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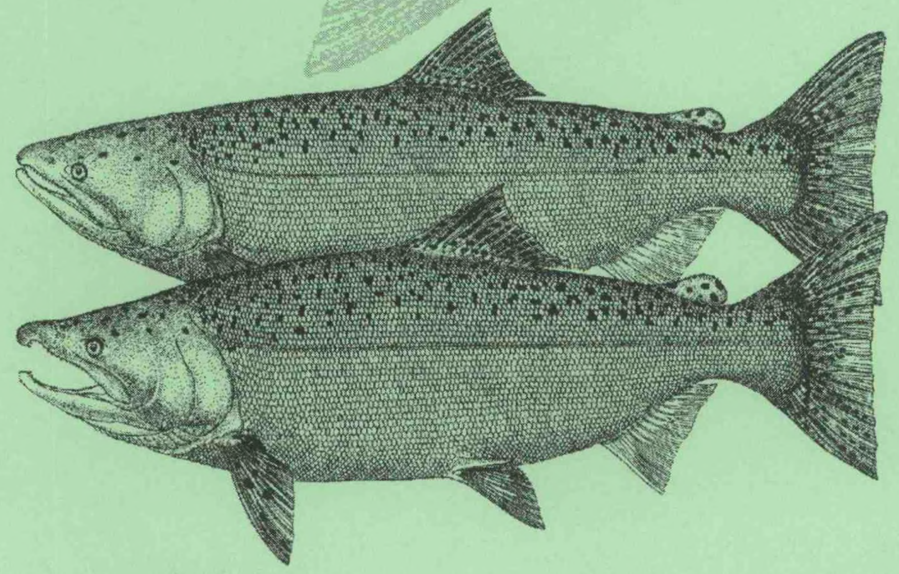
December 2010



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Report of research by

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National Marine Fisheries Service
National Oceanic and Atmospheric Administration
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EXECUTIVE SUMMARY

In 2009, we continued a multi-year 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 system. We sampled in the upper Columbia River estuary between river kilometers (rkm) 61 and 83 for 1,139 h between 6 March and 12 August, and during this time we detected a total of 23,247 PIT-tagged juvenile salmonids. Of these detections, 17% were wild fish and 80% were hatchery (3% were of unknown origin). Of total detections by species, 47% were yearling Chinook salmon, 13% were subyearling Chinook salmon, 33% were steelhead, 4% were sockeye, and 3% were unknown species.

In 2009, mid-river sampling was conducted exclusively with our matrix antenna system. This system was composed of a surface pair-trawl that funneled fish through a 2.6-m wide by 3.0-m tall antenna consisting of six PIT-tag detection coils monitored with a single transceiver. The matrix antenna was comprised of two components, each consisting of 3 parallel coils. The pair trawl was 105-m long and sampled to a depth of 4.9 m. We maintained a distance of 91.5-m between the trawl wing tips.

During the spring migration period, we targeted 669,629 yearling Chinook salmon and 285,710 juvenile steelhead that were PIT-tagged and released into the Snake River (PTAGIS; PSMFC 2009). Some of these released fish were diverted to transportation barges or trucks at collection facilities located at Lower Granite, Little Goose, Lower Monumental, and McNary Dams; a total of 178,591 fish were transported. Transported fish were generally released just downstream from Bonneville Dam, the lowermost dam on the Columbia River, and about 150 km upstream from our sample site.

Coincidental with the arrival of early migrating juvenile PIT-tagged salmon and steelhead in the estuary, we began sampling on 6 March with a single daily shift operating 3-5 d/week. As in previous years, we increased sample effort to a more intensive schedule of two-shifts/d operating 7 d/week. Intensive sampling began 1 May and continued through 13 June 2009, as large numbers of yearling Chinook salmon and steelhead arrived in the estuary. We gradually reduced sample effort in mid-June and returned to a single daily sampling shift. Sampling ended on 12 August as numbers of PIT-tagged fish in the sampling reach declined.

During intensive sampling, the trawl was deployed for an average of 15 h/d and detected 3.3% of the yearling Chinook and 3.5% of the steelhead previously detected at Bonneville Dam. By comparison, during intensive sampling in 2008, the trawl was

deployed for an average of 12 h/d and detected 2.4% of the yearling Chinook and 3.6% of the steelhead detected at Bonneville. Of Chinook salmon transported and released below Bonneville Dam, we detected 2.7% in 2009 vs. 1.7% in 2008; of steelhead similarly transported and released, we detected 3.3% in 2009 and 1.9% in 2008.

Of total fish detected with the pair trawl in 2009, 20% were transported and 14% were inriver-migrants previously detected at Bonneville Dam. The remaining 66% had not been transported or detected at Bonneville Dam, and generally represented fish released above Bonneville Dam that passed via spillway or turbines, which lack detection capability. Less than 3% of total detections were fish that had been released below Bonneville Dam. These proportions were similar to those observed in previous years.

Diel detection rates were similar between wild and hatchery rearing types for both yearling Chinook salmon and steelhead; thus, we pooled data among rearing types for analyses. During the two-shift sampling period, we averaged 14 detections h^{-1} during daylight and 27 h^{-1} during darkness for yearling Chinook salmon ($P = 0.034$). During the same period for steelhead, the trend was opposite, with 16 detections h^{-1} on average during daylight and 7 detections h^{-1} during darkness ($P = 0.122$).

Mean travel speed to Jones Beach was significantly different for inriver migrant yearling Chinook salmon detected passing Bonneville Dam (94 km d^{-1}) than for those released from barges just below the dam (70 km d^{-1}; $P = 0.000$). There was also a significant difference in travel speed between inriver migrant (95 km d^{-1}) and barged steelhead (88 km d^{-1}; $P = 0.000$). Travel speed to the estuary was also significantly slower for subyearling fall Chinook salmon released from barges (mean 57 km d^{-1}) than for those detected at Bonneville Dam (traveling inriver) during the same period (mean 76 km d^{-1}; $P = <0.001$).

We detected 1,731 subyearling fall Chinook salmon with the matrix trawl system in 2009. These subyearlings comprised most of the detections outside the two-shift sampling period. Of the 1,731 subyearlings we detected, 1,417 had originated in the Snake River basin (988 were in-river migrants and 429 had been transported). The remaining 315 were Columbia River stocks. Additionally in 2009, we detected 26 fall Chinook salmon from the Snake River basin that had been released as subyearlings in 2008 and overwintered in either the Snake or Columbia Rivers.

We also sampled using the shoreline trawl system at Jones Beach (rkm 75) from 10 March to 27 April 2009. Target fish during this period were subyearling fall Chinook salmon tagged and released in the Snake River the previous year and assumed to have overwintered in the tidal freshwater or brackish water portions of the estuary near the shoreline. We operated the shoreline system during daylight hours, 1-2 d/week, and only on ebb tides. In total, the shoreline system was deployed on nine ebb tides for a total of 42 h with no detections recorded. Sample effort with this system ended on 14 April, and no future sampling with this system is planned.

Also in 2009, we continued development and testing of a prototype mobile separation by PIT-tag code (MSbyC) system. The prototype MSbyC system was deployed and tested independent of the trawl in the lower Snake River in October. Testing was conducted first with surrogate fish implanted with PIT tags and then with yearling Chinook salmon and steelhead. After observing fish avoiding the diversion-system entrance, we introduced a manually operated air bubbler on the floor of the collection chamber to induce fish to enter the system.

In tests using the air bubbler, all but 5 of 56 tagged and untagged fish moved completely through the system within 90 seconds. However, fish moved through the system in clumps, and separation efficiency dropped as low as 65% from 100% when densities of fish passing through the system were lower. Fish were captured as they exited the bypass discharge and examined for injuries. Descaling was observed on one test fish, but observation of its handing revealed that this was most likely due to its impingement between the sampling net and the side of the sample tank during its retrieval for evaluation. No other impacts were observed on either diverted or non-diverted fish.

CONTENTS

INTRODUCTION

In 2009, we continued a multi-year study to collect data from migrating juvenile Pacific salmon *Oncorhynchus* spp. in the Columbia River estuary for estimates of survival and migration timing (Ledgerwood et al. 2006, 2007; Magie et al. 2008, 2010a,b). As in previous years, we used a large surface pair-trawl to guide fish through a detection antenna mounted in place of the cod end of the trawl (Ledgerwood et al. 2004). Target fish were those implanted with passive integrated transponder (PIT) tags in natal streams, hatcheries, or other upstream locations prior to migration (PSMFC 2009). As PIT-tagged fish passed through the trawl, their tag code and the date, time, and GPS position of passage was recorded. 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 (Magie et al. 2010b).

More than 2.3 million juvenile salmonids were PIT-tagged and released into the Snake and Columbia River Basins for migration in 2009 (PSMFC 2009). These fish were monitored during downstream migration at dams equipped with PIT-tag monitoring systems (Prentice et al. 1990a,b,c). These systems automatically upload detection information to PTAGIS (Columbia Basin PIT Tag Information System), a regional database used to store and disseminate information on PIT-tagged fish (PSMFC 2009). We uploaded our detection records to PTAGIS and downloaded information on fish detected with the trawl system. Data in PTAGIS includes release and detection time and location, species, origin (wild or hatchery), and migration history of individual PIT-tagged fish.

We also continued analyses of data from juvenile Chinook salmon *O. tshawytscha* and steelhead *O. mykiss* that either migrated downstream through the hydropower system or were transported and released below Bonneville Dam. In 2009, 178,591 PIT-tagged fish were transported from juvenile fish facilities at Lower Granite, Little Goose, Lower Monumental, or McNary Dam. The goal of our trawling effort in the estuary was to monitor timing and survival of PIT-tagged fish that migrated in the river through the hydropower system. We also evaluated timing and relative survival in the estuary of fish transported and released below Bonneville. Seasonal trends in these data may provide insight into the variation observed in smolt-to-adult return (SAR) ratios of NMFS transportation study fish, which has been shown to be related to timing of the juvenile migration (Marsh et al. 2008, 2010).

The pattern of seasonal variation in relation to SARs is not consistent, and its cause is not known. However, large colonies of avian predators in the lower estuary are known to have a significant impact on juvenile salmonid populations (Collis et al. 2001; Ryan et al. 2001, 2003; Sebring et al. 2009). Differences in estuary detection rates between transported and inriver migrants may help separate the freshwater and ocean components of mortality related to seasonal variation in SARs.

In addition to sampling with the pair trawl, we also continued intermittent sampling with a fixed-station shoreline-based PIT-tag detection system and initiated development and testing of a mobile separation-by-code (MSbyC) system. The shoreline system was developed to sample areas of the estuary that are inaccessible to the large matrix trawl system. However, no fish were detected with the shoreline system in 2009, and no further work is planned for development of this system at present.

The prototype MSbyC system was designed to be used either with the existing matrix antenna or as an independent sampling system. Separation-by-code technology has been utilized in the juvenile fish passage facilities of Columbia and Snake River dams since the early 1990s (Marsh et al. 1999). At the dams, researchers use SbyC to divert fish for physical or physiological examination, additional tagging or treatment, or transportation. Like other SbyC systems, the mobile SbyC may be programmed to divert an individual PIT-tagged fish, groups of PIT-tagged fish, or all PIT-tagged fish for a given period.

MATRIX ANTENNA TRAWL SYSTEM

Methods

Study Area

Trawling was conducted between rkm 83, near Eagle Cliff, and rkm 61, near the west end of Puget Island (Figure 1) in the upper Columbia River estuary. This is a freshwater reach characterized by frequent ship traffic, occasional severe weather, and river currents often exceeding 1.1 m s^{-1}. Tides in this area are semi-diurnal, with about 7 h of ebb and 4.5 h of flood. During the spring freshet (April-June), little or no flow reversal occurs in this reach during flood tides, particularly in 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.

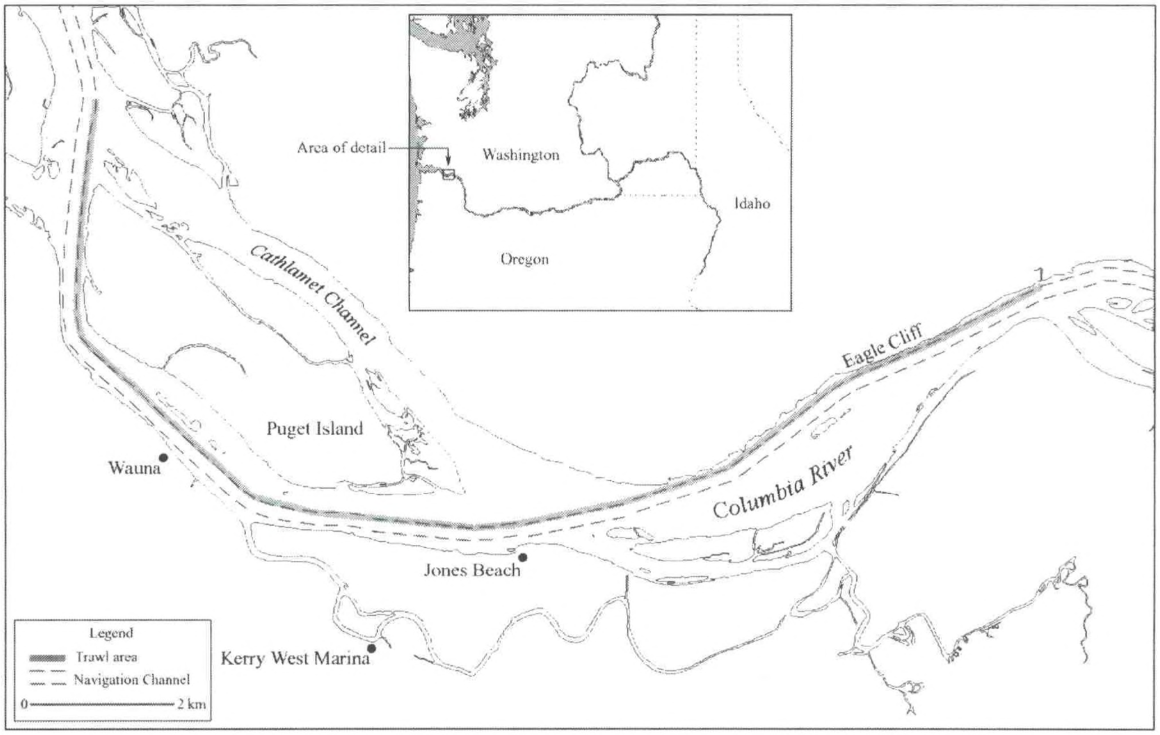


Figure 1. Trawling area adjacent to the ship navigation channel in the upper Columbia River estuary between rkm 61 and 83.

Study Fish

We continued to focus detection efforts on large release-groups of PIT-tagged fish, and in particular, inriver migrants detected passing Bonneville Dam and transported fish released just downstream from Bonneville Dam. The vast majority of these fish enter the upper estuary from late April through late July. Included were approximately 770,000 PIT-tagged fish released for a transportation study on the Snake River (PTAGIS; PSMFC 2009) and nearly 196,000 PIT-tagged fish released for a comparative hatchery-fish survival study (PSMFC 2009). Of the PIT-tagged fish released in the Columbia River basin for migration in 2009, nearly 179,000 were diverted from the hydropower system to transport barges and trucks and released downstream from Bonneville Dam. We also detected PIT-tagged fish from other studies. Double-tagged fish implanted with both a PIT and radio tag or PIT and acoustic tag were also detected (352 total), but were excluded from most of our analyses due to possible bias introduced by the larger radio and acoustic tags, which were both implanted surgically.

We coordinated trawl system operations with expected passage timing of fish tagged for the NMFS transportation study. These were large release groups of fish with known release locations and dates. After tagging at Lower Granite Dam (rkm 695), transportation study fish were either released to the tailrace to continue migration in the river or diverted to transport barges. Dams with transport facilities included Lower Granite, Little Goose (rkm 635), Lower Monumental (rkm 589), and McNary Dam (rkm 470).

Our transportation analysis included all PIT-tagged fish diverted to barges, including those diverted at Lower Granite Dam. To track PIT-tagged fish recorded in PTAGIS as having been diverted, or possibly diverted, to transportation at any of the four transport dams, we created a separate database (Microsoft Access). At the transport dams, PIT-tagged fish were diverted using separation-by-code (SbyC) systems (Stein et al. 2004). Diversion to a transport barge was verified for PIT-tagged fish whose last detection at a dam was on the route ending at a transport raceway or barge, according to monitor locations on the PTAGIS site map. Some fish had tag codes that indicated diversion for transport, but there was no detection record to confirm barge loading. These records were flagged and removed from our database, as were fish removed for biological or other samples.

Since 1987, we have collected records in our local database of over 2.8 million PIT-tagged fish that were transported. The USACE (Scott Dunmire, personal communication) provided individual barge-loading dates and times at each dam through the season. By comparing this loading information with the last detection date/time of diverted PIT-tagged fish, we were able to assign each fish to the next available transport barge. Thus, we obtained specific dates, times, and locations of release for individual transported PIT-tagged fish. Subsequent detections of transported fish in the trawl were compared to those of fish detected passing Bonneville Dam on the same dates for evaluations of relative travel speed, migration timing, and survival to the estuary.

In addition to the Snake River transportation study, several other studies in the Columbia River Basin 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, subyearling fall Chinook salmon, and steelhead; however, detections of PIT-tagged coho salmon *O. kisutch*, sockeye salmon *O. nerka*, and Coastal Cutthroat trout *O. clarki clarki*, were also recorded.

Sample Period

Spring and summer sampling with the matrix antenna trawl system began on 6 March and continued through 12 August 2009. Because sample effort varied according to fish availability, not all days were sampled equally. At the beginning and end of the migration season, we sampled with a single shift, 2-5 d/week for about 5 h d^{-1}. From 1 May through 13 June, we increased to two daily sampling shifts (day and night shift) for an average of 15 h d^{-1}. Generally, day shift began before daylight and sampled for 6-10 h, and night shift began in late afternoon and sampled until well after dark or until relieved by the day crew. Sampling was intended to be nearly continuous throughout the two-shift period except between 1400 and 1900, when we interrupted sampling for fueling and maintenance.

We estimate that our two-shift sampling period coincided with arrival in the estuary of 79% of all PIT-tagged inriver migrant releases and 88% of all PIT-tagged and transported fish (compared to 60 and 81% in 2008). Many fish detected at Bonneville Dam outside our two-shift sample period were early season subyearling Chinook salmon tagged and released at Bonneville Dam for a passage study (22,000). The majority of these fish were recaptured at the juvenile fish facility for biological studies. In addition, late in the season, there were releases of subyearling Chinook salmon from three hatcheries (11,600 fish total), and these releases migrated through the sample area after the two-shift sample period.

Extreme weather events have typically forced the cancellation of four to six shifts during the two-shift sample period each year. In 2009, conditions were moderate, and only one shift was missed due to high winds and poor river conditions. Columbia River flow rates for 2009 began below the 10-year average, but rose substantially by 18 May and remained above the 10-year average for the remainder of the season (Figure 2). After one shift was cancelled early in the season, sampling continued without interruption until the two-shift period ended on 13 June.

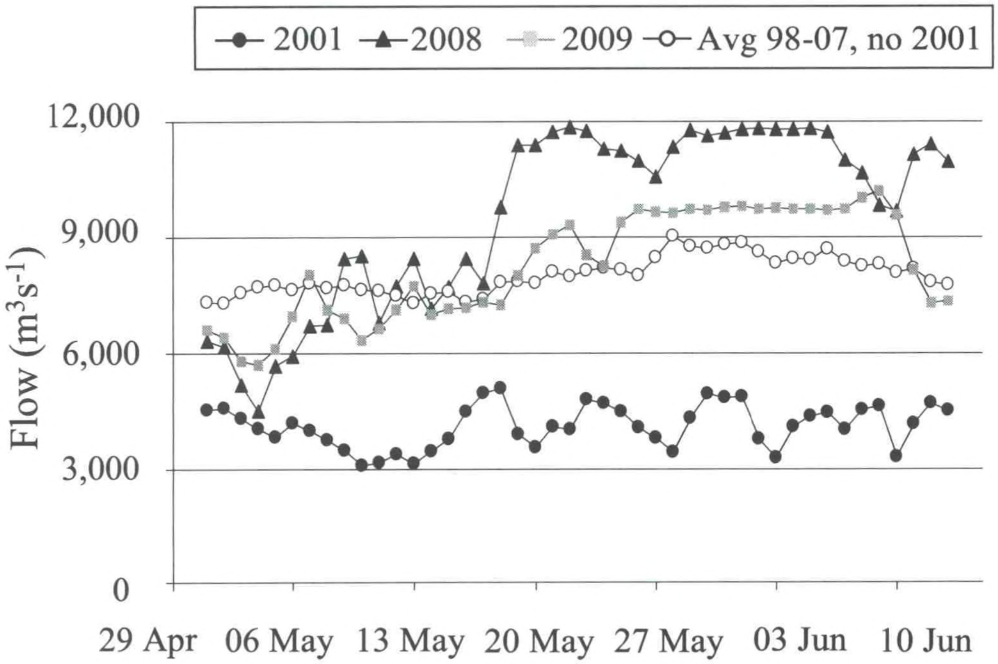


Figure 2. Columbia River flows at Bonneville Dam during the two-shift sample periods 2008 and 2009, as compared to the average flow from 1998 to 2007 (excluding 2001). Drought-year flows for 2001 are also shown for comparison.

Trawl System Design

In 2009, sampling was conducted exclusively with the matrix antenna system (Figure 3). The matrix antenna had a fish passage opening about 12 times larger than that of the cylindrical antenna systems used in previous years. It was configured with three parallel coils in front and three in the rear, for a total of six detection coils. Inside dimensions of individual coils measured 0.75 × 2.8 m. Front and rear components were separated by a 1.5-m length of net mesh, and the overall fish-passage opening was 2.6 by 3.0 m. The top of the matrix antenna was suspended by buoys 0.6 m beneath the surface, and the system was attached in place of the cod end of the trawl. Each 3-coil 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 (total weight of both components was 456 kg in air).

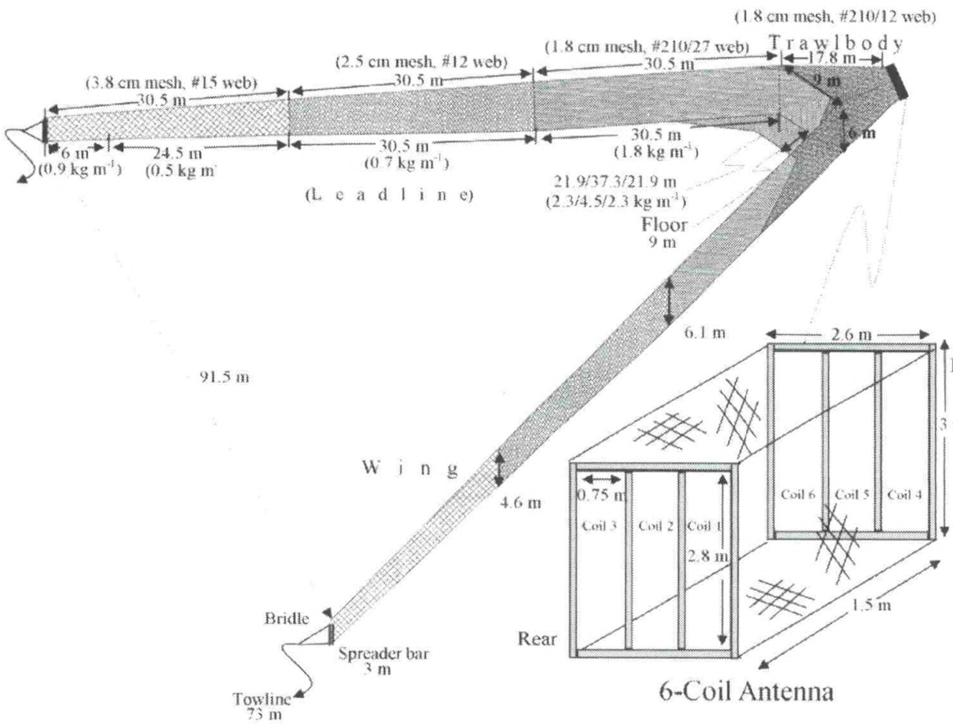


Figure 3. Basic design of the surface pair trawl used with the matrix antenna system to sample juvenile salmonids in the Columbia River estuary (rkm 75), 2009.

The basic configuration of the pair-trawl net has changed little through the years, despite changes to the detection apparatus (Ledgerwood et al. 2004; Figure 3). As in previous years, 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, which was modified for antenna attachment. The mouth of the trawl body opened between the wings and from the surface to a depth of 6 m with a floor extending 9 m forward from the mouth. Sample depth was about 4.6 m due to curvature in the side-walls under tow.

We towed the net with two 73-m-long tow lines to prevent turbulence on the net from the two tow vessels. During a typical deployment, the net was towed upstream facing into the current, with a distance of about 91.5 m between the trawl wings. Even though volitional passage through the antenna occurred while towing with the wings extended, we continued to bring the wings of the trawl together every 17 minutes to help clear debris. We detected a majority of fish during these 7-minute net-flushing periods.

Electronic Equipment and Operation

We used essentially the same electronic components and procedures as in 2001-2008, with the exception of the transceiver and software employed. We continued to use a single Digital Angel model FS1001M transceiver, which was capable of simultaneously monitoring and transmitting data from up to six antenna detection coils. Electronic components for the trawl system were contained in a water-tight box (0.8 × 0.5 × 0.3 m) mounted on a 2.4- by 1.5-m pontoon raft tethered behind the antenna. Data were transmitted from each antenna coil to specific transceiver ports via armored antenna cables. Each system used a DC power source for both the transceivers and the underwater antenna. Data were then wirelessly transmitted and recorded to a computer onboard a tow vessel.

Once the antenna was operating, the computer software program MiniMon, automatically recorded date, time, tag code, coil identification number, and GPS location. For each sampling cruise, written logs were maintained noting the time and duration of net deployment, net retrieval, approximate location, and any incidence of impinged fish. 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 2009). Pair-trawl detections in the PTAGIS database were identified with site code “TWX” (Estuary Towed Array-experimental).

Records of PIT-tagged fish detected at Bonneville Dam were downloaded from PTAGIS for comparison with our detections (PSMFC 2009). In addition, the USACE provided locations, dates, and times of loading and release for each transport barge. An independent database (Microsoft Access) of detection information was also maintained to facilitate data management and analysis. We modified the PTAGIS release information within our database to reflect the date, time, and location of release from transport barges.

Detection Efficiency Tests

As in previous years, we used a test tape to evaluate electronic performance of both the matrix and shoreline detection systems (Ledgerwood et al. 2005). For tape tests during deployment, a 2.5-cm diameter PVC pipe was positioned through the center of both the front and rear component of the matrix antenna. The pipe extended beyond the reading range of the electronic fields (at least 0.5 m) of both the front and rear antenna components. We evaluated detection efficiency by attempting to detect test PIT-tags attached at known intervals and orientations to a vinyl-coated tape measure, which was passed through the pipe (Figure 4). In 2009, we developed an additional procedure to evaluate the matrix antenna in a dry environment. Dry tests were conducted in an enclosed facility and were similar to in-water tests, except that pulleys mounted to the ceiling were used to guide the test tape through the antenna components, which were positioned horizontally (PVC pipe was not needed).

In 2009, SST tags were the primary PIT tags used throughout the basin (94% of all tags released) but ST tags were still used occasionally (5% of all tags released). Therefore, we constructed two test tapes, one with SST and one with ST tags, in order to test detection efficiency of both tag types. Tapes with both tag models had identical tag-spacing intervals and orientations (Appendix Tables 1-2).

We designed a new test tape to better understand the impact of tag collisions (signal cancelation due to more than one tag energized within the detection field) and to optimize antenna performance. The new test tape was composed of 6 individual groups of 9 tags. Spacing and orientation of tags were the same within each group, but differed between groups. Individual groups included two different orientations (0 and 45 degrees to the detection field) of tags spaced 30, 60, and 90 cm apart. Both the first and last tag in each group was omitted from analysis because the spacing of the tag before and after was not equal. We expected results from efficiency tests to be positively correlated with improved alignment, orientation, and proximity to the electronic field. Thus, the tape tests provided conservative estimates of efficiency. The angles and orientations used on the tape did not reflect those of actual PIT-tagged fish, which generally do not pass through the center of the coils but closer to the sides where detection efficiency is much higher.

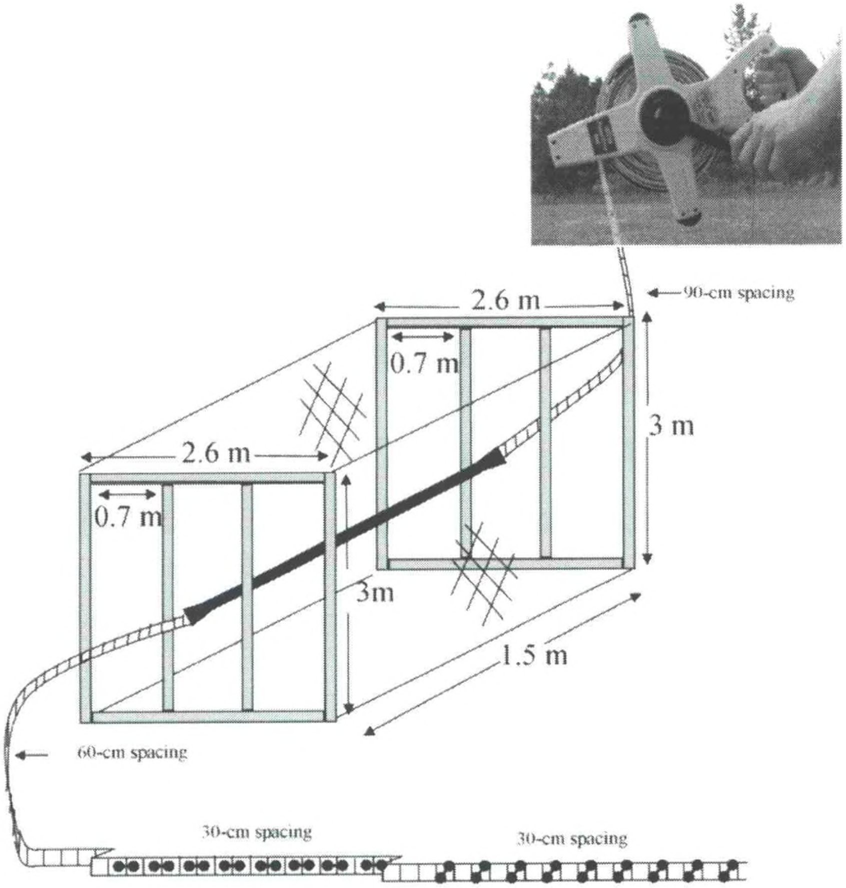


Figure 4. Funnel testing system depicting test tags on a vinyl tape measure, threaded through a PVC pipe in the center of the inner matrix antenna coils. PIT tags were oriented at 0 and 45 degrees to the direction of travel and spaced at intervals of 30, 60, and 90 cm.

We chose densities and orientations along the tape such that not all tags would be detected, partly because the relative consistency of tape detections helped validate electronic tuning and identified possible problems with the electronics. During tests, we suspended the antenna, either underwater or in air, and pulled the test tape back and forth several times. The start time of each pass was recorded, and we used standard PIT-tag software to record detections. Efficiency was calculated as the total number of individual (unique) tags decoded during each pass divided by the total number of tags passed through the antenna. The matrix detection system was evaluated for electronic performance at the beginning of the season, but due to the time and difficulty setting up for in-water tests, we generally relied on status reports generated by the MiniMon software to evaluate performance and tuning.

Impacts on Fish

To monitor injury to fish from debris, we used visual observation and periodic deployment of underwater video cameras to inspect debris accumulation near the antenna and in the cod end of the net. Other sections of the net were monitored visually from a small skiff, and accumulated debris was removed from all net sections as necessary. During retrieval of the net, the matrix antenna remained attached to the pair trawl (rather than being removed, as the cylindrical antenna had been in previous years), and was hoisted directly onto a tow vessel. This retrieval method could potentially allow significant accumulations of debris to remain in the trawl body. However, the larger fish-passage opening of the matrix antenna allowed most debris to pass out of the system, resulting in an overall reduction of debris accumulation when compared to the cylindrical antenna used in previous years. However, because the trawl was no longer inverted for retrieval, when debris accumulated it had to be removed by hand through zippers in the top of the trawl body or after retrieval. During all debris-removal activities, we recorded impinged or trapped fish as mortalities in operation logbooks.

Results and Discussion

Detection Totals and Species Composition

In 2009, we detected more juvenile PIT-tagged salmonids than in any previous year. This increase resulted primarily from development and implementation of the larger, more effective matrix antenna trawl system. The larger fish-passage opening of this system appeared to reduce fish avoidance of the trawl substantially. Increased detections in 2009 were also attributed to increased sample effort during the height of the spring migration (average 15 h d^{-1} in 2009 vs. 12 h d^{-1} in 2008).

We sampled with the matrix trawl system for 1,097 h during 2009 and detected 23,247 PIT-tagged fish. By comparison, in 2008 we sampled for 976 h and detected 16,560 fish (Figure 5). The higher detection rates in 2009 vs. 2008 (20 vs. 17 fish h^{-1}) occurred despite a similar number of PIT-tagged fish being released each year. Mean flow volumes in the Columbia River were about 13% lower during the two-shift sample period of 2009 (8,266 $m^3\ s^{-1}$) than during the two-shift period of 2008 (9,516 $m^3\ s^{-1}$; Figure 2).

The increased daily sample effort in 2009 was related to a dramatic reduction in debris in the river, which reduced the need to clean debris from the trawl, allowing more unencumbered sampling time. In contrast, during 2008, several full shifts were cancelled due to debris accumulation, and other shifts were shortened for net repairs required as a result of high debris loads. In previous years, with smaller antennas, even moderate debris loads required us to periodically halt sampling so the antenna could be pulled out of the water to remove debris. The larger fish-passage opening on the matrix antenna allowed small debris to pass through, while larger debris was removed through zippers located on the top of the trawl body. Overall, little sampling time was lost due to debris loading during 2009.

Lower flows tend to slow fish migration, which extends their period of availability in the sample area. Over the years, we have observed that sampling during periods of lower flow has proven more effective, even when the size of sampling gear remains the same. Pair-trawl sampling conducted at rkm 75 since 1998 shows a strong correlation between high flows and lower detection rates of PIT-tagged fish previously detected passing Bonneville Dam (a rough measure of sample efficiency).

Overall detections in 2009 totaled 23,022 juvenile salmonids of various species, runs, and rearing types; 4 northern pikeminnow; and 221 fish with no release information (unknown). All of these detections were made using the matrix trawl system near Jones

Beach (Appendix Table 3). Of these detections, 47% were yearling Chinook salmon, 13% were subyearling Chinook salmon, 33% were steelhead, 4% were sockeye, 2% were Coho and the remaining 1% were unknown salmonid species (Table 1). Total detections by origin were 17% wild, 80% hatchery, and 3% unknown origin. Proportions of the total detections by river basin source and migration history are shown in Figure 6 (note: incomplete data records for some fish account for the discrepancy between unknown species, origin and migration history percentages). Annual differences in PIT-tagging strategies, hydrosystem operations, and the number of fish transported contribute to variations in the proportions detected from each source, and proportions seen in 2009 were typical in comparison to recent years.

Table 1. Species composition and origin of PIT-tagged fish detected with the trawl system in the upper Columbia River estuary near rkm 75 in 2009.

	Origin			
Species/run	Hatchery	Wild	Unknown	Total
Spring/summer Chinook salmon	8,876	1,722	245	10,843
Fall Chinook salmon	2,943	32	53	3,028
Coho salmon	493	6	0	499
Steelhead	5,542	1,977	179	7,698
Sockeye	829	82	41	952
Sea-run Cutthroat	0	2	0	2
Northern pikeminnow	0	4	0	4
Unknown	0	0	221	221
Grand total	18,683	3,825	739	23,247

Although antennas for the trawl system have been improved over the years, the matrix antenna used in 2009 was considerably larger than any previous antenna. In 2008 we transitioned from the 0.9-m-diameter cylindrical antenna to the 6-coil (2.6 × 3.0 m) matrix antenna. During this transition year, we deployed both antenna systems simultaneously for 3 consecutive days to evaluate the effectiveness of both. With both systems attached to similar trawls and fished within about 1 km of each other, the matrix system detected 53% more PIT-tagged fish than the cylindrical system. Conducted during daytime hours, when higher proportions of steelhead migrate through the sampling reach, the matrix system detected significantly more steelhead than the smaller antenna system.

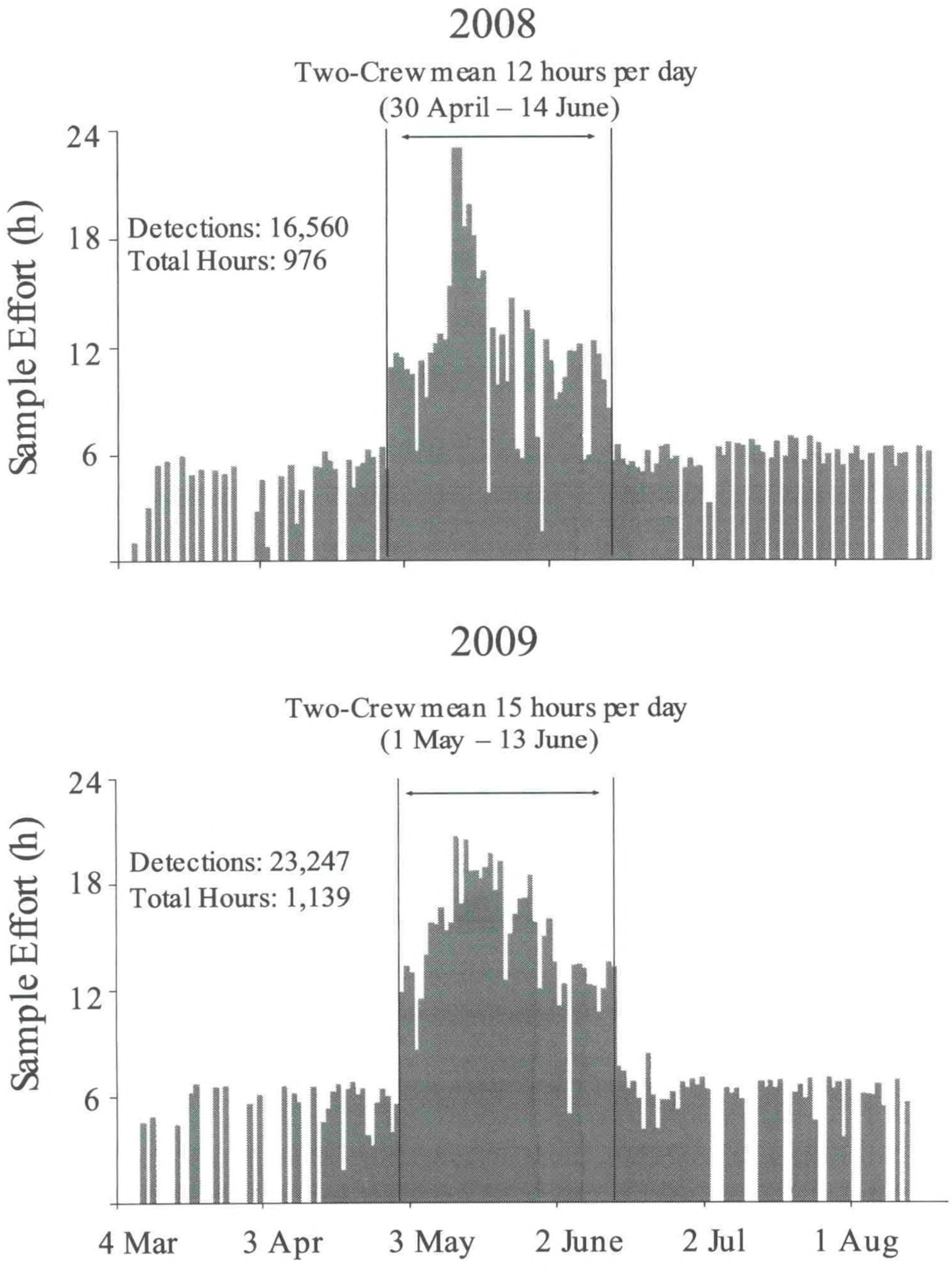
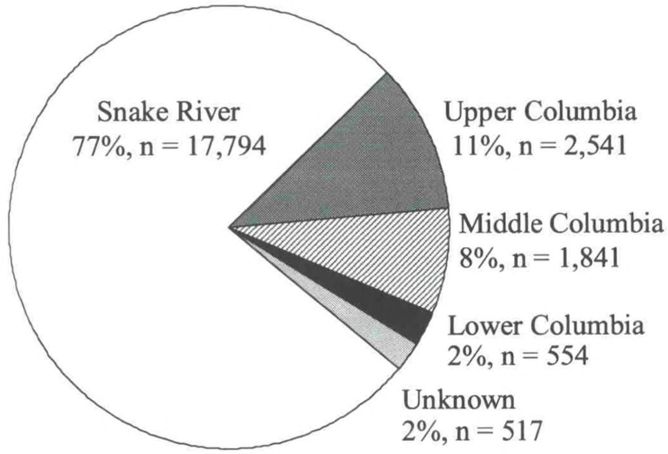


Figure 5. Daily sample effort during the spring and summer using the matrix antenna PIT-tag detection system near river kilometer 75, 2008-2009.

We believe that the sampling effectiveness of the matrix system was especially beneficial during daylight hours, when detections of fish with the cylindrical antenna system were typically lower. In 2009, we detected more fish during daytime hours than at night and we speculate that fish can more readily see and orient to the net during daylight hours (and some eventually escape) but were less encumbered and more likely to approach and pass through the larger opening of the matrix antenna system.

In 2009, we also detected 26 Snake River fall Chinook “reservoir-type” juveniles in the upper estuary, all between 26 April and 18 May (Appendix Table 9). Subyearlings designated with a "reservoir-type" life history begin migration in late spring or summer but overwinter in fresh or estuarine water and resume migration the following spring (Connor et al. 2005). From their records in PTAGIS, we found that 22 of these fish had been released from the Big Canyon Creek acclimation facility on the Clearwater River, 1 fish had been released 37 km downstream from this facility, and 3 had been released into the Snake River between rkm 224 and 303. According to detection histories in PTAGIS, 17 of these 26 reservoir-type juveniles had overwintered between Ice Harbor and Lower Granite Dam, and 4 of these had overwintered upstream from Lower Granite Dam. Of the remaining five fish, four had overwintered upstream from Bonneville Dam and one was never detected after release until our springtime detection in the estuary.



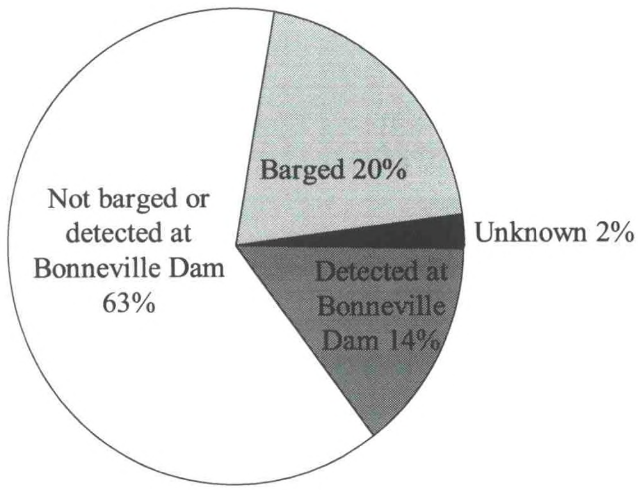


Figure 6. Sources and migration histories of fish detected using the trawl detection system in 2009. Upper and mid-Columbia River sources were defined relative to McNary Dam. Fish originating in the lower Columbia River could not be transported, nor could they pass Bonneville Dam.

Antenna Performance

Detection Efficiency—Test tags oriented perpendicular to the electronic field were detected at nearly equal or higher rates when passed through our antennas than those placed at an angle. Efficiencies were positively correlated with spacing between tags regardless of orientation. According to PTAGIS, about 94% of the PIT-tagged fish released into the basin for migration in 2009 were tagged with SST tags, which have longer read ranges than the older ST tags (PSMFC 2009). About 92% of detections in 2009 were SST tags and the remainder were ST tags. The enlarged fish passage opening of the matrix antenna was designed based on the longer read ranges of SST tags. However, because full transition to the SST tags was not complete in 2009, we tested detection efficiency using both ST and SST tags.

The 6-coil matrix antenna read less than 4% of ST or SST test-tags spaced 30-cm apart (nearest spacing tested) and held perpendicular to the electronic field (Figure 7). When spacing between tags was increased to 60 cm, detection efficiency for respective ST and SST tags was 87 and 86% for perpendicular tags and 62 and 89% for tags at a 45-degree angle to the field. At 90-cm tag spacing, reading efficiency for perpendicular tags increased to 98 and 100% for ST and SST tags, respectively, and for tags passed at 45 degrees, respective read efficiencies increased to 67 and 90%.

Antenna Efficiency—Similar to previous years, pooled read-rates for test tapes (all spaces and orientations) were evaluated *in situ* for the matrix antenna and for individual antenna coils through the season. These results are shown for comparison with antenna efficiency testing results from the 0.9-m-diameter 2-coil cylindrical antenna used initially during 2008 (Table 2). While there was a noticeable drop in total read efficiency going from the smaller cylindrical antenna to the larger matrix antenna for both tag types (67.3 to 53.3% for ST tags and 66.6 to 61.0% for SST tags) there was a gain in volitional fish passage associated with the larger opening of the matrix.

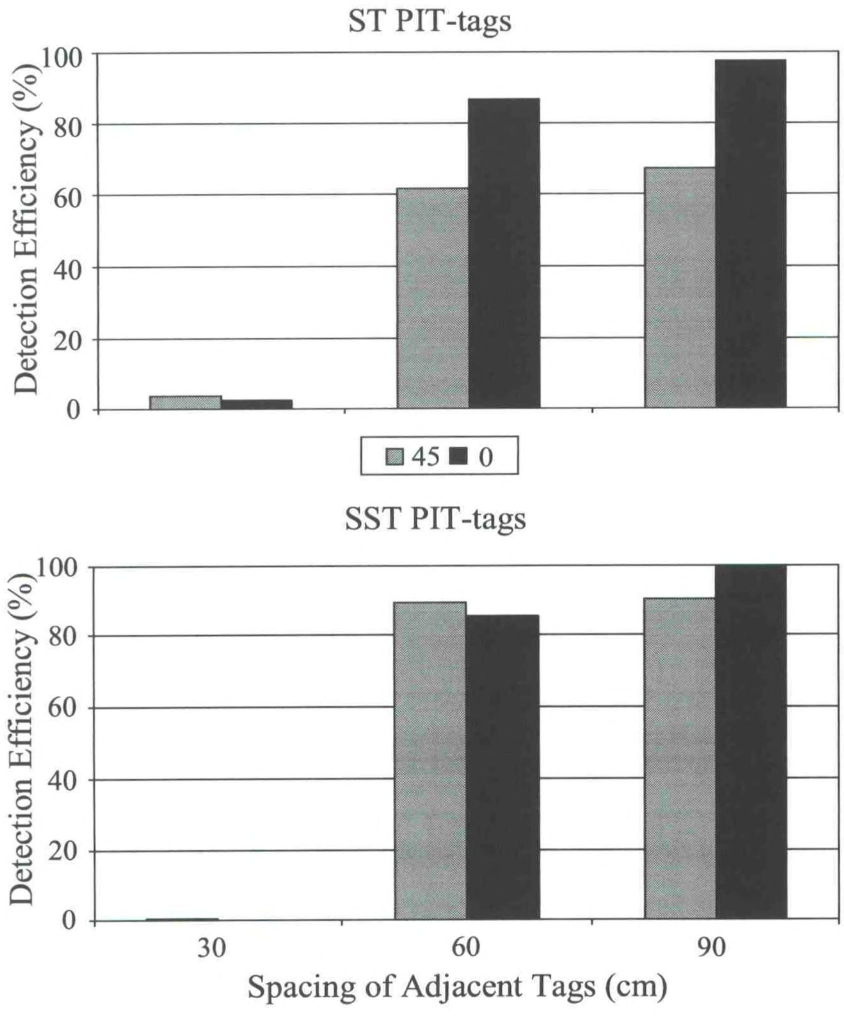


Figure 7. Detection rate/read efficiency of 6-coil matrix antenna determined by targeting 42 PIT-tags, out of an available 54, attached to vinyl tape measures, 2009. Various spacing between tags, orientations, and tag types (ST vs. SST) to the electronic field were used. Tags were passed through the antenna repeatedly on different dates. Results are combined reads of unique codes per pass for all 6 coils (336 tags were available for each spacing, orientation, and tag type).

Table 2. Antenna detection efficiencies for the cylindrical antenna (used in 2008) and the matrix antenna (used in 2009) were determined using the average read rate of 42 target tags at various spacing and orientation as placed on a vinyl tape passed through the center of the antennas (54 total tags on tape).

Antenna (dimensions)	Tag type	Total tags (N)	Overall antenna efficiency (%)
Cylindrical (0.9-m-diameter)	ST	820	67.3
Cylindrical (0.9-m-diameter)	SST	1,176	66.6
Matrix (0.7- × 2.8-m perimeter)	ST	1,008	53.3
Matrix (0.7- × 2.8-m perimeter)	SST	1,008	61.0

We believe that decreased read efficiency was caused by increased tag collisions resulting from the extended read-range of the matrix antenna. Tag collision occurs when two or more tags are present in the detection field simultaneously, and neither is correctly decoded. To reduce tag collisions, we began efforts to reduce the front to back detection field of the rear component of the matrix antenna without compromising field strength.

Various techniques (shielding and electronic current modulation) were tested in the lab. We improved the antenna reads for tags spaced 60 and 90 cm apart and provided an ability to read some tags spaced at 30 cm intervals. Problems with tag collisions are not common at most interrogation sites. Tag collision problems in the estuary were likely due to the periodic high densities of PIT-tagged fish passing through the matrix antennas.

It is important to note that in 2008, trawl detection rates of the matrix system were higher than those of the 0.9-m-diameter cylindrical system (53% more detections) when sampled simultaneously during a period of high fish density (Magie et. al 2010b). We believe these higher detection rates were mostly due to less fish avoidance of the matrix system's larger fish passage tunnel, resulting in an overall more effective PIT-tag detection system. Fish had a more balanced passage through the matrix antenna during net open and flush periods, whereas they tended to be more concentrated during flush periods with the smaller antenna.

As with previous antennas, we also evaluated the matrix antenna performance daily by comparing the total number of fish detected to the number detected on individual coils, all of the front coils, or all of the rear coils (Figure 8). A two-component antenna system provides a second chance to decode tagged fish on a rear component missed by coils on the front component. When the proportion of fish detected on an individual coil was significantly less than other coils, a problem was indicated. Normally more detection records and more unique fish detections occurred on the front component (coils 4, 5, and 6) than on the rear component (coils 1, 2, and 3). Some fish approach the front component close enough to be recorded, and then move forward into the trawl body to approach again and pass later. Some of these fish may escape the trawl forward of the antenna and have no opportunity for detection on the rear coil.

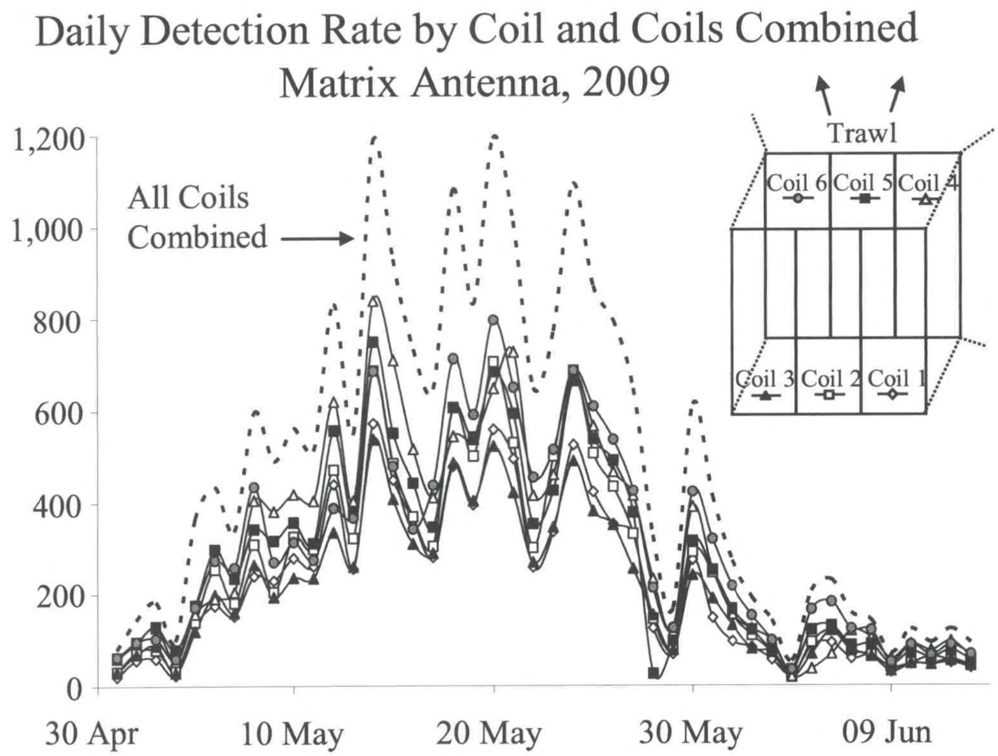


Figure 8. Daily detections of juvenile salmonids by matrix antenna coil during the two-shift sample period, 2009. Coils 1, 2, and 3 formed the rear component (exit) while coils 4, 5, and 6 formed the front component (entrance) attached to the trawl.

Overall, our tag-reading efficiency tests revealed a general inability to decode tags spaced at intervals of 30 cm or closer. This result was likely due to the longer read ranges of both the SST PIT-tags and the larger matrix antenna system, which increased the potential for tag-code collision. To remediate for this, we tested different methods to reduce the field size of the antenna without compromising the ability to detect tags passing completely through the antenna. In short, we attempted to reduce the front-to-rear reading ability of one component without compromising its side-to-side read range. In preliminary laboratory tests, similar to Axel et al. (2005), we found that field strength could be reduced using shielding and clamping techniques. This purposeful reduction in read-range allowed the matrix antenna to consistently read all tags spaced 60 and 90 cm apart and 50-90% of tags spaced 30 cm apart. Without shielding, tags spaced 30 cm apart have never been reliably detected on our test tape, regardless of antenna design or size. We believe that shielding could substantially increase detections of fish moving through the matrix system in high densities. Further testing is required, but these techniques appear promising.

Impacts on Fish

During inspection or retrieval of the trawls, we recovered juvenile salmonids that had been inadvertently impinged, injured, or killed during sampling. In 2009, we recorded 304 such salmonids from the matrix antenna system and trawls (Appendix Table 4). In previous years, divers have inspected the trawl body and wing areas of the net while underway, and they 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, areas where the sample gear is more visible.

Through the years, we have eliminated many visible transition areas between the trawl, wings, and other components. These visible transitions were found mainly in the seams joining sections of different web size or weight. We also now use a uniform color (black) of netting for the trawl body and cod-end areas, which reduced fish training and expedited passage out of the net. Although volitional passage through the antenna occurred with the wings extended, we continued to flush the net (bring the trawl wings together) every 17 minutes to expedite fish passage through the antenna. Flushing also helped to clear debris and may have reduced delay, and possible fatigue, for fish pacing the net transition areas or lingering near the antenna components. A majority of fish detections were recorded during these 7-min net-flushing periods.

At night fish appeared to move more readily through the system, probably because the trawl was less visible during darkness hours. Reduced visibility appeared to reduce the tendency of fish to pace near the net and generally avoid its entrance. In past years with the smaller cylindrical antenna, the majority of fish were detected during the short periods when we closed the wings of the trawl to flush the net. Detections during periods when the net was open were 10% greater with the matrix antenna than with the cylindrical antenna (Magie et al. 2010b). This result also indicated that fish were more willing to approach and exit through the larger opening of the matrix antenna.

ANALYSES FROM TRAWL DETECTION DATA

Diel Detection Patterns

Methods

To determine the hourly diel availability of yearling Chinook salmon and steelhead during the two-shift sampling period, we compiled detection data weighted by origin (hatchery or wild). A pooled value was used for the afternoon period between shifts, when sample effort was minimal. We found no significant difference in diel availability by origin (PTAGIS designation wild or hatchery), so we weighted the detection data by total fish detected within each category and plotted the hourly percentage of total detections by species.

Numbers of yearling Chinook salmon and steelhead detected per hour of daylight and per hour of darkness were evaluated using one-way ANOVA-unstacked (Zar 1999). The number of detections and the minutes within each hour of the day that the detection system was operating were separated into daylight- and darkness-hour categories. Preliminary analyses and mean hourly detection rates for wild and hatchery fish were pooled for each species. Mean hourly detection rates were weighted by the number of minutes within each hour that the detection system was operating. Detection rates between daylight and darkness hours were compared for yearling Chinook salmon and steelhead. There were insufficient detections of other species for meaningful analyses.

Results and Discussion

During the two-shift daily sample period between 1 May and 13 June 2009, we detected 11,482 yearling Chinook salmon and 7,089 steelhead. For both species, we examined hourly detection distributions during each diel period of intensive (two-shift/d) sampling. We then compared these distributions to the average hourly detections obtained during intensive sample periods from 2003 through 2008 (Figure 9). Detections of juvenile sockeye and coho salmon were too few to provide meaningful comparisons. During the two-shift sample period in 2009, we recorded detection data for an average of 15 h d^{-1}, but generally stopped sampling between 1400 and 1900 PDT for crew changes and fueling of vessels (Appendix Table 5).

Hourly detection rates of yearling Chinook salmon were not significantly greater ($\alpha = 0.05$) during nighttime (2100 to 0500) than during daytime hours (19 vs. 13 hatchery fish h^{-1}, $P = 0.09$; 3 vs. 2 wild fish h^{-1}, $P = 0.62$). However, for steelhead hourly detections rates differed significantly between darkness and daylight hours (3 vs. 11 hatchery fish h^{-1}, $P = 0.02$, and 2 vs. 3 wild fish h^{-1}, $P = 0.02$). Since 2003, no significant differences have been found between rearing types in the distribution of annual detections by diel hour. Thus, we pooled hatchery and wild totals for analysis (Figure 9). Detections of Chinook salmon have typically been more numerous during darkness hours, often significantly. In contrast, detections of steelhead have been more numerous during daylight hours, though rarely significantly.

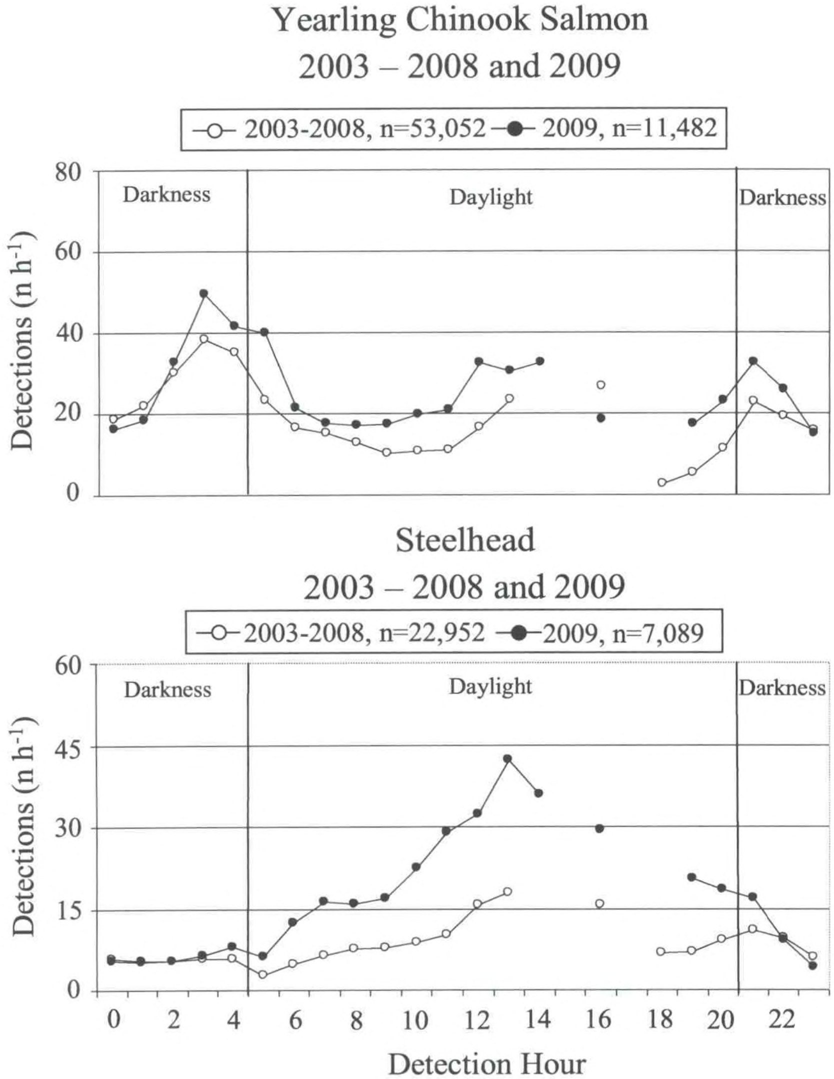


Figure 9. Average hourly detection rates of yearling Chinook salmon and steelhead during the two-shift sampling periods of 2003 through 2008 versus 2009 using the matrix antenna system in the upper estuary near river kilometer 75.

Detection numbers in 2009 were generally higher during darkness for Chinook salmon and significantly higher during daylight for steelhead. Higher detection rates of steelhead in 2009 can be partially attributed to use of the matrix trawl system. The larger fish-passage opening of the system and its location near the surface probably resulted in less avoidance of the gear. Purse-seine sampling in this river reach has indicated peak catches for steelhead in the afternoon hours between 1400 and 1600 (Ledgerwood et al. 1991). Thus, our practice of fueling, crew-change, and maintenance during the late-afternoon periods of high wind probably reduced the overall detection numbers for steelhead. However, recurring periods of difficult weather in late afternoon would probably have interfered with sampling during these hours, even if we had refueled at other times.

Downstream Passage Survival

Methods

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. Detections of Snake River yearling Chinook salmon and steelhead arriving at McNary Dam were pooled weekly, while those of upper Columbia yearling Chinook and steelhead were pooled annually because of sample size.

Results and Discussion

Survival probabilities were estimated from McNary to John Day, John Day to Bonneville, and McNary to Bonneville Dams (Table 3). Weighted annual survival estimates were compared for the years 1999-2009 for both Snake and Columbia River basin stocks (Figure 10). In some years, there were insufficient detections of one species or another for comparison between watersheds. However, we found no trends in survival over time for either basin or species. For Snake River yearling Chinook, survival estimates from the tailrace of McNary Dam to the tailrace of Bonneville Dam salmon was 70.5% in 2009 and ranged from 50.1 (2001) to 84.2% (2006). For Columbia River yearling Chinook, survival estimates ranged from 57.0 (1999) to 84.3% (2009).

Table 3. Weekly average survival from the tailrace of McNary Dam to the tailrace of Bonneville Dam for yearling Chinook salmon and steelhead, 2009. Total fish used in the survival estimates, weighted average survivals, and standard errors (SE) for each species and water basin are presented.

		McNary to John Day Dam		John Day to Bonneville Dam		McNary to Bonneville Dam	
Date	N*	%	SE	%	SE	%	SE
				Snake River yearling Chinook salmon			
20 Apr-26 Apr	1,646	110.5	10.9	61.3	13.9	67.7	13.8
27 Apr-03 May	5,072	86.9	5.2	110.7	18.0	96.2	14.6
04 Apr-10 May	25,980	97.6	5.0	76.6	6.7	74.8	5.3
11 May-17 May	43,488	85.7	3.3	78.8	5.2	67.5	3.6
18 May-24 May	31,900	75.6	3.4	86.9	7.6	65.7	4.9
25 May-31 May	4,189	73.1	10.1	96.4	28.5	70.5	18.5
Wt. Avg.	112,275	86.6	4.2	82.1	4.3	70.5	3.1
				Snake River steelhead			
20 Apr-26 Apr	1,867	104.4	9.5	79.9	25.7	83.4	25.7
27 Apr-03 May	6,077	90.3	5.3	94.7	14.3	85.5	11.9
04 May-10 May	6,371	97.1	5.8	74.3	9.8	72.1	8.5
11 May-17 May	5,187	101.4	7.7	95.6	16.3	96.9	14.8
18 May-24 May	5,387	94.3	8.2	156.8	46.7	147.8	42.1
25 May-31 May	1,282	87.4	19.2	93.1	47.5	81.4	37.5
01 Jun-07 Jun	465	70.7	11.1	54.6	27.5	38.6	18.5
08 Jun-14 Jun	349	86.5	21.0	79.0	51.2	68.4	41.1
Wt. Avg.	26,985	95.1	2.6	90.0	7.9	85.6	7.4
				Mid-Columbia River yearling Chinook salmon			
Pooled Upper Columbia		84.7	3.8	101.2	12.1	85.7	9.8
Pooled Yakima		82	3.4	107.7	13.7	88.3	10.8
				Mid-Columbia River steelhead			
Pooled		79.2	4	88.8	10	70.3	7.7

* N = number of fish from each group detected passing McNary Dam during each week.

For steelhead, survival estimates for Snake River stocks from the tailrace of McNary to the tailrace of Bonneville Dam ranged from 25.0 (2001) to 85.6% (2009). For Columbia River steelhead, survival was estimated at 75.6% in 2009 and ranged from 58.7 (2007) to 87.1% (1999). Complete analyses of these data are reported by Faulkner et al. (2010).

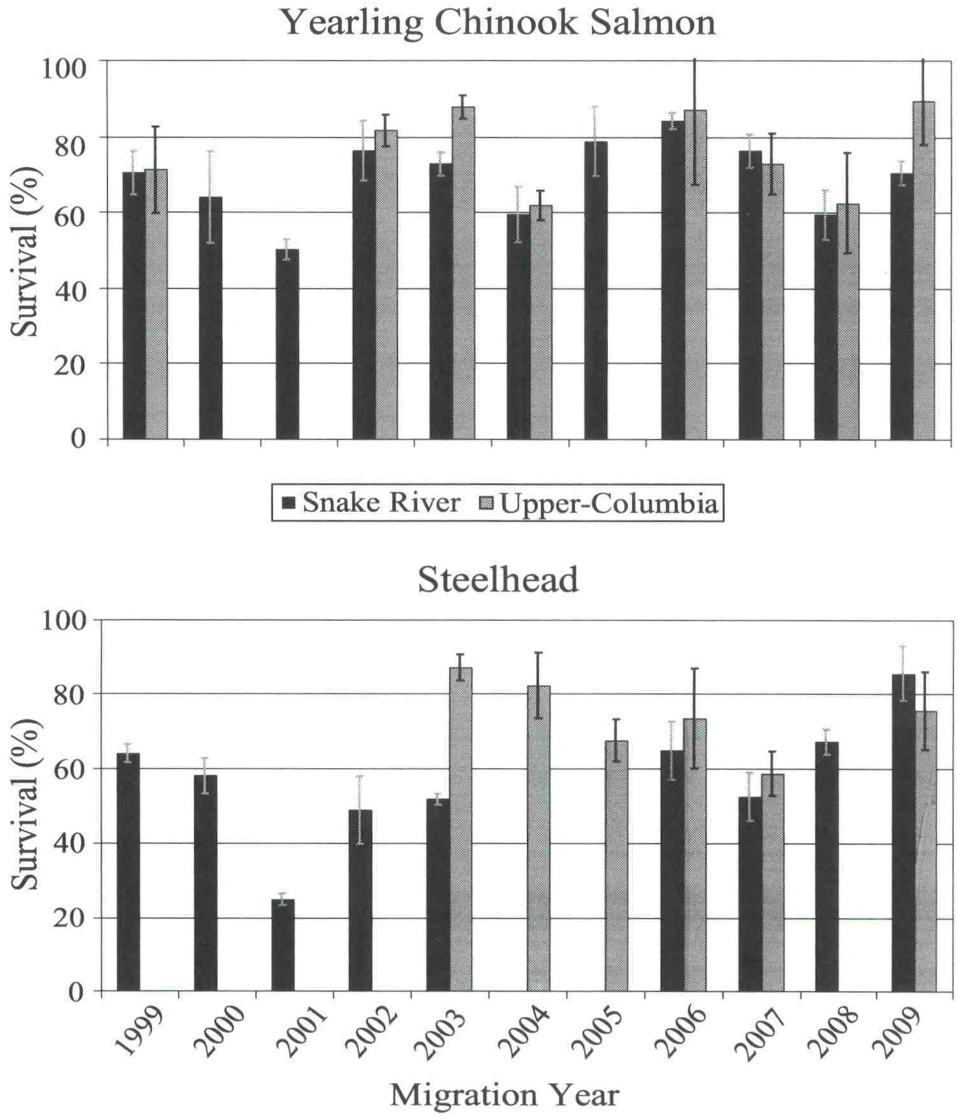


Figure 10. Weighted average annual survival and SE from the tailrace of McNary Dam to the tailrace of Bonneville Dam, for Snake and Columbia River yearling Chinook salmon and Steelhead, 1999-2009.

The annual benefit of transportation is sometimes related to river conditions experienced by fish left to migrate through the hydropower system. In 2008, seasonal average survival of inriver migrant yearling Chinook and steelhead from the tailrace of Lower Granite Dam to the tailrace of Bonneville Dam was 46.5 and 48.0%, respectively. In 2009, the survival estimates were higher for both yearling Chinook salmon and steelhead (55.5 and 67.6%, respectively, Table 4)

Table 4. 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, 1998-2009.

	Survival estimates			
	Yearling Chinook salmon		Steelhead	
Migration year	(%)	SE	(%)	SE
1998	53.8	4.6	50	5.4
1999	55.7	4.6	44	1.8
2000	48.6	9.3	39.3	3.4
2001	27.9	1.6	4.2	0.3
2002	57.8	6	26.2	5
2003	53.2	2.3	30.9	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
2008	46.5	5.2	48	2.7
2009	55.5	2.5	67.6	5.9

* Sample size insufficient to estimate annual survival probability.

We speculate that higher survival years for inriver migrants are associated with increased flow volumes. In 2001 and 2004, two years characterized by extremely low river flows due to regional drought, survival probabilities for yearling Chinook salmon (27.9 and 39.5%, respectively) were much lower than in other years. In 2009, flow volumes were generally lower than average prior to mid-May and higher than average from mid-May to mid-June. Similarly, for Snake River steelhead, survival probabilities through the entire hydropower system below Lower Granite Dam were 67.6 in 2009. Survival estimates for inriver migrant steelhead were exceptionally low in 2001 (4.2%); however, 2001 was a drought year during which most fish were transported. There did not appear to be any one specific reason for the increased survival of steelhead in 2009 other than increased river flows and perhaps general operation of surface bypass structures, which may particularly benefit the surface-oriented steelhead. In 2004 and 2005, steelhead detections at Bonneville Dam were too few to estimate survival probability.

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). Operation of the trawl detection system in the estuary has provided data for survival estimates used in various research and management programs for endangered salmonids (Faulkner et al. 2007, 2008, 2009, 2010). For the past several years, annual releases of PIT-tagged fish in the Columbia River basin have exceeded 2 million. The documented passage of these fish through the estuary has increased our understanding of behavior and timing during the critical freshwater-to-saltwater transition period.

Travel Time of Transported vs. Inriver Migrant Fish

Methods

We plotted travel-time distributions and compared detection rates for two subsets of yearling Chinook salmon and steelhead marked and released at Lower Granite Dam and detected in the estuary. These subsets were inriver migrants detected at Bonneville Dam, and transported fish released just downstream from Bonneville Dam. We prepared similar plots for subyearling Chinook salmon tagged and released to migrate inriver or transported in late June and July. These plots represented the seasonal presence in the estuary of 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 also used to evaluate differences in travel speed to Jones Beach between inriver migrants and transported fish. Daily median travel speeds (km d^{-1}) were calculated based on travel time divided by distance traveled from release to detection in the estuary, and plotted through their respective periods of availability. Flow data (daily average discharge rates at Bonneville Dam (m^3 s^{-1})) were plotted during the same periods for visual comparison.

Results and Discussion

Yearling Chinook Salmon and Steelhead—Median travel times (d) for inriver migrating fish from the tailrace of Lower Granite Dam (rkm 695) to detection in our trawl at rkm 75 are presented for yearling Chinook salmon and steelhead (Table 5). In 2009, median travel times were slower for yearling Chinook salmon (18.7 d) and steelhead (15.4 d), than in 2008 (18.3 and 14.4 d, respectively). Overall, travel times for yearling Chinook salmon and steelhead from Lower Granite Dam in 2009 were similar to previous years since 2000, with the exception of the low-flow drought year of 2001, when median travel times were > 30 d for both species.

Median travel time to the estuary for yearling Chinook salmon detected at Bonneville Dam in 2009 was similar to 2008, whereas for steelhead detected at Bonneville Dam travel times were slightly lower than in 2008 (1.7 vs. 1.7 d; 1.7 vs. 1.6 d, respectively). For fish released from barges just downstream from Bonneville Dam, median travel times to the estuary were the same in 2009 as in 2008 (2.1 d for yearling Chinook salmon; 1.6 d for steelhead).

We also compared the daily median differences in travel speed of fish to the estuary based on migration history (transported vs. inriver) and river flow (Figure 11). Travel speed to the estuary was significantly slower for yearling Chinook salmon released from barges (mean 70 km d^{-1}) than for those detected at Bonneville Dam (traveling inriver) during the same period (mean 94 km d^{-1}; $P = <0.001$). This difference was similar to observations from previous years. Steelhead detected at Bonneville Dam traveled significantly faster to the estuary than steelhead released from barges (means 95 and 88 km d^{-1}, respectively; $P \leq 0.001$) during the same period. Correlations between date of release from a barge or detection at Bonneville Dam, flow, and migration history were present in some comparisons.

Table 5. Median travel time to the upper estuary (rkm 75) in days for yearling Chinook salmon and steelhead that migrated inriver and were detected at Bonneville Dam or were released from barges just downstream from the dam, 2000-2009. Both transported and inriver migrant fish were previously detected or released at Lower Granite Dam. Also shown are mean flow volumes at Bonneville Dam from mid-April through June (approximate spring migration periods).

		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	Flow (m^3 s-1)	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)
2000	7,415	17.4	681	17.1	833	1.7	479	1.7	296	1.9	495	1.6	301
2001	3,877	32.9	680	30.1	44	2.3	792	2.5	59	2.9	1,329	2.3	244
2002	8,071	18.2	538	17.8	93	1.8	1,137	1.7	156	2	1,958	1.6	296
2003	7,120	17	563	16.5	95	1.8	1,721	1.7	567	2.1	2,382	1.7	435
2004	6,663	16.6	867	16.6	153	1.9	672	2	110	2.2	2,997	1.9	333
2005	5,776	17.3	1,183	16.9	278	1.8	81	2	471	2.2	2,910	1.9	400
2006	9,435	14.7	628	12.5	110	1.7	888	1.6	131	2.1	1,315	1.6	170
2007	6,858	15.7	1,196	15.6	117	1.7	1,510	1.7	362	2.2	1,096	1.7	143
2008	8,714	18.3	568	14.4	392	1.7	749	1.6	830	2.1	1,884	1.6	788
2009	7,871	18.7	1,188	15.4	1,321	1.7	1,438	1.7	892	2.1	1,681	1.6	1,325

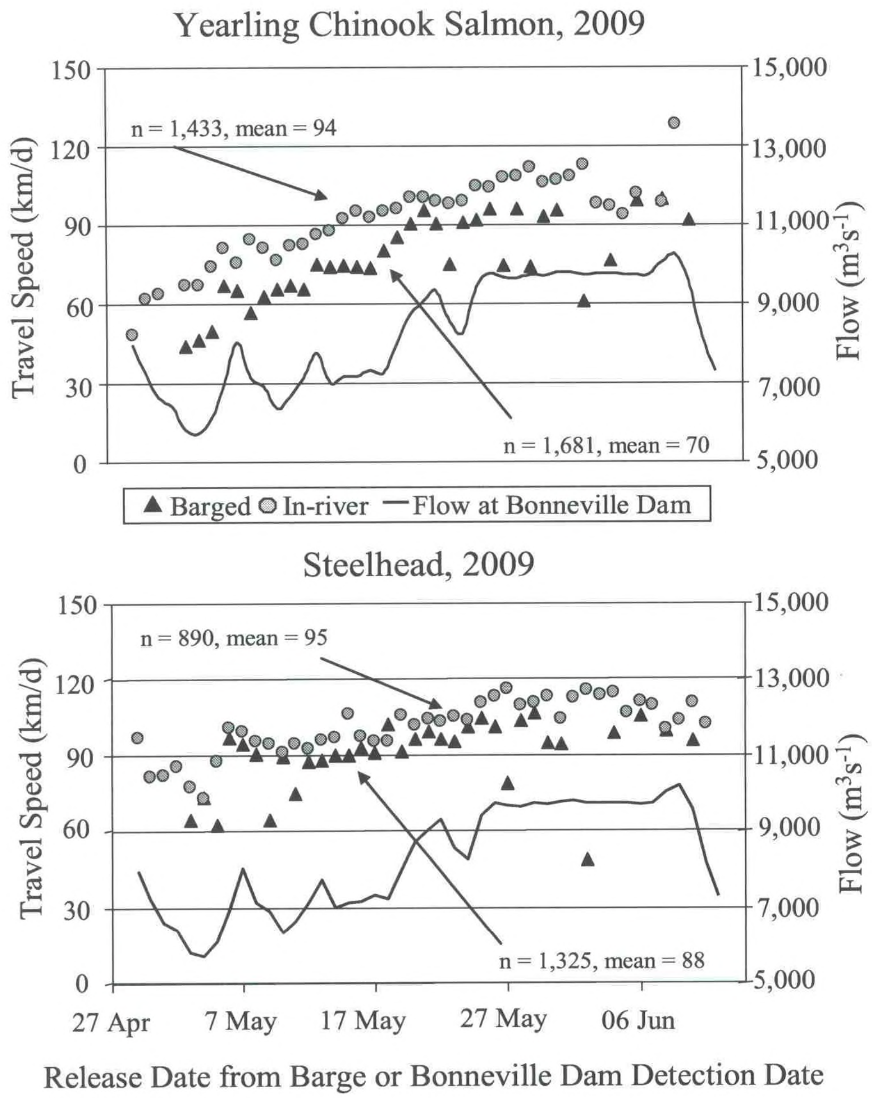


Figure 11. Daily median travel speed to the estuary of yearling Chinook salmon (upper chart) and steelhead (lower chart) following detection at Bonneville Dam or release from a barge to detection in the estuary (rkm 75), 2009.

Subyearling Fall Chinook Salmon—We detected 1,732 subyearling fall Chinook salmon, nearly all of which had been tagged and released after 30 April 2009 and were less than 120 mm fork-length at release. Most fall Chinook salmon released prior to 30 April were yearlings, and had been greater than 120 mm FL when tagged. We detected 429 transported and 1,303 inriver migrant subyearling fall Chinook salmon between May and mid-August (Figure 12). The majority of subyearlings we detected were Snake River fish. Of all subyearling Chinook salmon detected by the trawl system, 82% originated in the Snake River, 11% in the mid-Columbia River (between Bonneville and McNary Dam), 4% in the Upper Columbia River (at or upstream from McNary Dam), and 3% in the lower Columbia River (at or downstream from Bonneville Dam).

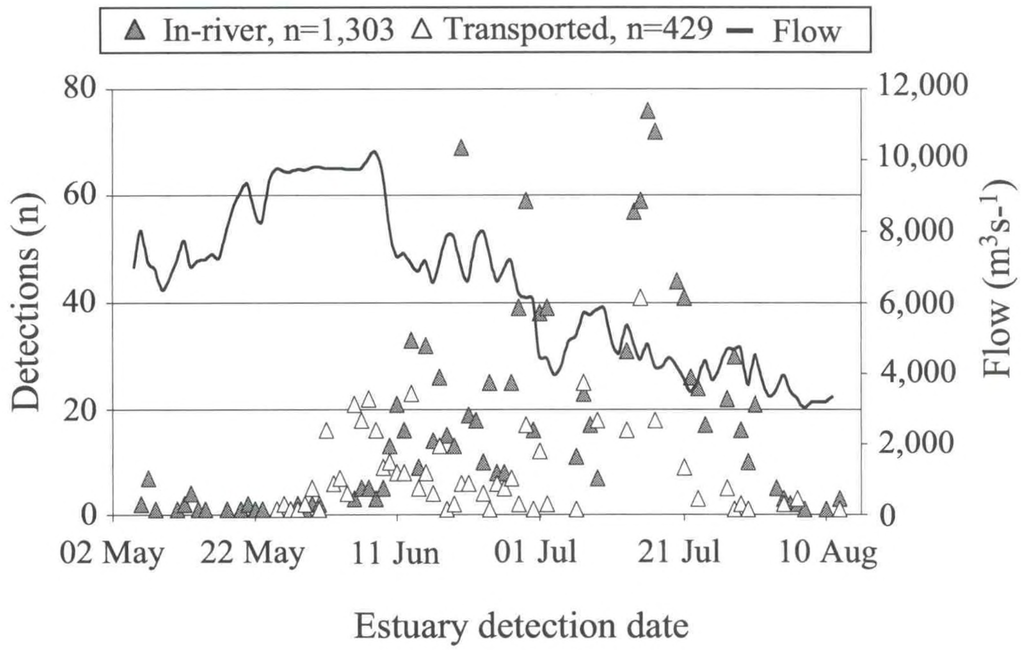


Figure 12. Temporal detection distribution for subyearling Chinook salmon in the estuary following release from barges or for inriver migrants previously detected passing Bonneville Dam, 2009. Daily river flow volume at Bonneville Dam is shown for comparison.

For PIT-tagged subyearling fall Chinook salmon, we compared daily median travel speed to the estuary for inriver migrants (detected at Bonneville Dam) vs. transported fish (released just downstream Bonneville Dam). For both groups, daily median travel speeds decreased with decreasing river flow during 2009 (Figure 13). Travel speed to the estuary was significantly slower for subyearling fall Chinook salmon released from barges (mean 57 km d^{-1}) than for those detected at Bonneville Dam (traveling inriver) during the same period (mean 76 km d^{-1}; P = <0.001).

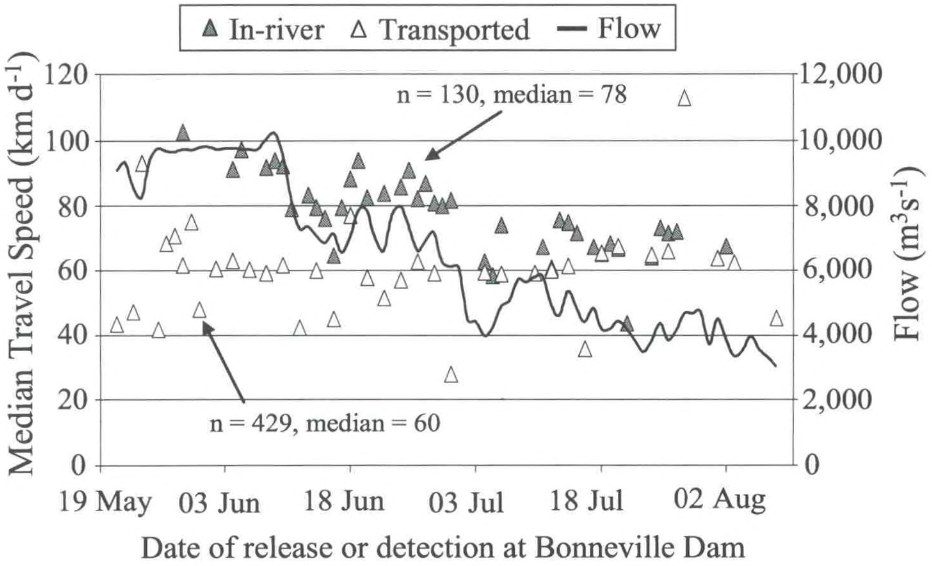


Figure 13. Daily median travel speed to the estuary for transported vs. inriver migrant subyearling Chinook salmon, 2009. Daily river flow volume at Bonneville Dam is shown for comparison.

Travel speed from the area of Bonneville Dam to the estuary for most fish groups was slower in 2009 than in 2008, which can be directly attributed to the lower flow volumes in the estuary. Overall flows in 2009 averaged 8,267m^3 s^{-1} during our 2-shift sample period compared to 9,516 m^3 s^{-1} in 2008 (a 13% decrease). Both daily and seasonal travel speeds of fish are strongly correlated with river flow volume. However, for yearling Chinook salmon, relative daily travel speed to the estuary was significantly slower for transported fish than for inriver migrants detected at Bonneville Dam on the same date. Similar differences were seen in previous years. For steelhead, travel to the estuary was also significantly slower for fish released from barges than for those detected passing Bonneville Dam on the same date. For subyearling fall Chinook salmon detected during the single and 2-shift sampling period, travel speed was also significantly higher for inriver migrant fish compared to those released from barges.

Evaluation of Mixing Assumption

Methods

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 systems 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.

We divided total seasonal detections for each group into interval hours based on time of estuary detection. Diel detection was analyzed only for yearling Chinook salmon and steelhead, since detections of other species were insufficient for analysis. Diel detection curves were based on the average number of fish detected each hour weighted by the number of minutes within each hour that the antenna was energized. Differences in average hourly detection rate between transported and inriver groups were then examined by species. Data from study years 2000 to 2008 were plotted to examine differences between and among years.

Results and Discussion

Average hourly detection distributions for yearling Chinook salmon varied from 0 to 4% (average 2000-2009), and no strong trends were seen for either transported or inriver fish (Figure 14). This finding validated the assumption that transported and inriver fish were mixed during passage through the estuary. Years with extreme values represented intervals of 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 2005, when most inriver fish (-9%) were detected at 14:00 and most barged fish (5%) at 21:00.

For steelhead, average hourly differences in detections varied from 0 to 3% from 2000 to 2009. 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 were mixed with inriver migrants 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 lower percentages present during evening, while 2001 data suggested the opposite. Ranges of difference were the highest in 2000, 2001, and 2006, when sample sizes of steelhead were larger.

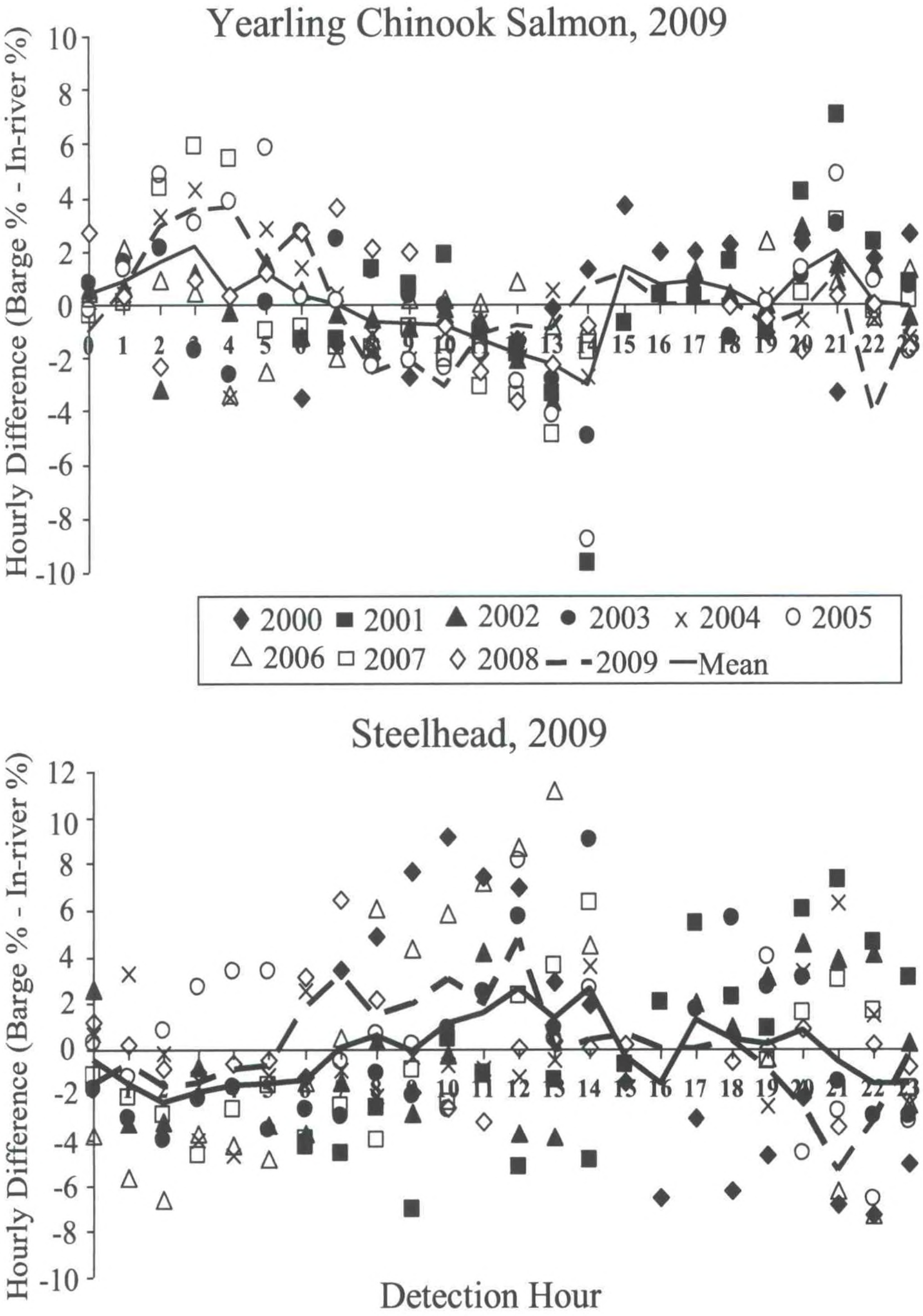


Figure 14. Hourly difference in estuarine detection percentages of barge-release fish compared to those fish previously detected at Bonneville Dam during two-shift sampling periods, 2000-2009. The pooled mean difference is plotted. A mean difference greater than zero indicates that a higher proportion of barged fish were detected during those hours and vice versa.

Detection Rates of Transported vs. Inriver Migrant Fish

Methods

During 2009, the NMFS transportation study PIT-tagged and released 204,102 yearling Chinook salmon, 510,257 subyearling Chinook salmon, and 45,501 steelhead. All of these fish were released upstream from McNary Dam. Including river-run fish diverted to barges and fish tagged and transported for other studies, 72,788 Chinook salmon and 55,874 steelhead were transported and released upstream from our sample site during the intensive, two-shift sample period. We compared detection rates between transported fish and inriver migrants during this period to assess whether differences in detection rates were related to migration history or arrival timing in the estuary.

Estuarine detection rates of PIT-tagged salmonids released from barges were compared to those of fish detected at Bonneville Dam (inriver migrants) using logistic regression (Hosmer and Lemeshow 2000; Ryan et al. 2003). Inriver migrants detected at Bonneville Dam were grouped by day of detection and paired to transported fish released from a barge on the same day. Paired groups included only fish released at or upstream from McNary Dam. Fish released from a barge just after midnight were grouped with fish detected the previous day at Bonneville Dam.

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. 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-shift sampling periods.

Results and Discussion

Of the fish released upstream from McNary Dam for NMFS transportation studies, river-run fish diverted to barges and fish tagged and transported for other studies, we detected 1,950 yearling Chinook salmon and 1,857 steelhead in the upper estuary (Appendix Tables 6-7). Of the Snake and Columbia River fish released upstream from McNary Dam that completed migration in the river, we detected 1,436 of the 43,033 yearling Chinook salmon detected at Bonneville Dam and 895 of the 25,257 steelhead detected at Bonneville Dam (Appendix Table 8- also includes those released below McNary Dam).

As in previous years, a small portion of both barged and inriver migrant groups passed through the estuary either before or after the trawl-sampling period in 2009. However, allowing 2 d for fish to reach the sample area, we estimate that 88% of the barged juvenile salmonids and 79% of those detected at Bonneville Dam were at or near rkm 75 during the two-shift sample period (1 May-13 June; Table 6). During that period, we detected 2.7% of the transported Chinook salmon, and 3.3% of the inriver migrant Chinook (detected passing Bonneville Dam). For steelhead, we detected 3.3% of the transported fish and 3.5% of the inriver migrants.

Table 6. Detection rates in the trawl of PIT-tagged fish released from barges or detected passing Bonneville Dam during the intensive sample period, 1 May-13 June 2009. Release totals during this period represent 94% of the annual totals and were selected allowing 2 days for fish to travel to the sample area.

	Barged			[b]Inriver		
	[a]Released	Detected	%	[a]Released	Detected	%
Chinook salmon	72,788	1,950	2.68	43,033	1,436	3.34
Steelhead	55,874	1,857	3.32	25,257	895	3.54

[a] Fish originating from sources above McNary Dam.
[b] Fish passing Bonneville Dam and detected in juvenile bypass system or corner collector bypass.

For yearling Chinook salmon, regression analysis showed significant interaction between date of barge-release or detection at Bonneville Dam, date-squared, and migration history (all P <0.001; Figure 15, upper panel). There was no significant interaction between date or date-squared and migration history (P = 0.282 and P = 0.305, respectively). Estimated detection rates for inriver migrants increased from around 3.0% early in the season to 4.0% by mid-May and then decreased to less than 1.0% by mid-June. Estimated detection rates for transported yearling Chinook salmon were lower early in the season (2.0%), increased to 3.0% by mid-May, and gradually decreased in a similar pattern as observed for inriver migrants from late-May through mid-June. The adjustment for overdispersion was 3.94.

For steelhead, regression analysis showed no significant interaction between date of barge-release or Bonneville Dam detection, date-squared, or migration route (P = 0.479, 0.712, and 0.555, respectively). There was no significant interaction between date or date-squared and migration history (P = 0.180 and 0.393, respectively). Estimated detection rates of both barged and inriver migrant steelhead remained constant throughout the two-shift period at 3.4% (Figure 15, lower panel). The adjustment for overdispersion was 7.28. The trend in 2009, where the daily detection data for steelhead was more variable than for yearling Chinook salmon, was unlike that of 2005-2008.

For yearling Chinook salmon, the ratio of detection rates between transported fish and inriver migrants differed significantly during the migration season. Detection rates were higher for inriver migrants than for transported fish by about 33% during the early season and by about 25% during mid-season. There was no difference in detection rates late in the season. It is possible that the lower detection rates for transported fish represent higher mortality following release from the barges than following detection at Bonneville Dam. For steelhead, there were no significant differences in temporal detection rates between transported and inriver migrant fish, and thus no indication of delayed mortality. Detection rates of both transported and inriver migrant steelhead showed no upward or downward trend throughout the sampling period.

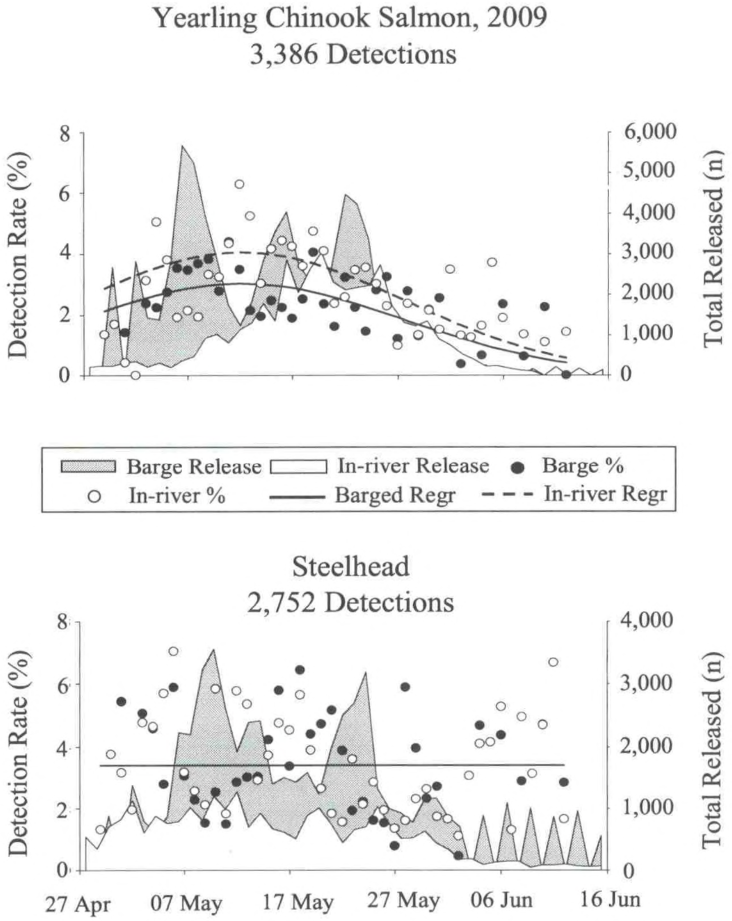


Figure 15. Logistic regression analysis of the daily detection percentage of transported and inriver migrant yearling Chinook salmon and steelhead detected at or released near Bonneville Dam on the same dates, 2009.

Comparison Between Transport Dams

Methods

To compare estuarine detection rates between fish transported from different dams at different locations, we used a logistic regression model (Hosmer and Lemeshow 2000). Due to data constraints, we compared fish transported from Lower Granite Dam (upstream dam) to those transported from Little Goose and Lower Monumental Dams combined (downstream dams). Date and date-squared were also considered in the model. 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 the *i* daily cohorts (i.e., $\ln[p_i/(1-p_i)]$) as a linear function of components, assuming a binomial distribution for the errors. Daily detection rates were then estimated as:

$$\hat{p}_i = \frac{e^{\hat{\beta}_0 + \hat{\beta}_1 \text{day}_i + \hat{\beta} X_i}}{1 + e^{\hat{\beta}_0 + \hat{\beta}_1 \text{day}_i + \hat{\beta} X_i}}$$

where the ^ notation is an estimated parameter and $\hat{\beta}$ is the coefficient of the component (i.e., $\hat{\beta}_0$ for the intercept, $\hat{\beta}_1$ for day *i*, and $\hat{\beta}$ 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. Second, we determined the amount of overdispersion in the data relative to the binomial distribution assumption (Ramsey and Schafer 1997). Overdispersion was estimated as "σ," the square root of the model deviance statistic divided by the degrees of freedom. If $\sigma > 1.0$, 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. Third, if the interaction terms were not significant (likelihood ration test $\alpha > 0.05$) the terms were removed and a reduced model was fitted. The model was further reduced depending on the significance(s) 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 passed the sample area at similar times. Thus, we assumed these groups were subject to the same sampling biases (sample effort). If these assumptions were correct, then differences in relative detection rates would reflect differences in survival between the two groups.

Results and Discussion

For yearling Chinook salmon, there was no significant interaction between Snake River transport dam and barge release date ($P = 0.551$) or date-squared ($P = 0.382$; Figure 16, upper panel). After a short early season increase, detection rates for fish transported from Lower Granite Dam decreased from 3.8% in early May to 0.6% in mid-June. Detection rates for fish from Little Goose and Lower Monumental Dams combined showed a similar, but significantly lower ($P < 0.001$) detection pattern, where detection rates decreased from 2.7 to 0.5%. The estimated coefficient *P*-values for date and date-squared (0.078 and 0.061, respectively) indicated no trend through time. The adjustment for overdispersion was 3.56.

For steelhead, estuary detection data showed no significant interaction between Snake River transport dam and release date ($P = 0.494$) or date-squared ($P = 0.308$; Figure 16, lower panel). During the two-shift period, when all dams were in transportation mode, detection rates of steelhead from Lower Granite Dam remained constant at 2.7%, and neither date nor date-squared showed significant interaction ($P = 0.425$ and 0.790). Detection rates from Little Goose and Lower Monumental Dams combined showed a similar, but significantly higher ($P = 0.008$) detection rate of 3.7% throughout the two-shift period. The adjustment for overdispersion was 6.48.

Detection rates for yearling Chinook salmon transported from Lower Granite Dam were between 29% (early season) and 17% (late season) higher than those of yearling Chinook transported from downstream dams. In 2008, we observed an opposite pattern for yearling Chinook salmon, with fish transported from Lower Granite Dam having lower overall detection rates than those transported from downstream dams. We know of no explanation for this difference, although it is possible that fish arriving at Lower Granite in 2009 were more fit than those arriving in 2008. There was no significant temporal trend in detection rates of steelhead transported from Lower Granite Dam vs. those transported from downstream dams.

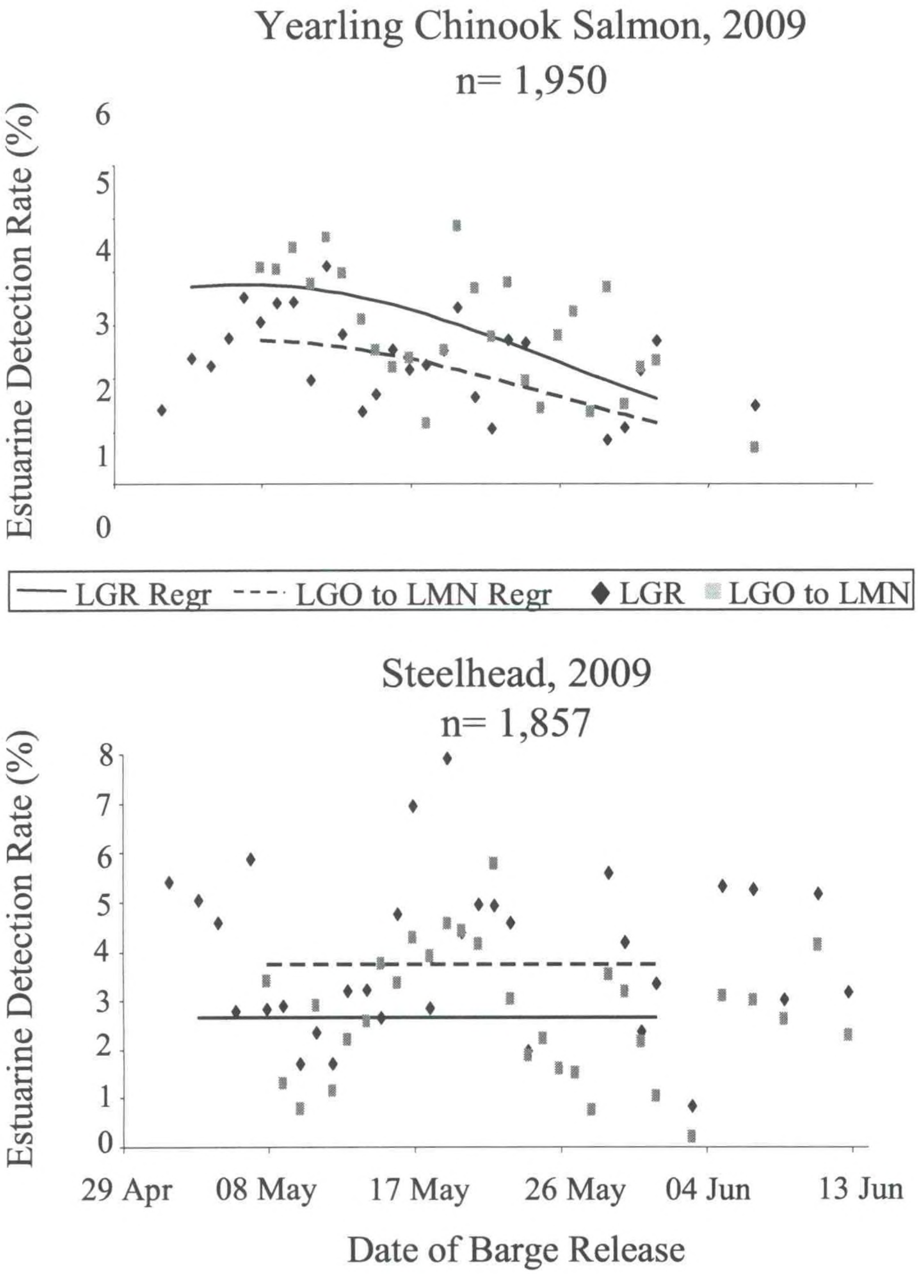


Figure 16. Daily detection rates of yearling Chinook salmon and steelhead released from barges loaded at Lower Granite Dam (LGR) or other downstream dams, Little Goose Dam (LGO), and Lower Monumental Dam (LMN), 2009.

SHORELINE DETECTION SYSTEM

Methods

Configuration of the shoreline PIT-tag detection system was similar to that of the mid-river matrix system, with a single-component matrix detection antenna used in place of the cod-end of a modified trawl. The shoreline trawl net had one 36.1-m-long wing anchored to a truck-mounted winch on shore and one 19.8-m-long wing anchored to a tow vessel via an 18.3-m-long tow line (Figure 17). The trawl body was 5.2 m long with an opening (3.6 m^2 between wings) that tapered to a 2-coil matrix-style antenna with a fish passage opening of 2.6 by 3.0 m. The antenna was oriented 0.6 m below the surface of the water and held in place with buoys. Electronic components were contained in a water-tight box (0.8 × 0.5 × 0.3 m) mounted on a 1.9- by 1.2-m pontoon raft. A DC power source was used for both the transceiver and underwater antenna.

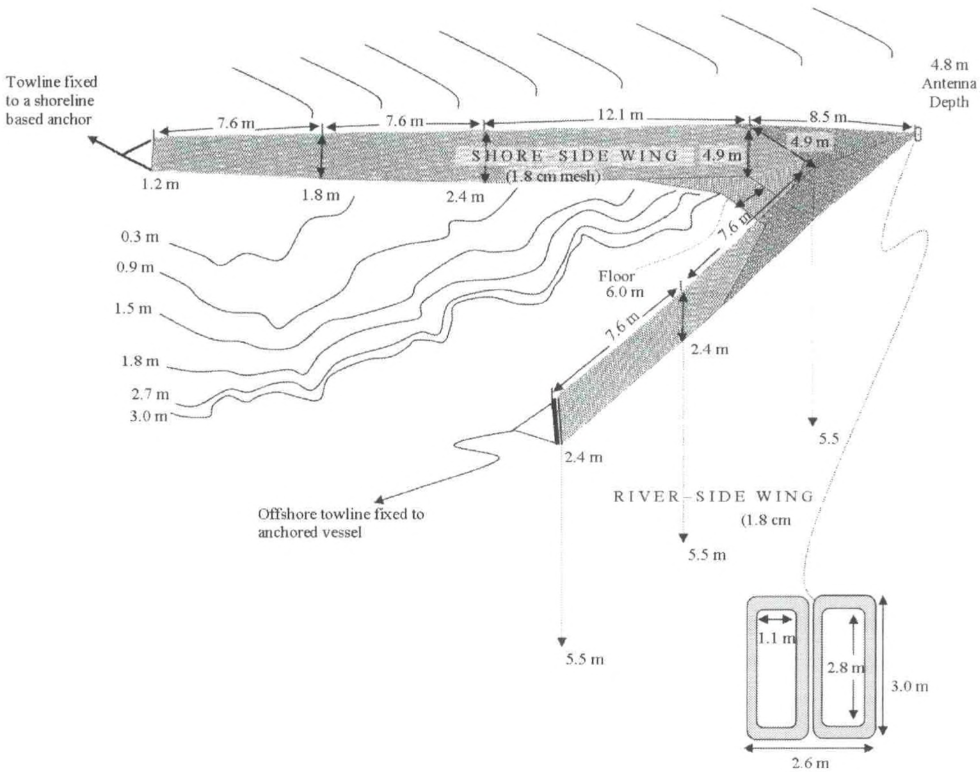


Figure 17. Design of the shoreline PIT-tag detection system used at Jones Beach (rkm 75) parallel to the shipping channel in the Columbia River estuary, 2009.

The shoreline detection system was deployed at a fixed site along Jones Beach (rkm 75) and was operated only during ebb tides. Generally, we deployed the shoreline system near high tide during daylight hours. We used a 12.5-m-long tow vessel equipped with a net reel to deploy and retrieve the net and antenna. Configuration of electronic components for the shoreline antenna system was similar to that described previously for the matrix antenna system, except the pontoon raft towing the electronics was slightly smaller (1.9-m long by 1.2-m wide). Current velocities along the shoreline varied from 0 to about 1.5 knots at maximum ebb tide. Detection efficiency was evaluated using the same tape methods described for the matrix system.

Results and Discussion

Shoreline sampling was conducted in early spring to target subyearling Chinook salmon that had overwintered in fresh water and were perhaps migrating along the shoreline. Sampling with the shoreline system began on 10 March and ended on 27 April. Sampling occurred during daylight, 1-2 d/week (Mon-Fri), and only ebb tides could be sampled. Shoreline areas are thought to provide potential rearing and shelter zones for juvenile fish. The shoreline sampling system was deployed at rkm 75 on nine ebb tides for a total of 42 h. Target fish were juvenile salmonids in the shallow near-shore waters of the estuary inaccessible to the larger mid-river trawl system and particularly for subyearling fall Chinook salmon that had potentially overwintered in the estuary downstream from Bonneville Dam. The mid-river matrix trawl sampling system was also deployed during this period (147 h). There were no shoreline detections during this time and only 134 mid-river detections (Chinook salmon and steelhead). Sampling with the shoreline and matrix systems was halted on 27 April.

Similar sampling had been conducted in the fall of 2008 targeting Snake River fall Chinook salmon. Of particular interest were individuals transported late in the migration season that showed decreased travel speed following barge release. However, shoreline sampling in the fall of 2008 detected only one fish from the Snake River. This fish was detected 4 d after being transported and released from a truck near Bonneville Dam. Shoreline sampling conducted in the spring of 2009 produced no detections. Due to poor detection rates in both fall and spring, no future sampling with the shoreline system is planned. Previous beach-seine sampling at this site (rkm 75) has shown that juvenile salmonids, particularly subyearling Chinook salmon, utilize the shoreline throughout the year (Dawley et al. 1986). We speculate that our lack of detections at this site was due to active avoidance of the net and antenna by fish. The sample gear was highly visible in shallow water, and because it was a passive stationary system, relying on ebb tide and river currents to pass fish, the system was probably easy for fish to avoid.

DEVELOPMENT OF A MOBILE SEPARATION-BY-CODE SYSTEM

Methods

We deployed the MSbyC system on the RV *Electric Barge* since it was no longer required for the trawl system (used with the 0.9-m cylindrical antenna). Conceptually, when used with the trawl system, the MSbyC system would attach directly to the rear component of the matrix antenna with a short netting collar. Thus, migrating fish would be concentrated in the trawl, pass through the matrix antenna, and then be collected in the MSbyC and diverted to a holding tank for examination (Figure 18). The MSbyC vessel could also be used independently with a smaller tow vessel and trawl. MSbyC sampling would be conducted to sample both tagged and untagged fish (similar to purse and beach seines), all PIT-tagged fish, or a specific cohort of PIT-tagged fish.

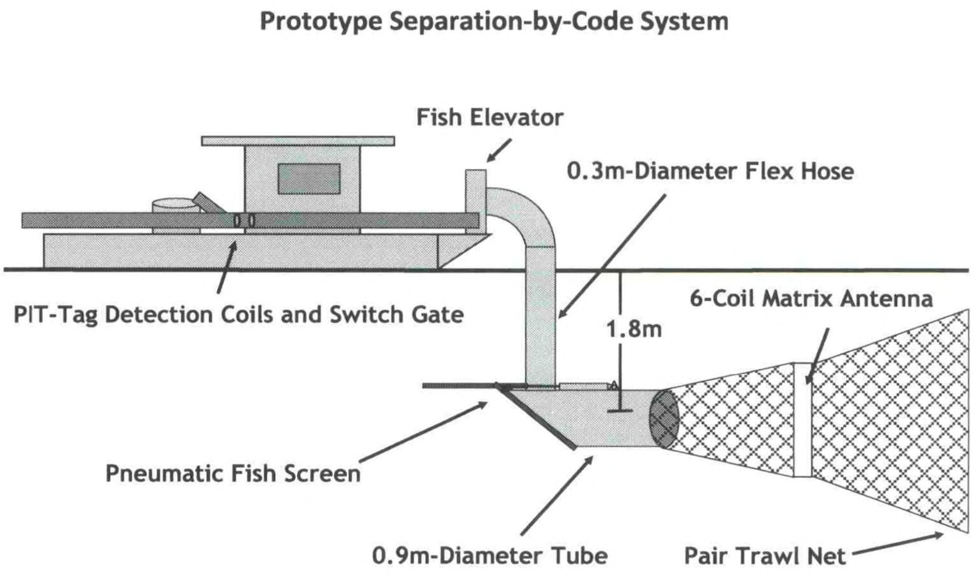


Figure 18. Diagram of the prototype mobile system designed to divert fish by PIT-tag code after passing through the surface trawl and matrix antenna.

A prototype MSbyC system was constructed and tested (independent of a trawl) near Pasco, WA, in fall 2009. The underwater collection chamber of the MSbyC system was netted off to prevent test tags (PIT-tag in a 0.3 m stick) and test fish (tagged and untagged yearling Chinook salmon and steelhead) from escaping. Underwater cameras monitored the collection chamber. Test tags and test fish were pumped from the collection tube through a 25.4-cm-diameter pipe, which passed through PIT-tag detection coils before returning fish to the river or diverting them to a sample tank at the rear of the vessel. Preliminary testing of the prototype showed a flow rate between 2.4 and 3.0 m s^{-1} (similar to that of the SbyC systems at dams). The two detection coils controlled a switch gate to the diversion pipe. An electronic tuning module allowed activation and timing of the gate to divert fish in ratios as desired.

Results and Discussion

The prototype MSbyC system was tested near Pasco, WA, on 7 October and again on 21-22 October. During initial tests, vessel stability, diversion-gate timing, and separation efficiency were evaluated. PIT-tagged surrogates (stick fish, oranges, and small sausages) were sent through the MSbyC system, and after initial diversion-gate timing adjustments were completed, separation efficiency was nearly 100%. With its holding tank filled and plumbing system charged with water, the vessel was maneuverable, appeared stable, and the fish pump and diversion system functioned as designed.

On 21-22 October, live-fish trials were conducted using hatchery juvenile Chinook salmon (n = 150) and steelhead (n = 150) provided by WDFW and Chelan PUD. The objective of these tests was to evaluate impacts to fish as they passed through the MSbyC system. For each trial, both tagged and untagged juvenile Chinook salmon and steelhead were released into the collection chamber. Fish were then either diverted to the sample tank or bypassed back to the river (into a separate recovery tank for these tests). Proportions of fish that arrived at the intended destination were used to measure system effectiveness and separation efficiency (Table 7). Fish were then examined for descaling, fin damage, hemorrhage, and opercula damage. Fish behaviour was monitored using video cameras mounted inside the collection chamber.

For our first test on 21 October, we released 12 fish into the collection chamber, and after 16 minutes, no fish passed through the system. Next we removed a debris screen at the pump intake and increased flow by adjusting pump speed from 2300 to 3100 rpm. As a result, were able to pass 30% of the fish (23 released) through the system, diverting all PIT-tagged fish into the sample tank within 34 minutes. During this

Table 7. Results from live fish tests of the prototype MSbyC system test conducted in Pasco, WA, October 2009. We used both PIT-tagged and non-tagged yearling Chinook salmon and steelhead (obtained from Lyons Ferry Hatchery). As testing progressed, impromptu modifications to the MSbyC system were implemented to improve system effectiveness.

			PIT-tagged		Non-tagged		Test duration	Total	Total not	System passage	PIT-tag diversion
Test condition	Date	Release	Chinook	Steelhead	Chinook	Steelhead	(min)	passed	passed	(%)	(%)
Debris screen, pump 2300 rpm,	21 Oct	1	6	5	1	0	16.0	0	12	0.0	0.0
Pump 3100 rpm	21 Oct	2	6	5	6	6	34.0	7	16	30.4	100.0
Bubbler at top of collection tube, pump 2300 rpm, density test	22 Oct	3	22	22	20	20	112.0	17	67	20.2	88.9
Intake reducer (12-6"), bubbler at bottom of collection tube, pump 2300 rpm	22 Oct	4	10	10	10	10	5.0	32	8	80.0	58.8
Bubbler at bottom of collection tube, pump 2300 rpm	22 Oct	5	2	15	0	0	22.0	11	6	64.7	100.0
Bubbler at bottom of collection tube, pump 2300 rpm	22 Oct	6	14	14	14	14	1.5	51	5	91.1	73.9

test, we observed no negative impacts, other than delay, to fish passing through the system. To improve these results, modifications were suggested, and sampling was halted until the following day.

Prior to a second test on 22 October, the collection chamber was modified to encourage passage and to reduce delay in the chamber. These modifications included painting the interior of the collection chamber black and adding a manually activated air-bubbler to encourage fish to move through the system.

For the first test, we used the air bubbler fixed at the top forward section of the collection chamber to encourage movement toward the back and near the pump intake. We then periodically released fish (84 total) into the collection chamber to evaluate the effect of fish density on passage rate. After 112 minutes, system passage was 20%, with 89% of passing fish bearing PIT-tags successfully diverted to the sample tank. We then moved the bubbler to the rear and bottom of the collection chamber (below the pump intake) and inserted a reducer at the pump intake to increase suction velocity. We then released 40 fish and recovered 32 (80% system passage) within 5 minutes. However, only 59% of fish bearing PIT-tags were diverted to the sample tank.

These tests showed that when passing the system in groups, improper diversion-gate timing reduced effective separation of tagged fish. The intake reducer was removed for the next test and gate timing was adjusted. After 22 minutes, 65% of 17 fish released passed through the system, with 100% of those bearing PIT-tags diverted to the sample tank. During our last test we released 56 fish, and by activating the air-bubbler at key moments, we observed on underwater cameras that all but 5 fish passed through the system within 90 seconds. However, because fish moved through the system in clumps, separation efficiency dropped (74%). These tests concluded with acceptable separation of PIT-tagged fish, diversion into an onboard sample tank, and little negative impacts to sampled fish (1 tagged Chinook bearing an abrasion– most likely from a dip-net). Further improvements will be made to stabilize flow through the system and increase the accuracy of the diversion gate by adjustments in timing.

At present, programmable separation-by-code is possible using older MultiMon software and associated hardware. For our tests, we used MiniMon software, which currently cannot separate on the basis of a tag-code list. However, new M4 interrogation software is under development to provide separation-by-code capability at monitoring sites within the basin. The M4 software will replace MultiMon at dams and wills be used for the MSbyC application when it becomes available.

We installed underwater cameras to monitor behavior in the fish collection chamber and installed a remote-controlled air-bubbler to encourage fish to more readily pass through the system. When the MSbyC system is fully deployed behind the trawls, cameras will be used to monitor fish behavior, adult fish presence, and debris loading. A pneumatically activated rear drop-gate, also monitored by underwater cameras, will allow adults to exit the chamber and will facilitate clearing of accumulated debris. These preliminary tests have been promising, and we will apply for ESA permits for additional testing of the MSbyC system in 2010.

In summary, the development and initial testing of a prototype mobile separation-by-code system in the fall of 2009 was promising. Test fish were moved through the system with little or no impact, and tagged fish were diverted into a sample tank effectively.

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APPENDIX

Data Tables

Appendix Table 1. Configuration of SST PIT-tags on a vinyl-tape measure used to test antenna performance in 2009.

Position on tape measure (ft)	Orientation (°)	Distance from previous tag (ft)[a]	PIT tag code[b]
5	45	0	3D9.1C2CC4AE3F
6	45	1	3D9.1C2CC45A80
7	45	1	3D9.1C2CC42A83
8	45	1	3D9.1C2CC42AAA
9	45	1	3D9.1C2CC8107D
10	45	1	3D9.1C2CC711DF
11	45	1	3D9.1C2CC48B0F
12	45	1	3D9.1C2CC4E48C
13	45	1	3D9.1C2CC47161
21	0	8	3D9.1C2CC43D0C
22	0	1	3D9.1C2CC710F1
23	0	1	3D9.1C2CC4D578
24	0	1	3D9.1C2CC4625D
25	0	1	3D9.1C2CC440E7
26	0	1	3D9.1C2CC46137
27	0	1	3D9.1C2CC7008A
28	0	1	3D9.1C2CC81379
29	0	1	3D9.1C2CC6F306
37	45	8	3D9.1C2CC817E9
39	45	2	3D9.1C2CC4A641
41	45	2	3D9.1C2CC4B83D
43	45	2	3D9.1C2CC4E762
45	45	2	3D9.1C2CC6F1E5
47	45	2	3D9.1C2CC46298
49	45	2	3D9.1C2CC4C92B
51	45	2	3D9.1C2CC4E9E0
53	45	2	3D9.1C2CC43F3B
61	0	8	3D9.1C2CC4D3C5
63	0	2	3D9.1C2CC4CE33
65	0	2	3D9.1C2CC4393C

Appendix Table 1 Continued.

Position on tape measure (ft)	Orientation (°)	Distance from previous tag (ft)[a]	PIT tag code[b]
67	0	2	3D9.1C2CC45743
69	0	2	3D9.1C2CC4DE17
71	0	2	3D9.1C2CC43EB4
73	0	2	3D9.1C2CC713DC
75	0	2	3D9.1C2CC4C630
77	0	2	3D9.1C2CC4EFEB
85	45	8	3D9.1C2CC70808
88	45	3	3D9.1C2CC49929
91	45	3	3D9.1C2CC6F33E
94	45	3	3D9.1C2CC4AF9E
97	45	3	3D9.1C2CC43C37
100	45	3	3D9.1C2CC4634A
103	45	3	3D9.1C2CC44376
106	45	3	3D9.1C2CC4928D
109	45	3	3D9.1C2CC43F3A
117	0	8	3D9.1C2CC4C79D
120	0	3	3D9.1C2CC4B62B
123	0	3	3D9.1C2CC44382
126	0	3	3D9.1C2CC43AA4
129	0	3	3D9.1C2CC43EBE
132	0	3	3D9.1C2CC49BCA
135	0	3	3D9.1C2CC42A98
138	0	3	3D9.1C2CC46225
141	0	3	3D9.1C2CC43DF6

[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. Configuration of ST PIT-tags on a vinyl tape measure used to test antenna performance, 2009.

Position on tape measure (ft)	Orientation (°)	Distance from previous tag (ft)[a]	PIT tag code[b]
110	45	0	3D9.1BF1C45519
111	45	1	3D9.1BF1BFA4DC
112	45	1	3D9.1BF1C3CD41
113	45	1	3D9.1BF1BF9F9A
114	45	1	3D9.1BF1C35015
115	45	1	3D9.1BF1C5CD8F
116	45	1	3D9.1BF1BE0BB5
117	45	1	3D9.1BF1C3B99A
118	45	1	3D9.1BF1C5BF08
126	0	8	3D9.1BF1BCC1B9
127	0	1	3D9.1BF1C365E7
128	0	1	3D9.1BF1C44747
129	0	1	3D9.1BF1C5DF37
130	0	1	3D9.1BF1BE83BB
131	0	1	3D9.1BF1C3B5B6
132	0	1	3D9.1BF1C3B1B2
133	0	1	3D9.1BF1C44EC5
134	0	1	3D9.1BF1C356A3
142	45	8	3D9.1BF1C358EB
144	45	2	3D9.1BF1BE932D
146	45	2	3D9.1BF18087F3
148	45	2	3D9.1BF1BF9414
150	45	2	3D9.1BF24DAA3E
152	45	2	3D9.1BF1C5DD4F
154	45	2	3D9.1BF1BE9337
156	45	2	3D9.1BF176DB47
158	54	2	3D9.1BF1C3528A
166	0	8	3D9.1BF1BE9938
168	0	2	3D9.1BF1BE2774
170	0	2	3D9.1BF1C3B5AF
172	0	2	3D9.1BF1806F11
174	0	2	3D9.1BF1C34B9A
176	0	2	3D9.1BF1BE9980
178	0	2	3D9.1BF1BE83F4

Appendix Table 2 Continued.

Position on tape measure (ft)	Orientation (°)	Distance from previous tag (ft)[a]	PIT tag code[b]
180	0	2	3D9.1BF1BFABF7
182	0	2	3D9.1BF1BE882F
190	45	8	3D9.1BF1C3C2D1
193	45	3	3D9.1BF1BE6633
196	45	3	3D9.1BF1BF9F73
199	45	3	3D9.1BF1C34F97
202	45	3	3D9.1BF1BE843D
205	45	3	3D9.1BF1BF3F8D
208	45	3	3D9.1BF1BDA7C2
211	45	3	3D9.1BF1C333E3
214	45	3	3D9.1BF1BDA7BE
222	0	8	3D9.1BF1BF2EF5
225	0	3	3D9.1BF1C441DA
228	0	3	3D9.1BF1BF949B
231	0	3	3D9.1BF24DD1B9
234	0	3	3D9.1BF24D2DE4
237	0	3	3D9.1BF24D328C
240	0	3	3D9.1BF24D1AC6
243	0	3	3D9.1BF24D68E8
246	0	3	3D9.1BF25234BE

[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 3. Daily total PIT-tag sample time and detections for each salmonid species using the matrix pair trawl antenna system at Jones Beach, 2009.

		PIT-tag detections (N)					
Date	Hours sampled	Unknown	Chinook salmon	Coho salmon	Steelhead	Sockeye salmon	Total
6 Mar	1.05	0	0	0	0	0	0
7 Mar	0	--	--	--	--	--	--
8 Mar	0	--	--	--	--	--	--
9 Mar	4.57	0	0	0	0	0	0
10 Mar	0	--	--	--	--	--	--
11 Mar	4.87	0	0	0	0	0	0
12 Mar	0	--	--	--	--	--	--
13 Mar	0	--	--	--	--	--	--
14 Mar	0	--	--	--	--	--	--
15 Mar	0	--	--	--	--	--	--
16 Mar	4.43	0	1	0	0	0	1
17 Mar	0	--	--	--	--	--	--
18 Mar	0	--	--	--	--	--	--
19 Mar	6.22	0	1	0	0	0	1
20 Mar	6.72	0	0	0	0	0	0
21 Mar	0	--	--	--	--	--	--
22 Mar	0	--	--	--	--	--	--
23 Mar	0	--	--	--	--	--	--
24 Mar	6.55	0	0	0	0	0	0
25 Mar	0	--	--	--	--	--	--
26 Mar	6.57	0	0	0	0	0	0
27 Mar	0	--	--	--	--	--	--
28 Mar	0	--	--	--	--	--	--
29 Mar	0	--	--	--	--	--	--
30 Mar	0	--	--	--	--	--	--
31 Mar	5.62	0	0	0	0	0	0
1 Apr	0	--	--	--	--	--	--
2 Apr	6.1	0	0	0	0	0	0
3 Apr	0	--	--	--	--	--	--
4 Apr	0	--	--	--	--	--	--
5 Apr	0	--	--	--	--	--	--
6 Apr	0	--	--	--	--	--	--
7 Apr	6.6	0	0	0	0	0	0
8 Apr	0	--	--	--	--	--	--
9 Apr	6.18	0	0	0	1	0	1
10 Apr	5.67	0	0	0	0	0	0
11 Apr	0	--	--	--	--	--	--
12 Apr	0	--	--	--	--	--	--
13 Apr	6.53	0	0	0	0	0	0
14 Apr	0	--	--	--	--	--	--
15 Apr	4.57	0	0	0	1	0	1
16 Apr	5.33	0	2	0	0	0	2
17 Apr	6.28	0	8	0	0	0	8
18 Apr	6.68	0	0	0	1	0	1

Appendix Table 3. Continued.

Date	Hours sampled	PIT-tag detections (N)					
		Unknown	Chinook salmon	Coho salmon	Steelhead	Sockeye salmon	Total
19 Apr	1.83	0	2	0	0	0	2
20 Apr	6.4	0	1	0	12	0	13
21 Apr	6.82	0	9	0	3	0	12
22 Apr	6.07	0	8	0	4	0	12
23 Apr	6.43	0	6	0	2	0	8
24 Apr	3.8	0	2	0	0	0	2
25 Apr	3.23	0	5	0	0	0	5
26 Apr	5.65	0	10	0	26	0	36
27 Apr	6.4	0	11	0	17	0	28
28 Apr	6	0	13	0	25	0	38
29 Apr	3.98	0	7	0	9	0	16
30 Apr	5.55	0	18	0	23	0	41
1 May	11.88	4	34	0	42	0	80
2 May	13.33	4	51	0	89	0	144
3 May	12.97	3	57	0	122	0	182
4 May	8.58	4	36	0	59	0	99
5 May	11.48	5	141	0	220	0	366
6 May	13.95	3	176	0	256	0	435
7 May	15.78	3	145	0	190	0	338
8 May	15.67	3	216	1	376	0	596
9 May	16.63	3	267	0	222	0	492
10 May	15.32	5	356	0	199	2	562
11 May	15.78	5	395	2	111	1	514
12 May	20.63	4	450	0	372	6	832
13 May	16.82	2	402	0	147	0	551
14 May	20.47	5	730	0	442	7	1184
15 May	18.68	5	613	0	311	1	930
16 May	18.7	4	490	2	232	4	732
17 May	18.27	5	403	2	235	2	647
18 May	18.88	6	769	2	296	8	1081
19 May	19.7	11	580	2	218	21	832
20 May	17.6	8	717	4	422	41	1192
21 May	19.23	13	705	4	254	35	1011
22 May	12.53	2	359	3	210	75	649
23 May	15.15	3	366	8	233	161	771
24 May	16.25	7	637	13	291	145	1093
25 May	17.08	6	601	15	176	73	871
26 May	17.17	9	479	20	221	65	794
27 May	18.47	7	406	19	122	93	647
28 May	15.82	8	197	10	81	31	327
29 May	12.07	2	81	10	56	18	167
30 May	15.02	8	299	30	235	40	612
31 May	16	8	147	28	200	30	413
1 Jun	13.58	12	132	18	102	8	272
2 Jun	11.07	4	84	18	77	8	191
3 Jun	12.33	3	64	19	45	11	142
4 Jun	5.03	4	20	10	18	1	53

Appendix Table 3. Continued.

Date	Hours Sampled	PIT-tag detections (N)					
		Unknown	Chinook salmon	Coho salmon	Steelhead	Sockeye salmon	Total
5 Jun	13.4	8	86	28	66	17	205
6 Jun	13.43	5	68	52	98	7	230
7 Jun	13.22	1	66	31	55	5	158
8 Jun	12.28	1	53	18	68	2	142
9 Jun	12.17	4	32	8	23	3	70
10 Jun	10.72	0	46	20	53	3	122
11 Jun	12.07	2	44	18	21	8	93
12 Jun	13.58	2	35	13	68	5	123
13 Jun	13.28	3	63	7	15	5	93
14 Jun	7.67	0	16	7	15	1	39
15 Jun	7.4	0	46	9	10	2	67
16 Jun	6.42	0	23	6	37	3	69
17 Jun	6.82	0	47	6	11	1	65
18 Jun	5.85	3	20	6	20	0	49
19 Jun	4.12	0	19	2	4	0	25
20 Jun	8.38	0	94	1	30	1	126
21 Jun	6.03	0	32	0	18	0	50
22 Jun	4.18	0	23	0	18	0	41
23 Jun	5.77	0	24	3	6	0	33
24 Jun	5.77	0	34	0	10	0	44
25 Jun	6.23	1	14	1	4	0	20
26 Jun	5.23	0	18	0	8	0	26
27 Jun	6.75	0	54	6	9	0	69
28 Jun	6.47	0	55	2	11	0	68
29 Jun	6.95	0	93	3	4	1	101
30 Jun	6.57	0	25	1	3	0	29
1 Jul	7.02	0	68	4	2	0	74
2 Jul	6.35	1	54	3	0	1	59
3 Jul	0	--	--	--	--	--	--
4 Jul	0	--	--	--	--	--	--
5 Jul	0	--	--	--	--	--	--
6 Jul	6.45	0	15	2	0	0	17
7 Jul	6.12	0	63	1	1	0	65
8 Jul	6.4	0	26	0	0	0	26
9 Jul	5.82	0	40	0	3	0	43
10 Jul	0	--	--	--	--	--	--
11 Jul	0	--	--	--	--	--	--
12 Jul	0	--	--	--	--	--	--
13 Jul	6.8	0	58	0	0	0	58
14 Jul	6.47	0	65	0	0	0	65
15 Jul	6.87	0	149	0	0	0	149
16 Jul	6.43	1	88	1	0	0	90
17 Jul	6.88	0	97	0	1	0	98
18 Jul	0	--	--	--	--	--	--
19 Jul	0	--	--	--	--	--	--
20 Jul	6.17	0	46	0	0	0	46
21 Jul	6.62	0	52	0	0	0	52
22 Jul	5.88	0	28	0	0	0	28
23 Jul	6.97	1	29	0	0	0	30

Appendix Table 3. Continued.

Date	Hours sampled	PIT-tag detections (N) Unknown	Chinook salmon	Coho salmon	Steelhead	Sockeye salmon	Total
24 Jul	4.6	0	18	0	0	0	18
25 Jul	0	--	--	--	--	--	--
26 Jul	0	--	--	--	--	--	--
27 Jul	7.02	0	28	0	0	0	28
28 Jul	6.38	0	34	0	0	0	34
29 Jul	6.78	0	19	0	0	0	19
30 Jul	3.65	0	11	0	0	0	11
31 Jul	6.9	0	21	0	0	0	21
1 Aug	0	--	--	--	--	--	--
2 Aug	0	--	--	--	--	--	--
3 Aug	6.13	0	5	0	0	0	5
4 Aug	6.08	0	5	0	0	0	5
5 Aug	6.05	0	2	0	0	0	2
6 Aug	6.65	0	5	0	0	0	5
7 Aug	5.42	0	1	0	0	0	1
8 Aug	0	--	--	--	--	--	--
9 Aug	0	--	--	--	--	--	--
10 Aug	6.9	0	1	0	0	0	1
11 Aug	0	--	--	--	--	--	--
12 Aug	5.65	0	4	0	0	0	4
Totals	1,096	221	13,871	499	7,698	952	23,241

Appendix Table 4. Combined daily total of impinged or injured fish on the matrix antenna system used in the upper Columbia River estuary, 2009.

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

Appendix Table 4. Continued.

Date	Chinook Salmon Yearling	Chinook Salmon Subyearling	Coho	Steelhead	Sockeye
22 Apr	1	0	0	0	0
23 Apr	0	0	0	0	0
24 Apr	0	0	0	0	0
25 Apr	0	0	0	0	0
26 Apr	1	0	0	0	0
27 Apr	0	0	0	0	0
28 Apr	1	0	0	1	0
29 Apr	0	0	0	0	0
30 Apr	0	0	0	0	0
1 May	1	0	0	1	0
2 May	5	0	2	2	1
3 May	5	0	1	1	0
4 May	0	0	0	0	0
5 May	43	0	5	4	3
6 May	15	0	6	7	3
7 May	1	0	0	0	0
8 May	7	0	1	2	0
9 May	18	0	3	3	1
10 May	2	0	1	0	0
11 May	5	0	1	2	0
12 May	9	0	2	1	0
13 May	1	0	0	0	0
14 May	7	0	0	2	0
15 May	5	0	2	5	2
16 May	3	0	1	0	0
17 May	1	0	2	1	0
18 May	0	0	0	0	0
19 May	3	0	1	4	1
20 May	1	0	0	1	0
21 May	0	0	2	0	0
22 May	0	0	1	0	0
23 May	1	0	1	0	0
24 May	1	0	0	0	0
25 May	2	0	0	0	0
26 May	4	0	0	0	0
27 May	0	0	1	2	0
28 May	0	0	2	0	0
29 May	0	0	0	0	1
30 May	0	0	0	0	0
31 May	1	0	1	0	0
1 Jun	1	0	0	0	0
2 Jun	0	0	0	0	0
3 Jun	1	0	1	0	0
4 Jun	0	0	2	0	1
5 Jun	2	0	1	0	0
6 Jun	2	0	1	8	0
7 Jun	1	0	0	1	0
8 Jun	0	0	1	0	0

Appendix Table 4. Continued.

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

Appendix Table 4. Continued.

Date	Chinook Salmon		Coho	Steelhead	Sockeye
	Yearling	Subyearling			
27 Jul	0	0	0	0	0
28 Jul	2	0	0	0	0
29 Jul	2	0	0	0	0
30 Jul	0	0	0	0	0
31 Jul	0	0	0	0	0
1 Aug	--	--	--	--	--
2 Aug	--	--	--	--	--
3 Aug	0	0	0	0	0
4 Aug	0	0	0	0	0
5 Aug	0	0	0	0	0
6 Aug	0	0	0	0	0
7 Aug	4	0	1	0	0
8 Aug	--	--	--	--	--
9 Aug	--	--	--	--	--
10 Aug	1	0	0	0	0
11 Aug	--	--	--	--	--
12 Aug	1	0	0	0	0
Totals	186	0	51	49	17

Appendix Table 5. Diel sampling of yearling Chinook salmon and steelhead using a PIT-tag detector surface pair-trawl at Jones Beach (rkm 75), 2009. Two-crew effort (1 May-13 June) was rounded to the nearest tenth and presented as a decimal hour.

		Yearling Chinook salmon				Steelhead			
	Effort	Number detected		detections/h		Number detected		detections/h	
Diel hour	(h)	Hatchery	Wild	Hatchery	Wild	Hatchery	Wild	Hatchery	Wild
0	42.5	451	69	10.6	1.6	96	57	2.3	1.3
1	41.3	500	71	12.1	1.7	88	56	2.1	1.4
2	24.9	540	70	21.7	2.8	65	25	2.6	1
3	16.2	535	62	33	3.8	47	22	2.9	1.4
4	10.3	276	44	26.8	4.3	36	19	3.5	1.8
5	12.5	317	57	25.4	4.6	31	21	2.5	1.7
6	37	463	127	12.5	3.4	190	116	5.1	3.1
7	41.3	451	97	10.9	2.4	324	127	7.9	3.1
8	42.2	453	89	10.7	2.1	313	135	7.4	3.2
9	40.7	461	67	11.3	1.6	357	104	8.8	2.6
10	40.7	521	84	12.8	2.1	447	162	11	4
11	39.8	537	87	13.5	2.2	573	196	14.4	4.9
12	30.2	649	86	21.5	2.8	493	158	16.3	5.2
13	22.7	444	71	19.5	3.1	499	141	22	6.2
14	16.9	338	72	20	4.3	329	75	19.5	4.4
15	5.2	107	23	20.4	4.4	138	20	26.4	3.8
16	1	0	1	0	0	1	0	0	0
17	0.3	0	0	0	0	0	0	0	0
18	4.6	18	4	3.9	0.9	44	13	9.6	2.8
19	16.6	174	43	10.5	2.6	174	52	10.5	3.1
20	38.8	561	110	14.5	2.8	345	132	8.9	3.4
21	42.6	891	148	20.9	3.5	359	121	8.4	2.8
22	43	715	112	16.6	2.6	182	82	4.2	1.9
23	43	419	67	9.7	1.6	76	48	1.8	1.1
Total	654	9,821	1,661			5,207	1,882		

Appendix Table 6. Number of PIT-tagged yearling Chinook salmon loaded for transport at dams and numbers detected in the estuary. LGR, Lower Granite; LGO, Little Goose; LMN, Lower Monumental; MCN, McNary Dam. Transport dates 11 Apr-2 Aug; trawl operation 6 Mar-12 Aug, with intensive sampling 1 May-13 Jun 2009. Season totals are shown, excluding acoustic-tagged fish and fish released below our sample site.

	Numbers loaded at each dam and total fish loaded (n)				Percent detected from each dam and total numbers detected (n)				
Release date and time	LGR	LGO	LMN	n	LGR	LGO	LMN	n	(%)
4/11/2009 2:45	518	0	0	518	0.58	--	--	3	0.58
4/17/2009 22:50	434	0	0	434	0.92	--	--	4	0.92
4/24/2009 21:10	193	0	0	193	0.52	--	--	1	0.52
5/1/2009 21:05	2,676	0	0	2,676	1.42	--	--	38	1.42
5/3/2009 17:00	2,827	0	0	2,827	2.37	--	--	67	2.37
5/4/2009 21:30	1,435	0	0	1,435	2.23	--	--	32	2.23
5/6/2009 0:10	1,385	0	0	1,385	2.74	--	--	38	2.74
5/6/2009 21:45	2,813	0	0	2,813	3.52	--	--	99	3.52
5/7/2009 22:15	3,345	2,340	0	5,685	3.05	4.06	--	197	3.47
5/8/2009 21:30	2,987	2,263	0	5,250	3.41	4.02	--	193	3.68
5/9/2009 22:30	2,422	1,531	0	3,953	3.43	4.44	--	151	3.82
5/10/2009 22:50	1,580	753	551	2,884	1.96	3.05	4.72	80	2.77
5/11/2009 22:30	782	588	384	1,754	4.09	4.76	4.43	77	4.39
5/12/2009 21:00	531	552	155	1,238	2.82	3.62	5.16	43	3.47
5/14/2009 1:20	1,017	637	171	1,825	1.38	3.3	2.34	39	2.14
5/14/2009 21:45	1,997	611	223	2,831	1.7	2.13	3.59	55	1.94
5/15/2009 22:00	2,716	511	305	3,532	2.54	2.15	2.3	87	2.46
5/16/2009 21:20	2,812	1,017	204	4,033	2.17	2.75	0.49	90	2.23
5/17/2009 21:45	1,812	798	149	2,759	2.26	1.38	0	52	1.88
5/19/2009 0:30	1,312	674	320	2,306	2.52	2.82	1.88	58	2.52
5/19/2009 20:30	782	460	221	1,463	3.32	3.91	6.79	59	4.03
5/20/2009 21:30	1,877	662	347	2,886	1.65	3.78	3.46	68	2.36
5/21/2009 21:20	3,024	940	503	4,467	1.06	2.98	2.39	72	1.61
5/22/2009 21:00	2,244	1,491	495	4,230	2.72	3.82	3.64	136	3.22
5/23/2009 22:35	1,355	1,515	488	3,358	2.66	2.18	1.23	75	2.23
5/24/2009 21:00	0	898	347	1,245	--	1.67	0.86	18	1.45
5/25/2009 21:20	0	626	161	787	--	2.56	3.73	22	2.8
5/26/2009 21:00	1	770	249	1,020	0	2.34	6.02	33	3.24

Appendix Table 6. Continued.

	Numbers loaded at each dam and total fish loaded (n)				Percent detected from each dam and total numbers detected (n)				
Release date and time	LGR	LGO	LMN	n	LGR	LGO	LMN	n	(%)
5/27/2009 21:15	116	676	203	995	0	1.18	1.97	12	1.21
5/28/2009 21:35	349	403	221	973	0.86	3.72	3.62	27	2.77
5/29/2009 21:50	276	142	123	541	1.09	1.41	1.63	7	1.29
5/30/2009 21:30	232	127	100	459	2.16	1.57	3	10	2.18
5/31/2009 20:15	111	49	37	197	2.7	2.04	2.7	5	2.54
6/6/2009 20:55	404	394	183	981	1.49	0.76	0.55	10	1.02
6/14/2009 21:15	15	18	4	37	0	0	0	0	0
6/16/2009 19:50	36	25	9	70	0	0	0	0	0
6/18/2009 20:45	24	12	7	43	4.17	8.33	14.29	3	6.98
6/20/2009 19:30	24	8	4	36	0	0	0	0	0
6/22/2009 20:50	29	10	0	39	0	0	--	0	0
6/24/2009 20:15	13	11	4	28	0	0	0	0	0
6/26/2009 21:00	14	6	2	22	0	0	0	0	0
6/28/2009 20:55	10	5	1	16	0	0	0	0	0
6/30/2009 20:25	15	10	0	25	0	0	--	0	0
7/2/2009 19:00	8	6	4	18	0	0	0	0	0
7/4/2009 20:50	8	11	7	26	0	0	0	0	0
7/6/2009 20:55	10	8	3	21	0	12.5	33.33	2	9.52
7/8/2009 20:30	10	11	4	25	0	0	0	0	0
7/10/2009 21:00	6	9	6	21	0	0	0	0	0
7/12/2009 20:05	7	6	2	15	0	16.67	0	1	6.67
7/14/2009 20:25	6	2	3	11	0	0	0	0	0
7/17/2009 4:00	6	2	0	8	0	0	--	0	0
7/19/2009 4:30	0	0	2	2	--	--	0	0	0
7/21/2009 3:20	0	1	0	1	--	0	--	0	0
7/23/2009 2:55	1	0	1	2	0	--	0	0	0
7/25/2009 1:20	3	2	1	6	0	0	0	0	0
7/29/2009 1:20	3	0	0	3	0	--	--	0	0
7/31/2009 2:30	3	0	1	4	0	--	0	0	0
8/2/2009 1:25	0	1		1	--	0	--	0	0
Totals/means	46,616	21,592	6,205	74,413	2.37	3.11	2.98	1964	2.64

Appendix Table 7. Number of PIT-tagged steelhead loaded for transport at dams and numbers detected in the estuary. LGR, Lower Granite; LGO, Little Goose; LMN, Lower Monumental; MCN, McNary Dam. Transport dates 11 Apr-2 Aug; trawl operation 6 Mar-12 Aug, with intensive sampling 1 May-13 Jun 2009. Season totals are shown, excluding acoustic-tagged fish and fish released below our sample site.

	Numbers loaded at each dam and total fish loaded (n)				Percent detected from each dam and total numbers detected (n)				
Release date and time	LGR	LGO	LMN	n	LGR	LGO	LMN	n	(%)
4/11/09 2:45 AM	132	0	0	132	1	--	--	1	0.76
4/17/09 10:50 PM	654	0	0	654	12	--	--	12	1.83
4/24/09 9:10 PM	189	0	0	189	5	--	--	5	2.65
5/1/09 9:05 PM	886	0	0	886	48	--	--	48	5.42
5/3/09 5:00 PM	1,387	0	0	1,387	70	--	--	70	5.05
5/4/09 9:30 PM	787	0	0	787	36	--	--	36	4.57
5/6/09 12:10 AM	610	0	0	610	17	--	--	17	2.79
5/6/09 9:45 PM	868	0	0	868	51	--	--	51	5.88
5/7/09 10:15 PM	1,345	883	0	2,228	38	30	--	68	3.05
5/8/09 9:30 PM	1,343	852	0	2,195	39	11	--	50	2.28
5/9/09 10:30 PM	2,579	644	0	3,223	44	5	--	49	1.52
5/10/09 10:50 PM	2,349	675	536	3,560	55	18	17	90	2.53
5/11/09 10:30 PM	1,578	598	451	2,627	27	8	4	39	1.48
5/12/09 9:00 PM	1,284	382	259	1,925	41	10	4	55	2.86
5/14/09 1:20 AM	1,610	477	302	2,389	52	17	3	72	3.01
5/14/09 9:45 PM	1,616	457	343	2,416	43	16	14	73	3.02
5/15/09 10:00 PM	861	293	244	1,398	41	7	11	59	4.22
5/16/09 9:20 PM	848	382	274	1,504	59	16	12	87	5.78
5/17/09 9:45 PM	738	494	197	1,429	21	23	4	48	3.36
5/19/09 12:30 AM	885	419	283	1,587	70	16	16	102	6.43
5/19/09 8:30 PM	616	292	321	1,229	27	14	13	54	4.39
5/20/09 9:30 PM	1,395	336	220	1,951	69	13	10	92	4.72
5/21/09 9:20 PM	1,862	383	259	2,504	92	23	14	129	5.15
5/22/09 9:00 PM	1,443	814	439	2,696	66	28	10	104	3.86
5/23/09 10:35 PM	1,478	944	768	3,190	29	12	20	61	1.91
5/24/09 9:00 PM	0	849	467	1,316	--	17	12	29	2.20
5/25/09 9:20 PM	0	732	268	1,000	--	8	8	16	1.60
5/26/09 9:00 PM	5	686	238	929	--	12	2	14	1.51
5/27/09 9:15 PM	236	371	162	769	2	3	1	6	0.78

Appendix Table 7. Continued.

Release date and time	Numbers loaded at each dam and total fish loaded (n)				Percent detected from each dam and total numbers detected (n)				
	LGR	LGO	LMN	n	LGR	LGO	LMN	n	(%)
5/28/09 9:35 PM	761	277	120	1,158	54	11	3	68	5.87
5/29/09 9:50 PM	882	197	86	1,165	37	5	4	46	3.95
5/30/09 9:30 PM	633	163	69	865	15	2	3	20	2.31
5/31/09 8:15 PM	508	118	78	704	17	1	1	19	2.70
6/3/09 12:40 AM	362	299	225	886	3	--	1	4	0.45
6/4/09 10:35 PM	769	196	127	1,092	41	5	5	51	4.67
6/6/09 8:55 PM	608	259	142	1,009	32	6	6	44	4.36
6/8/09 7:00 PM	561	210	98	869	17	5	3	25	2.88
6/10/09 9:00 PM	521	303	134	958	27	12	6	45	4.70
6/12/09 5:55 PM	345	135	85	565	11	2	3	16	2.83
6/14/09 9:15 PM	226	40	33	299	12	5	2	19	6.35
6/16/09 7:50 PM	64	40	16	120	5	1	2	8	6.67
6/18/09 8:45 PM	73	44	34	151	8	5	3	16	10.60
6/20/09 7:30 PM	46	25	10	81	3	3	0	6	7.41
6/22/09 8:50 PM	28	15	8	51	1	--	1	2	3.92
6/24/09 8:15 PM	23	15	5	43	1	2	1	4	9.30
6/26/09 9:00 PM	18	9	7	34	3	1	0	4	11.76
6/28/09 8:55 PM	9	8	3	20	--	1	0	1	5.00
6/30/09 8:25 PM	4	3	0	7	--	0	--	0	0
7/2/09 7:00 PM	0	4	1	5	--	0	0	0	0
7/4/09 8:50 PM	0	2	0	2	--	0	--	0	0
7/6/09 8:55 PM	2	1	1	4	1	0	0	1	25.00
7/8/09 8:30 PM	0	1	0	1	--	0	--	0	0
7/12/09 8:05 PM	1	4	0	5	--	0	--	0	0
7/14/09 8:25 PM	2	0	0	2	--	--	--	0	0
7/19/09 4:30 AM	1	0	0	1	--	--	--	0	0
7/23/09 2:55 AM	0	1	0	1	--	0	--	0	0
7/25/09 1:20 AM	0	0	1	1	--	--	0	0	0
7/29/09 1:20 AM	0	0	1	1	--	--	0	0	0
Totals/means	36,031	14,332	7,315	57,678	1,343	374	219	1,936	3.36

Appendix Table 8. Trawl system detections of PIT-tagged juvenile Chinook salmon and steelhead previously detected at Bonneville Dam, 2009.

	Bonneville Dam detections		Jones Beach detections		Bonneville detections seen at Jones Beach (%)	
Detection at Bonneville Dam	Chinook salmon (n)	Steelhead (n)	Chinook salmon (n)	Steelhead (n)	Chinook salmon (%)	Steelhead (%)
24 Feb	40	0	1	--	2.5	--
25 Feb	18	0	0	--	0	--
26 Feb	19	0	0	--	0	--
27 Feb	3	0	0	--	0	--
28 Feb	2	0	0	--	0	--
1 Mar	6	0	0	--	0	--
2 Mar	10	0	0	--	0	--
3 Mar	28	0	0	--	0	--
4 Mar	20	0	0	--	0	--
5 Mar	22	1	0	0	0	0
6 Mar	11	0	0	--	0	--
7 Mar	9	0	0	--	0	--
8 Mar	10	0	0	--	0	--
9 Mar	6	0	1	--	16.67	--
10 Mar	8	0	0	--	0	--
11 Mar	1	0	0	--	0	--
12 Mar	3	0	0	--	0	--
13 Mar	2	0	0	--	0	--
14 Mar	1	0	0	--	0	--
15 Mar	1	0	0	--	0	--
16 Mar	4	0	0	--	0	--
17 Mar	1	0	0	--	0	--
18 Mar	0	0	--	--	--	--
19 Mar	0	0	--	--	--	--
20 Mar	0	0	--	--	--	--
21 Mar	2	0	0	--	0	--
22 Mar	0	0	--	--	--	--
23 Mar	1	0	0	--	0	--
24 Mar	1	0	0	--	0	--
25 Mar	1	0	0	--	0	--
26 Mar	1	0	0	--	0	--
27 Mar	1	0	0	--	0	--
28 Mar	0	0	--	--	--	--
29 Mar	0	0	--	--	--	--
30 Mar	1	2	0	0	0	0
31 Mar	0	0	--	--	--	--
1 Apr	0	0	--	--	--	--
2 Apr	0	0	--	--	--	--
3 Apr	2	3	0	0	0	0
4 Apr	1	4	0	0	0	0
5 Apr	0	0	--	--	--	--
6 Apr	5	2	0	0	0	0

Appendix Table 8. Continued.

Detection at Bonneville Dam	Bonneville Dam detections		Jones Beach detections		Bonneville detections seen at Jones Beach (%)	
	Chinook salmon (n)	Steelhead (n)	Chinook salmon (n)	Steelhead (n)	Chinook salmon (%)	Steelhead (%)
7 Apr	3	4	0	0	0	0
8 Apr	2	3	0	0	0	0
9 Apr	10	2	0	0	0	0
10 Apr	19	2	0	0	0	0
11 Apr	21	1	0	0	0	0
12 Apr	35	1	1	0	2.86	0
13 Apr	29	1	0	0	0	0
14 Apr	563	7	5	0	0.89	0
15 Apr	211	5	4	0	1.9	0
16 Apr	129	4	0	0	0	0
17 Apr	142	11	1	0	0.7	0
18 Apr	206	12	4	1	1.94	8.33
19 Apr	190	19	6	0	3.16	0
20 Apr	200	12	5	0	2.5	0
21 Apr	155	18	0	0	0	0
22 Apr	200	29	2	0	1	0
23 Apr	236	37	2	0	0.85	0
24 Apr	298	57	1	2	0.34	3.51
25 Apr	267	113	1	5	0.37	4.42
26 Apr	255	244	2	5	0.78	2.05
27 Apr	383	222	2	3	0.52	1.35
28 Apr	240	469	1	6	0.42	1.28
29 Apr	301	580	4	9	1.33	1.55
30 Apr	316	368	9	16	2.85	4.35
1 May	325	742	2	23	0.62	3.1
2 May	705	850	3	18	0.43	2.12
3 May	600	1,183	13	54	2.17	4.56
4 May	341	650	13	32	3.81	4.92
5 May	464	966	16	54	3.45	5.59
6 May	310	799	7	54	2.26	6.76
7 May	519	888	12	25	2.31	2.82
8 May	588	1,137	11	27	1.87	2.37
9 May	1,091	918	34	17	3.12	1.85
10 May	1,199	1,295	37	73	3.09	5.64
11 May	999	1,070	39	22	3.9	2.06
12 May	1,361	1,382	75	76	5.51	5.5
13 May	1,478	784	69	45	4.67	5.74
14 May	1,936	1,129	59	34	3.05	3.01
15 May	1,496	882	58	32	3.88	3.63
16 May	2,994	793	128	36	4.28	4.54
17 May	2,166	599	87	25	4.02	4.17
18 May	2,756	1,029	97	61	3.52	5.93
19 May	3,169	1,171	146	47	4.61	4.01
20 May	2,418	917	96	27	3.97	2.94
21 May	2,179	513	53	10	2.43	1.95
22 May	2,233	759	56	14	2.51	1.84

Appendix Table 8. Continued.

Detection at Bonneville Dam	Bonneville Dam detections		Jones Beach detections		Bonneville detections seen at Jones Beach (%)	
	Chinook salmon (n)	Steelhead (n)	Chinook salmon (n)	Steelhead (n)	Chinook salmon (%)	Steelhead (%)
23 May	2,262	822	78	30	3.45	3.65
24 May	2,770	1,162	97	25	3.5	2.15
25 May	1,746	815	52	24	2.98	2.94
26 May	1,326	576	30	12	2.26	2.08
27 May	1,242	568	12	7	0.97	1.23
28 May	1,370	688	32	10	2.34	1.45
29 May	912	486	14	11	1.54	2.26
30 May	752	454	16	13	2.13	2.86
31 May	537	252	8	6	1.49	2.38
1 Jun	415	227	14	4	3.37	1.76
2 Jun	232	121	3	1	1.29	0.83
3 Jun	253	166	3	4	1.19	2.41
4 Jun	197	170	4	6	2.03	3.53
5 Jun	161	189	6	8	3.73	4.23
6 Jun	139	70	2	2	1.44	2.86
7 Jun	125	99	0	1	0	1.01
8 Jun	233	111	4	4	1.72	3.6
9 Jun	265	124	3	6	1.13	4.84
10 Jun	279	98	2	5	0.72	5.1
11 Jun	311	100	2	5	0.64	5
12 Jun	273	110	2	1	0.73	0.91
13 Jun	289	66	2	4	0.69	6.06
14 Jun	270	137	1	3	0.37	2.19
15 Jun	294	61	5	3	1.7	4.92
16 Jun	309	61	2	3	0.65	4.92
17 Jun	521	76	1	2	0.19	2.63
18 Jun	584	71	9	4	1.54	5.63
19 Jun	328	65	1	4	0.3	6.15
20 Jun	301	68	2	4	0.66	5.88
21 Jun	348	84		2	0	2.38
22 Jun	466	66	6	1	1.29	1.52
23 Jun	315	35	1	0	0.32	0
24 Jun	384	67	2	1	0.52	1.49
25 Jun	269	112	4	2	1.49	1.79
26 Jun	440	40	12	3	2.73	7.5
27 Jun	441	32	6	0	1.36	0
28 Jun	239	29	4	1	1.67	3.45
29 Jun	343	29	5	0	1.46	0
30 Jun	323	12	6	0	1.86	0
1 Jul	546	7	1	0	0.18	0
2 Jul	284	14	0	0	0	0
3 Jul	217	20	1	0	0.46	0
4 Jul	84	12	5	0	5.95	0
5 Jul	109	4	2	0	1.83	0
6 Jul	182	4	2	1	1.1	25
7 Jul	279	7	4	0	1.43	0

Appendix Table 8. Continued.

Detection at Bonneville Dam	Bonneville Dam detections		Jones Beach detections		Bonneville detections seen at Jones Beach (%)	
	Chinook salmon (n)	Steelhead (n)	Chinook salmon (n)	Steelhead (n)	Chinook salmon (%)	Steelhead (%)
8 Jul	395	6	0	0	0	0
9 Jul	325	7	2	0	0.62	0
10 Jul	399	4	0	0	0	0
11 Jul	348	4	14	0	4.02	0
12 Jul	575	2	8	0	1.39	0
13 Jul	255	5	4	0	1.57	0
14 Jul	417	1	11	0	2.64	0
15 Jul	425	3	5	1	1.18	33.33
16 Jul	269	1	1	0	0.37	0
17 Jul	432	2	4	0	0.93	0
18 Jul	177	1	1	0	0.56	0
19 Jul	158	0	4	--	2.53	--
20 Jul	165	1	2	0	1.21	0
21 Jul	171	1	2	0	1.17	0
22 Jul	122	0	0	--	0	--
23 Jul	68	1	0	0	0	0
24 Jul	68	0	3	--	4.41	--
25 Jul	159	1	2	0	1.26	0
26 Jul	138	1	2	0	1.45	0
27 Jul	172	2	1	0	0.58	0
28 Jul	107	0	0	--	0	--
29 Jul	124	0	1	--	0.81	--
30 Jul	68	0	0	--	0	--
31 Jul	26	1	1	0	3.85	0
1 Aug	50	0	1	--	2	--
2 Aug	19	0	2	--	10.53	--
3 Aug	16	6	0	0	0	0
4 Aug	6	0	0	--	0	--
5 Aug	8	0	0	--	0	--
6 Aug	9	0	0	--	0	--
7 Aug	11	3	0	0	0	0
8 Aug	15	3	0	0	0	0
9 Aug	10	1	0	0	0	0
10 Aug	6	0	0	--	0	--
11 Aug	10	1	0	0	0	0
12 Aug	10	7	0	0	0	0
Totals	65,677	31,341	1,702	1,077	2.59	3.44

Appendix Table 9. Release and consecutive observation sites and dates for the 26 subyearling Chinook salmon released in 2008 and detected in 2009. Overwintering location is between the last detection site in 2008 and the first detection site in 2009.

PIT Tag ID	Release/observation site and abbreviation		Release/ observation date
3D9.1C2C56AF44	Big Canyon Creek Acclimation Pond	BCCAP	2008-06-29 16:00:00
	Big Canyon Creek	BCC	2009-05-08 07:40:53
	Estuary Towed Array	TWX	2009-05-10 00:53:07
3D9.1C2C581497	Big Canyon Creek Acclimation Pond	BCCAP	2008-06-27 18:00:00
	Lower Granite Dam	GRJ	2009-04-02 04:37:34
	Estuary Towed Array	TWX	2009-05-09 13:29:15
3D9.1C2C5BB46E	Snake R. (Clearwater to Salmon R., rkm 224-303)	SNAKE3	2008-05-26 17:30:00
	McNary Dam	MCJ	2009-04-13 07:55:49
	Estuary Towed Array	TWX	2009-05-18 23:30:22
3D9.1C2C5C439E	Clearwater River	CLWR	2008-08-19 11:18:00
	Lower Granite Dam	GRJ	2008-11-17 13:45:18
	McNary Dam	MCJ	2009-04-29 15:48:15
	Bonneville Dam	B2J	2009-05-05 21:56:53
	Estuary Towed Array	TWX	2009-05-07 22:33:35
3D9.1C2C5D27BB	Snake R. (Clearwater to Salmon R., rkm 224-303)	SNAKE3	2008-05-22 18:30:00
	Little Goose Dam	GOJ	2009-04-12 19:08:52
	Estuary Towed Array	TWX	2009-05-06 00:27:10
3D9.1C2C5E5E6F	Big Canyon Creek Acclimation Pond	BCCAP	2008-07-11 16:30:00
	Lower Granite Dam	GRJ	2008-11-27 19:38:34
	Little Goose Dam	GOJ	2009-04-14 21:11:47
	Lower Monumental Dam	LMJ	2009-04-17 09:23:57
	McNary Dam	MCJ	2009-04-22 17:10:06
	Estuary Towed Array	TWX	2009-05-04 06:10:12
3D9.1C2C6067D1	Big Canyon Creek Acclimation Pond	BCCAP	2008-07-07 17:00:00
	Little Goose Dam	GOJ	2009-04-13 20:05:46
	Lower Monumental Dam	LMJ	2009-04-17 11:01:30
	Big Canyon Creek	BCC	2009-05-16 20:38:06
	Estuary Towed Array	TWX	2009-05-18 09:52:14
3D9.1C2C60E1BF	Big Canyon Creek Acclimation Pond	BCCAP	2008-07-08 16:00:00
	Lower Granite Dam	GRJ	2008-11-24 00:52:18
	Lower Monumental Dam	LMJ	2009-04-26 21:39:54
	McNary Dam	MCJ	2009-05-01 05:43:24
	Estuary Towed Array	TWX	2009-05-08 03:16:15
3D9.1C2C612785	Big Canyon Creek Acclimation Pond	BCCAP	2008-07-09 18:00:00
	Lower Monumental Dam	LMJ	2009-03-25 17:38:55
	McNary Dam	MCJ	2009-04-08 23:47:46
	Estuary Towed Array	TWX	2009-04-17 07:40:13

Appendix Table 9. Continued.

PIT Tag ID	Release/observation site and abbreviation		Release/ observation date
3D9.1C2C61E829	Big Canyon Creek Acclimation Pond	BCCAP	2008-07-10 18:00:00
	Little Goose Dam	GOJ	2009-04-23 20:02:18
	McNary Dam	MCJ	2009-05-02 08:41:49
	Big Canyon Creek	BCC	2009-05-12 06:13:40
	Estuary Towed Array	TWX	2009-05-14 09:22:14
3D9.1C2C62B2F7	Big Canyon Creek Acclimation Pond	BCCAP	2008-07-11 16:30:00
	John Day Dam	JDJ	2009-04-27 15:55:50
	Estuary Towed Array	TWX	2009-05-02 21:06:55
3D9.1C2C62B7CD	Big Canyon Creek Acclimation Pond	BCCAP	2008-07-11 16:30:00
	Little Goose Dam	GOJ	2009-03-29 11:48:56
	Ice Harbor Dam	ICH	2009-05-06 01:54:11
	Bonneville Dam Powerhouse 2	B2J	2009-05-14 07:36:56
	Estuary Towed Array	TWX	2009-05-16 13:24:05
3D9.1C2C64985A	Big Canyon Creek Acclimation Pond	BCCAP	2008-07-10 18:00:00
	Estuary Towed Array	TWX	2009-05-02 00:49:06
3D9.1C2C6498C5	Big Canyon Creek Acclimation Pond	BCCAP	2008-07-11 16:30:00
	Lower Granite Dam	GRJ	2008-11-14 15:00:06
	Ice Harbor Dam	ICH	2009-04-10 17:34:55
	John Day Dam	JDJ	2009-04-18 00:40:48
	Estuary Towed Array	TWX	2009-04-22 06:38:00
3D9.1C2C64F0E3	Big Canyon Creek Acclimation Pond	BCCAP	2008-07-03 16:30:00
	Little Goose Dam	GOJ	2009-04-25 17:01:13
	Estuary Towed Array	TWX	2009-05-08 03:12:44
3D9.1C2C654EB6	Big Canyon Creek Acclimation Pond	BCCAP	2008-07-03 16:30:00
	Little Goose Dam	GOJ	2009-03-25 12:42:04
	Lower Monumental Dam	LMJ	2009-04-20 22:40:34
	Estuary Towed Array	TWX	2009-05-02 10:54:38
3D9.1C2C65545C	Big Canyon Creek Acclimation Pond	BCCAP	2008-07-01 15:05:00
	Little Goose Dam	GOJ	2009-03-26 16:50:45
	McNary Dam	MCJ	2009-04-17 04:53:40
	Estuary Towed Array	TWX	2009-05-06 22:21:14
3D9.1C2C656CEF	Big Canyon Creek Acclimation Pond	BCCAP	2008-07-01 15:05:00
	Lower Granite Dam	GRJ	2008-11-06 12:49:24
	Lower Monumental Dam	LMJ	2009-05-03 20:00:57
	Bonneville Dam Powerhouse 2	B2J	2009-05-13 19:12:22
	Estuary Towed Array	TWX	2009-05-15 12:50:54
3D9.1C2C66EC38	Snake R. (Clearwater to Salmon R., rkm 224-303)	SNAKE3	2008-05-29 19:00:00
	Little Goose Dam	GOJ	2009-05-03 22:24:59
	McNary Dam	MCJ	2009-05-08 05:57:05
	Big Canyon Creek	BCC	2009-05-12 18:37:53
	Estuary Towed Array	TWX	2009-05-14 09:46:34

Appendix Table 9. Continued.

PIT Tag ID	Release/observation site and abbreviation		Release/ observation date
3D9.1C2C6B168B	Big Canyon Creek Acclimation Pond	BCCAP	2008-07-09 18:00:00
	John Day Dam	JDJ	2009-04-14 22:08:10
	Estuary Towed Array	TWX	2009-04-22 06:37:25
3D9.1C2C6C3775	Big Canyon Creek Acclimation Pond	BCCAP	2008-07-09 18:00:00
	Lower Granite Dam	GRJ	2009-04-10 21:46:29
	John Day Dam	JDJ	2009-05-01 09:04:07
	Big Canyon Creek	BCC	2009-05-03 15:26:48
	Estuary Towed Array	TWX	2009-05-06 00:27:23
3D9.1C2C8C23E2	Big Canyon Creek Acclimation Pond	BCCAP	2008-07-07 17:00:00
	Lower Granite Dam	GRJ	2009-03-27 08:23:42
	Little Goose Dam	GOJ	2009-04-08 10:08:54
	Lower Monumental Dam	LMJ	2009-04-29 08:10:58
	Ice Harbor Dam	ICH	2009-05-01 04:37:41
	McNary Dam	MCJ	2009-05-03 12:43:41
	Big Canyon Creek	BCC	2009-05-09 04:46:06
	Estuary Towed Array	TWX	2009-05-11 00:27:22
3D9.1C2C8C267E	Big Canyon Creek Acclimation Pond	BCCAP	2008-07-09 18:00:00
	Lower Granite Dam	GRJ	2009-03-25 07:29:44
	Little Goose Dam	GOJ	2009-04-08 12:03:21
	Lower Monumental Dam	LMJ	2009-04-11 20:29:51
	Estuary Towed Array	TWX	2009-04-26 10:28:11
3D9.1C2C8C2FDE	Big Canyon Creek Acclimation Pond	BCCAP	2008-07-09 18:00:00
	Lower Monumental Dam	LMJ	2009-04-02 22:10:20
	Estuary Towed Array	TWX	2009-05-07 23:17:52
3D9.1C2CC3B9D8	Big Canyon Creek Acclimation Pond	BCCAP	2008-06-23 17:00:00
	Ice Harbor Dam	ICH	2009-04-23 19:14:35
	Estuary Towed Array	TWX	2009-05-06 21:05:08
3D9.1C2CE14580	Big Canyon Creek Acclimation Pond	BCCAP	2008-07-10 17:00:00
	Lower Granite Dam	GRJ	2008-11-14 22:28:48
	McNary Dam	MCJ	2009-05-05 22:01:22
	Estuary Towed Array	TWX	2009-05-14 02:16:19