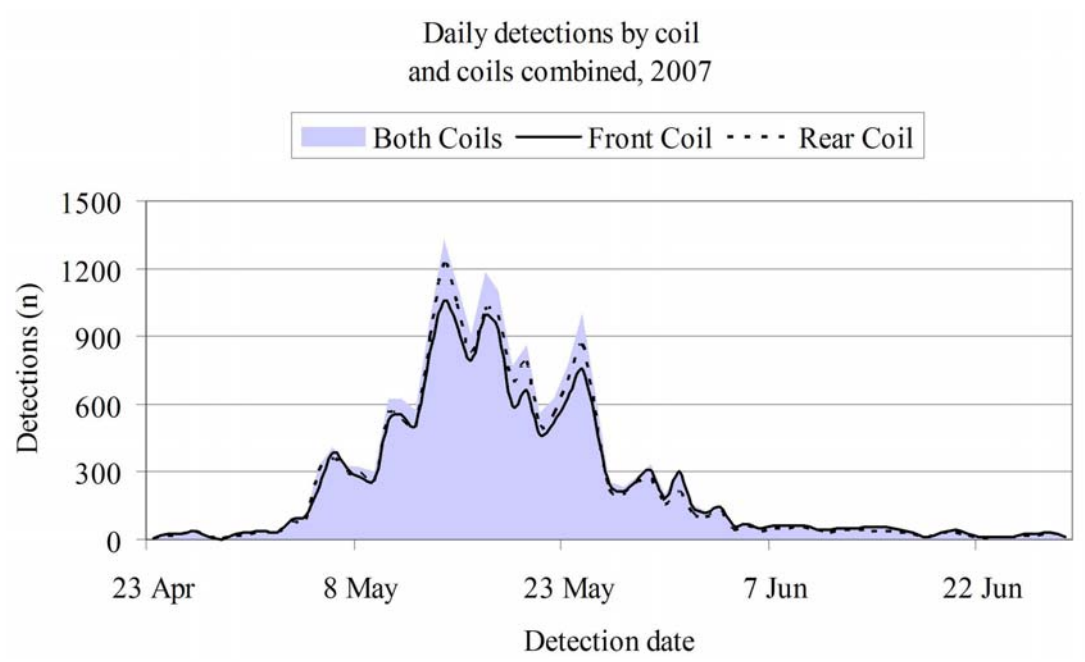

Figure 9. Daily detection rates by coil of juvenile salmonids using the large trawl system during the two-crew sample period (0.9-m-diameter antenna).

Impacts on Fish

During inspection or retrieval of the trawls, we recovered juvenile salmonids that had been inadvertently injured or killed during sampling. In 2007, we recovered 106 of these fish on the standard trawl and 40 on the Matrix trawl (Appendix Table 2). Due to the net inversion process of the standard (large) trawl, it is possible that additional fish were unknowingly injured or killed. However, in previous years, divers have inspected the trawl body and wing areas of the nets and have reported that fish rarely swam close to the webbing. Rather, fish tended to linger near the entrance to the trawl body and directly in front of the antenna.

Over the years we have eliminated many visible transition areas between the trawl and wings or other components. These mainly were found in the seams joining sections with different web sizes. We also now use a uniform color (black) of netting for the trawl body and cod end areas, which in the past have appeared to attract fish and delay their passage out of the net. We continued to flush the net (bring the trawl wings together) every 15 min to expedite fish passage through the antenna. The purpose of flushing is to reduce delay and possible fatigue of fish that may be pacing the net transition areas or lingering near the antenna components. While volitional passage through the antenna occurred while towing with the wings extended, we continued to bring the wings together every 15 minutes and detected most fish during these 5 min net-flushing periods.

Sampled PIT-Tagged Fish

Of the 171,479 yearling Chinook salmon and 93,561 steelhead PIT tagged for the NMFS transportation study in 2007, 159,756 and 70,711, respectively, were released above our sample site. A total of 30,344 ycs and 40,967 stld of those, respectively, were diverted at Snake and Columbia River dams for transport. Including diverted river-run fish and fish tagged for other studies, totals of 64,846 yearling Chinook salmon and 47,894 steelhead were transported and released above our sample site. Of those, we detected 1,886 yearling Chinook salmon and 1,183 steelhead in the upper estuary near river kilometer 75 and associated analyses of those detections are presented separately (Magie et al. In prep.)

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. We detected 1,678 yearling Chinook salmon and 472 steelhead that had previously been detected at Bonneville Dam in 2007 (Appendix Table 3). Detections of these fish in the estuary are an essential, and often limiting, component in the single-release model for estimating survival probabilities for these species to the tailrace of Bonneville Dam.

Beginning in 2004, fish could exit the second powerhouse forebay at Bonneville Dam through a corner collector which returned fish to the tailrace. Of the other routes of passage to the tailrace including spillway or turbines, only fish guided into the juvenile bypass system from the turbine entrances were interrogated for PIT-tags. Detection numbers were much reduced during 2004 and 2005 as a result of the successful operation of the corner collector. Beginning in 2006, the corner collector had PIT-tag detection capability (lacking in previous years). In 2006 and 2007, respectively, an estimated 42% and 60% of the 73,842 and 76,996 PIT-tagged migrants interrogated at Bonneville Dam passed the dam via the corner collector and the balance were detected in the juvenile bypass facility. The addition of the detection capability in the corner collector at Bonneville Dam improved our ability to increase the precision of survival estimates to the tailrace of Bonneville Dam.

As in previous years, only a small portion of either barged or in-river migrants passed through the estuary before or after the trawl sampling period. Further, 70% of the barged juvenile salmonids and 71% of those detected at Bonneville Dam were at or near river kilometer 75 during the daily two-crew trawling period from 23 April to 28 June (Table 5). During that two-crew sample period, we detected 3.0% of the barged PIT-tagged juvenile Chinook salmon available and 3.6% of those previously detected at Bonneville Dam; for steelhead, 2.4% and 3.8% were detected from the respective groups.

Table 5. Detections of PIT-tagged fish released from barges and inriver migrant fish detected previously at Bonneville Dam during the intensive two-crew daily sample period in the estuary from 23 April to 28 June, 2007. The release totals for PIT-tagged fish during this sample period represented 91% of the annual totals in these categories and were selected allowing two days for fish to travel from Bonneville Dam to the sample area.

	Barged (release below Bonneville Dam)			In-river (detected at Bonneville Dam)		
	Released	Detected	%	Released	Detected	%
Chinook salmon	64,104	1,894	3.0	44,078	1,575	3.6
Steelhead	47,849	1,162	2.4	10,462	394	3.8

Survival Estimates of Inriver Migrants to the Tailrace of Bonneville Dam

Detection data from the trawl are essential for calculating survival probabilities for juvenile salmonids to the tailrace of Bonneville Dam, the last dam encountered by seaward migrants (Muir et al. 2001; Williams et al. 2001; Zabel et al. 2002). Detections of yearling Chinook salmon and steelhead arriving at McNary Dam were pooled weekly, and survival probabilities of fish released in the Snake and mid-Columbia Rivers were estimated from McNary to John Day, John Day to Bonneville, and McNary to Bonneville Dams. An example of weekly pooled survival estimates is shown in Table 6 (data are for 2006).

Weighted annual survival estimates were compared for the years 1999-2007 for both Snake and Mid-Columbia River basin stocks (Figure 10). In some years, an insufficient number of PIT tags was released for one species or the other for a comparison between watersheds. However, there does not appear to be a general trend in survival between the two sources for either species. Annual survival estimates for Snake River stocks of yearling Chinook salmon ranged from 50.1% in 2001 to 80.6% in 2006 (76.0% in 2007). Similar estimates for mid-Columbia River stocks ranged from 67.8% in 2006 to 76.7% in 2003 (70.9% in 2007). Survival estimates for Snake River stocks of steelhead ranged from 25.0% in 2001 to 77.0% in 1998 (55.9% in 2007). Similar estimates for mid-Columbia River stocks range from 39.2% in 2007 to 74.2% in 1999. Complete analyses of these data is reported by Faulkner et al. (in press).

Fish loaded aboard trucks and barges at Lower Granite, Little Goose, or Lower Monumental Dams on the Snake River or at McNary Dam on the Columbia River bypass between seven and three downstream dams, respectively. The effectiveness of fish transportation is evaluated in part by comparing smolt to adult return ratios for transported and 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 migrant yearling Chinook and steelhead from the tailrace of Lower Granite Dam to the tailrace of Bonneville Dam was 64.3 and 67.6%, respectively. In 2007, the survival estimates were slightly lower at 59.4 and 66.3%, respectively (Table 7).

The high survival probabilities in for yearling Chinook through the entire hydropower system below Lower Granite Dam in 2006 and 2007 could be expected, considering the higher than average river flow volumes those years. In 2001 and 2004, two years characterized by extremely low river flows due to regional drought, survival probabilities were much lower than in other years at 27.9 and 39.5%, respectively.

Survival probabilities for steelhead through the entire hydropower system downstream from Lower Granite Dam in 2006 and 2007 were about mid-range compared to previous years, with the exceptions of 2004 and 2005, when detection rates at Bonneville Dam were too low to estimate the survival probability and the drought year 2001 when survival was just over 4%.

Table 6. Weekly average survival percentages from the tailrace of McNary Dam to the tailrace of Bonneville Dam for yearling Chinook salmon and steelhead, 2006[2]. Total fish used in the survival estimates, weighted average survivals, and standard errors (SE) for each species and water basin are presented. Dashes indicate sample size was too small for estimates of survival.

		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	1,917	85.1	6.8	75.8	39.6	64.5	33.4
27 Apr-03 May	9,932	79.1	2.6	111.5	22.4	88.2	17.5
04 May-10 May	27,949	89.1	2.2	88.5	6.8	78.9	5.8
11 May-17 May	31,498	89.0	3.0	90.4	10.4	80.5	8.8
18 May-24 May	9,904	95.6	8.3	100.8	33.4	96.4	30.8
25 May-31 May	1,532	103.9	20.8	120.8	119.7	125.5	121.8
Wt. Avg.	82,732	86.8	1.9	89.1	1.1	80.6	2.2
			Snake River steelhead				
20 Apr-26 Apr	694	79.5	4.9	128.3	60.6	102.0	47.8
27 Apr-03 May	1,528						
04 May-10 May	2,532	89.0	5.8	55.4	12.6	49.3	10.7
11 May-17 May	1,906						
Wt. Avg.	6,660	84.0	4.8	69.1	28.5	58.7	20.1
			Mid-Columbia River yearling Chinook salmon				
20 Apr-26 Apr	200	75.4	8.6	79.5	51.6	59.9	38.3
27 Apr-03 May	850						
04 May-10 May	1,583	102.0	10.7	77.5	36.9	79.0	36.8
11 May-17 May	1,551						
18 May-24 May	654	78.0	21.0	51.8	49.7	40.4	37.2
25 May-31 May	101						
Wt. Avg.	4,939	88.9	9.3	74.5	6.5	67.8	9.9
			Mid-Columbia River steelhead				
27 Apr-03 May	39	98.2	36.3	0.0	0.0	0.0	--[a]
04 May-10 May	162						
11 May-17 May	1,021	75.2	6.4	--[a]	--[a]	--[a]	--[a]
18 May-24 May	939						
25 May-31 May	1,287	86.1	9.7	--[a]	--[a]	--[a]	--[a]
01 Jun-07 Jun	226						
Wt. Avg.	3,674	79.8	4.4				

[2] Weekly survival estimates for mid-Columbia and Snake River stocks in 2007 have not yet been published.

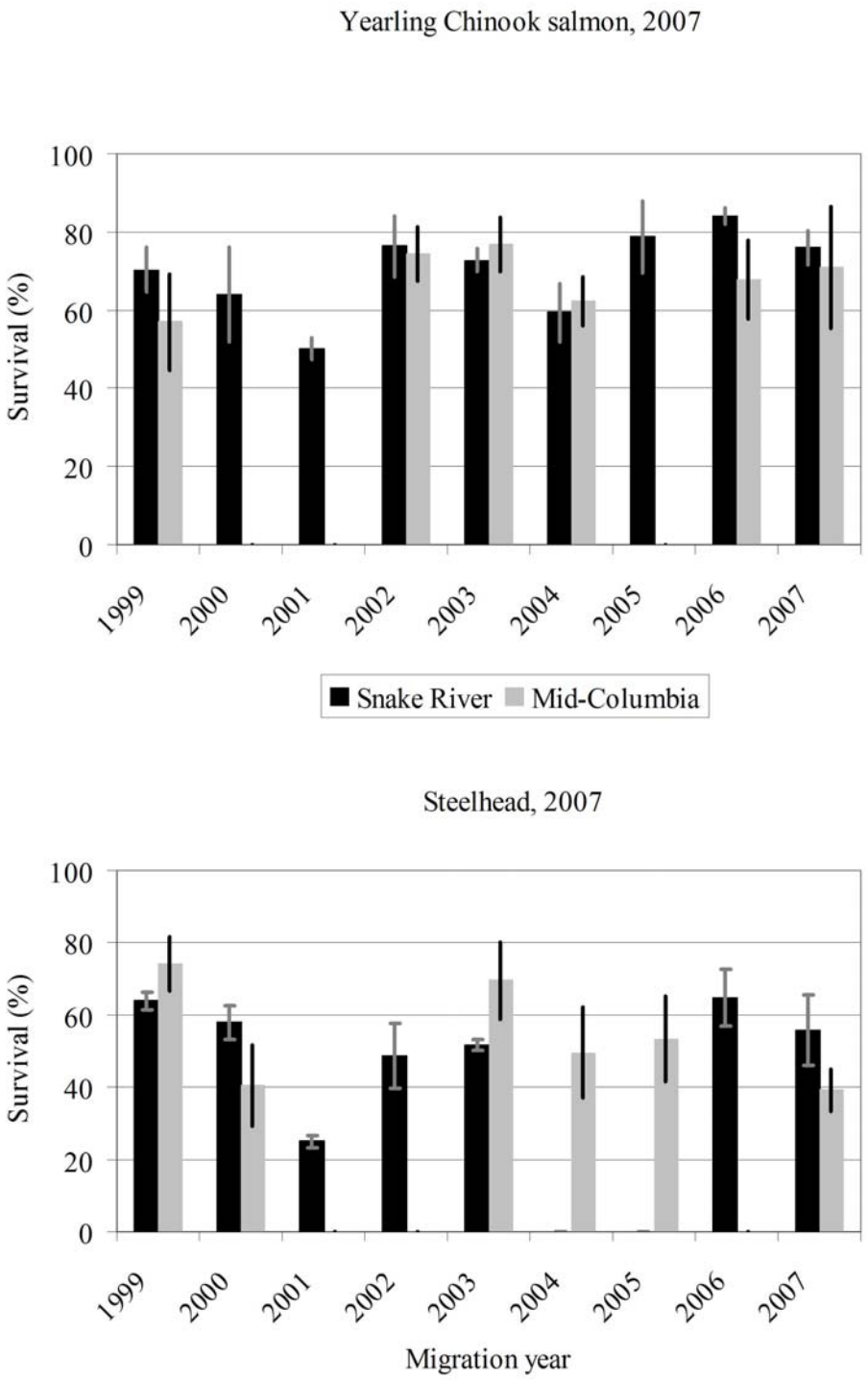

Figure 10. Weighted average annual survival probabilities and standard errors from the tailrace of McNary Dam to the tailrace of Bonneville Dam for yearling Chinook salmon and steelhead from the Snake and mid-Columbia Rivers, 1999-2007.

Table 7. Weighted annual mean survival probabilities and standard errors from the tailrace of Lower Granite Dam to the tailrace of Bonneville Dam for yearling Chinook salmon and steelhead, 1998-2007.

	Survival Probabilities			
	Yearling Chinook salmon		Steelhead	
Migration year	Survival (%)	SE	Survival (%)	SE
1998	53.8	4.6	50.0	5.4
1999	55.7	4.6	44.0	1.8
2000	48.6	9.3	39.3	3.4
2001	27.9	1.6	4.2	0.3
2002	57.8	6.0	26.2	5.0
2003	53.2	2.3	30.9	1.1
2004	39.5	5.0	--*	--*
2005	57.7	6.9	--*	--*
2006	64.3	1.7	45.5	5.6
2007	59.4	3.5	38.6	6.9

* Sample size too small to estimate annual survival probability

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APPENDIX

Data Tables

Appendix Table 1. Configuration of tags on tape measure used to test antenna performance in 2007.

Position on tape measure (ft)	Orientation (°)	Distance from previous tag (ft)[a]	PIT-tag code[b]
17	0	0	3D9.1BF22F5437
19	0	2	3D9.1BF1A73554
21	0	2	3D9.1BF1A723D6
23	45	2	3D9.1BF1A6BBD5
25	45	2	3D9.1BF1F8B9A4
28	0	3	3D9.1BF1A6BE89
31	0	3	3D9.1BF1F7DDEA
34	0	3	3D9.1BF1A1E4AF
37	45	3	3D9.1BF1CF5597
40	45	3	3D9.1BF1E73089
43	45	3	3D9.1BF1F81373
45	0	2	3D9.1BF1F7D25F
47	0	2	3D9.1BF1F7DC5C
49	0	2	3D9.1BF1F7D8EA
50	0	1	3D9.1BF1A71E13
51	0	1	3D9.1BF1A1CD75
52	0	1	3D9.1BF1F7CDF7
55	0	3	3D9.1BF1F8F242
58	0	3	3D9.1BF1A7A629
59	0	1	3D9.1BF1F85701
62	0	3	3D9.1BF1A72BFD
63	0	1	3D9.1BF1F8CAB0
66	0	3	3D9.1BF1F8BBEB
69	45	3	3D9.1BF1F7CD88
70	45	1	3D9.1BF1A9ADDC
72	0	2	3D9.1BF1F7268D
73	0	1	3D9.1BF1A972D5
75	0	2	3D9.1BF1A6B38B
77	0	2	3D9.1BF1F81389
81	0	4	3D9.1BF1A98D9E

Appendix Table 1. Continued.

Position on tape measure (ft)	Orientation (°)	Distance from previous tag (ft)[a]	PIT-tag code[b]
83	0	2	3D9.1BF1A7885E
85	0	2	3D9.1BF1A73F1E
88	45	3	3D9.1BF1A9B578
89	45	1	3D9.1BF1A9919F
91	45	2	3D9.1BF1A78FC4
92	45	1	3D9.1BF1A76D70
94	45	2	3D9.1BF1A9C00C
96	45	2	3D9.1BF1CF51C6
100	45	4	3D9.1BF1A9C20F
102	45	2	3D9.1BF1F7C65E
104	45	2	3D9.1BF1A77453
106	0	2	3D9.1BF1A6C70C
108	0	2	3D9.1BF1A1D513
110	0	2	3D9.1BF1A6C4CF
112	0	2	3D9.1BF1A98396
114	45	2	3D9.1BF1A1D0F8
116	45	2	3D9.1BF22BF651
118	45	2	3D9.1BF1F8DA09
120	45	2	3D9.1BF22A8198
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. Combined daily total of impinged fish 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
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

Appendix Table 2. Continued.

Date	Chinook salmon Yearling	Subyearling	Coho salmon	Steelhead	Sockeye
20 Apr	0	0	0	0	0
21 Apr	--	--	--	--	--
22 Apr	--	--	--	--	--
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

Appendix Table 2. Continued.

Date	Chinook salmon Yearling	Subyearling	Coho salmon	Steelhead	Sockeye
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
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	115	2	4	30	0

Appendix Table 8. Detections in the Columbia River estuary of PIT-tagged juvenile Chinook salmon and steelhead previously detected at Bonneville Dam, 2007. The juvenile bypass system and corner collector at Bonneville Dam operated 16 Feb-20 Oct; trawl operation 7 Mar-19 Jul, intensive sampling 23 Apr-28 Jun. Totals for the entire season are shown, including all release sites.

Detection date	Bonneville Dam detections		Jones Beach detections			
at Bonneville Dam	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	1164	252	37	9	3.18	3.57
08 May	1348	250	36	5	2.67	2.00
09 May	1861	452	51	17	2.74	3.76
10 May	2518	349	54	14	2.14	4.01
11 May	2381	467	85	21	3.57	4.50
12 May	2836	392	150	20	5.29	5.10
13 May	2978	759	133	30	4.47	3.95
14 May	3417	243	98	7	2.87	2.88
15 May	2934	291	125	6	4.26	2.06
16 May	2756	402	87	16	3.16	3.98
17 May	1608	423	69	17	4.29	4.02
18 May	2011	289	85	10	4.23	3.46
19 May	1933	304	72	9	3.72	2.96
20 May	1191	299	43	9	3.61	3.01
21 May	1686	621	70	19	4.15	3.06
22 May	1721	304	70	17	4.07	5.59
23 May	1577	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
05 Jun	86	209	2	6	2.33	2.87

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 (%)
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