Detection of PIT-Tagged Juvenile Salmonids in the Columbia River Estuary Using a Pair-Trawl, 2013

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Executive Summary

In 2013, 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 along the navigation channel in the upper Columbia River estuary between river kilometers (rkm) 61 and 83. We deployed the trawl for a total of 889 h between 25 March and 25 July and detected a total of 22,879 PIT-tagged juvenile salmonids. These detections were comprised of 19% wild and 79% hatchery-reared fish (2% were of unknown origin). The species composition of all PIT-tagged fish detected in the trawl during 2013 was 45% spring/summer Chinook salmon, 5% fall Chinook salmon, 41% steelhead, 4% sockeye, 3% coho, less than 1% cutthroat trout, and 1% unknown species.

In 2013, sampling was conducted with our matrix-antenna PIT-tag detection system used since 2008. This system was composed of a 122-m-long surface pair-trawl that funneled fish through a 2.6-m wide by 3.0-m tall fish-passage opening. The fish-passage structure was constructed with separate front and rear components, with each component consisting of 3 parallel antenna coils. The trawl sampled from the surface to a depth of about 5.0 m and was towed into the current while we maintained a distance of 91.5 m between the forward wings of the trawl.

Sampling began on 25 March with a single daily shift operating 3-5 d week^{-1} to coincide with the anticipated arrival of early migrating juvenile PIT-tagged salmon and steelhead in the estuary. As numbers of migrating juvenile salmonids in the estuary increased, sample effort was increased to two daily shifts operating 7 d week^{-1} during daylight and 6 d week^{-1} during darkness. This intensive sampling period began on 29 April and continued through 6 June. During this period we averaged 13 detections h^{-1} during daylight and 23 detections h^{-1} during darkness for yearling Chinook salmon (P = 0.02). During the same period for steelhead the trend was opposite, with 21 detections h^{-1} during daylight and 7 detections h^{-1} during darkness (P <0.001). Sampling continued with a single daily shift through 25 July when sampling ended as numbers of PIT-tagged fish in the sampling reach declined.

During the intensive sampling period, the trawl was deployed for an average of 14 h d^{-1} and we detected 2.7% of the yearling Chinook and 3.8% of the steelhead previously detected at Bonneville Dam. By comparison, during intensive sampling in 2012, the trawl was deployed for an average of 14 h d^{-1} and detected 1.7% of the yearling Chinook and 2.6% of the steelhead detected at Bonneville Dam. We also detected 1.9% of the yearling Chinook salmon and 3.7% of the steelhead transported and released below

Bonneville Dam in 2013. These rates were higher for transported fish than in 2012, when we detected 1.3% of the yearling Chinook and 3.5% of the steelhead. However, the detection rate of barged steelhead in 2012 was exceptionally high compared to flow volume due to an apparent shift of their peak availability from mid-day to mid-morning. Under lower flow conditions, as in 2013, the peak detection rate of steelhead has tended to occur towards mid-day, and our afternoon refueling period has generally reduced their overall detection rate. Flow volume at Bonneville Dam was below average in 2013 (8,013 $m^3 s^{-1}$) while in 2012 it was above average (9,912 $m^3 s^{-1}$). Detection rates in the trawl are typically inversely correlated with flow, where rates are higher in low to moderate flow years.

In 2013, 19% of the PIT-tagged fish detected with the trawl system had been transported, while 10% had been detected in the juvenile bypass system or corner collector at the Bonneville Dam Second Powerhouse. There is no PIT-tag detection capability at the First Powerhouse bypass or Spillway. The remaining 71% of fish detected with the trawl had not been transported or detected at Bonneville Dam, although 99% of them had originated upstream from Bonneville.

In 2013, estimated survival from Lower Granite to Bonneville Dam tailrace was 61.9% for combined wild and hatchery Snake River yearling Chinook (Table 1). This was slightly lower than the 63.4% estimated for these fish in 2012. Estimated survival

Table 1. Estimated survival by species and run from Lower Granite and McNary Dam to Bonneville Dam in 2012 and 2013. All estimates are tailrace-to-tailrace. Standard errors shown in parenthesis.

	Tailrace-to-tailrace estimated survival percentages (SE)			
	Lower Granite to Bonneville		McNary to Bonneville	
Combined wild and hatchery stocks	2012	2013	2012	2013
Snake River				
Yearling Chinook	63.4 (±4.2)	61.9 (±5.7)	79.6 (±6.4)	80.2 (±5.1)
Steelhead	59.7 (±13.8)	51.5 (±7.5)	85.6 (±19.6)	79.8 (±11.2)
Sockeye	47.2 (±6.2)	53.6 (±6.6)	84.0 (±40.5)	(65.8 (±21.7)
Upper Columbia R (above Yakima R)				
Yearling Chinook			84.5 (±9.2)	102.5 (± 10.3)
Steelhead			106.9 (±15.9)	91.0 (±7.5)
Yakima River yearling Chinook			55.8 (±7.9)	76.0 (±12.1)

through this same reach for combined wild and hatchery Snake River steelhead was 51.5%, which was lower than the 59.7% estimated for these fish in 2012. For Snake River sockeye, estimated survival through the same reach was 53.6% in 2013, which was higher than the 47.2% estimated in 2012.

Estimated survival from McNary to Bonneville Dam tailrace was similar in 2013 and 2012 for combined wild and hatchery Snake River yearling Chinook (79.6 vs. 80.2%). In the same reach for combined wild and hatchery upper Columbia River yearling Chinook, survival was higher in 2013 than in 2012, both for groups released above the confluence of the Yakima River (102.5 vs. 84.5%) and for those released in the Yakima River (76.0 vs. 55.8%). For mixed wild and hatchery Snake River steelhead, estimated survival through this reach was lower in 2013 than in 2012 (79.8 vs. 85.6%). For combined wild and hatchery steelhead from the upper Columbia River, estimated survival was 91.0% in 2013 vs. 106.9% in 2012. Due to low rates of detection for upper Columbia River sockeye salmon, estimates of survival from McNary to Bonneville Dam were imprecise in both years, at 65.8% (±21.7) in 2013 and 84.0% (±40.5) in 2012.

Seasonal mean travel speed to Jones Beach was significantly faster for yearling Chinook salmon detected passing Bonneville Dam (96 km d^{-1}) than for those released from barges just below the dam (71 km d^{-1}, $P \leq 0.001$). Similar differences in travel speed between inriver-migrant and barged fish were noted for steelhead (100 vs. 93 km d^{-1}, $P < 0.001$). There was not a significant difference in travel speed between sockeye salmon passing Bonneville Dam (103 km d^{-1}) and those released from barges below the dam (106 km d^{-1}, $P < 0.10$), although low inriver detections may have contributed to this (n = 78). There were insufficient detections of subyearling Chinook salmon in 2013 for meaningful comparisons of travel speed.

We detected a total of 477 subyearling fall Chinook salmon in 2013, with detections occurring after the intensive sample period. Of these 477 fish, 216 originated in the Snake River basin (201 inriver migrants and 15 transported). The remaining 261 subyearling fish were Columbia River stocks. We also detected 54 fall Chinook salmon from the Snake River basin that had been released as subyearlings in 2012. Of these 54 fish, 31 had overwintered in either the Snake or Columbia River above Bonneville Dam, and 23 had not been detected in 2013 prior to being detected in the estuary.

In 2013, we detected 1,023 sockeye salmon; 83% of these fish had been released into the Snake River and 17% into the Columbia River. Of these 1,023 fish, 89% were hatchery reared, 2% were wild, and the remaining 9% were of unknown origin. Fish migrating inriver made up 55% of the total sockeye detections (563), while the other 45% were fish that had been transported (460).

In late 2012, we began developing a stationary PIT-tag detection system featuring the larger antennas now possible due to a new transceiver (model IS1001 MTS). The new system was installed along a pile dike in the lower estuary during spring 2013. The antennas we deployed measured 2.4 by 6.1 m and were housed with 10.2-cm-diameter, rigid PVC pipe. In June, we also briefly tested this new system by towing it behind a modified trawl. These tests showed significant stress on the PVC frame, and the large, rigid antenna frame required complicated logistics for deployment and retrieval. As a result, we developed an antenna of similar dimensions but housed using a flexible light-weight hose. This design was much easier to deploy and was more resistant to vibration and stress when under tow. In October, we conducted preliminary testing of this flexible antenna attached to a rope-frame for added strength. While results were promising, more testing of the flexible design is needed to reduce vibration and to develop a larger matrix of multiple antenna coils.

Contents

Introduction

In 2013, we continued a multi-year study in the Columbia River estuary to collect data on migrating juvenile Pacific salmon *Oncorhynchus* spp. implanted with passive integrated transponder (PIT) tags (Ledgerwood et al. 2004; Morris et al. 2013). Data from estuary detections are used to estimate the survival and downstream migration timing of these fish.

As in previous years, we used a large surface pair-trawl to guide fish through an array of detection antennas mounted in place of the cod-end of the trawl. Target fish were those PIT-tagged by other researchers for various research projects at natal streams, hatcheries, collection facilities at dams, and other upstream locations (PSMFC 2013). When PIT-tagged fish pass through the trawl and antennas, the tag code, GPS position, and date and time of detection is electronically 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.

More than 1.9 million Snake and Columbia River juvenile salmonids were PIT-tagged and released prior to or during the spring 2013 migration season (PSMFC 2013). During the season, a portion of these fish were detected at dams equipped with PIT-tag monitoring systems (Prentice et al. 1990a,b). These systems automatically upload detection information to the PIT Tag Information System database (PTAGIS), a regional database that stores and disseminates information on PIT-tagged fish (PSMFC 2013).

We uploaded trawl detection records to PTAGIS and downloaded information on the fish we detected. This information included the species, run, tagging and release time and location, and date and time of detection at interrogation sites downstream. These data were used to evaluate migration timing of transported fish between Bonneville Dam and the estuary and to evaluate survival and migration timing of yearling Chinook salmon, steelhead, and sockeye salmon migrating through the hydrosystem in 2013 and annually since 1998.

Trawl detection data in 2013 was sufficient to conduct survival and timing analyses for juvenile Chinook salmon *O. tshawytscha*, steelhead *O. mykiss*, and sockeye salmon *O. nerka*. In 2013, over 178,000 PIT-tagged fish were transported from dams on the Snake River and over 90,000 inriver migrants were detected at Bonneville Dam. Seasonal trends in these data may provide insight into the relationship observed between smolt-to-adult return ratios and juvenile migration timing (Marsh et al. 2008, 2012).

Matrix Antenna Trawl System

Methods

Study Area

Trawl sampling was conducted in the upper Columbia River estuary between Eagle Cliff (rkm 84) and the west end of Puget Island (rkm 66; Figure 1). 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 tide, especially in years of medium-to-high river flow. The trawl was deployed adjacent to a 200-m-wide navigation channel, which is maintained at a depth of 14 m.

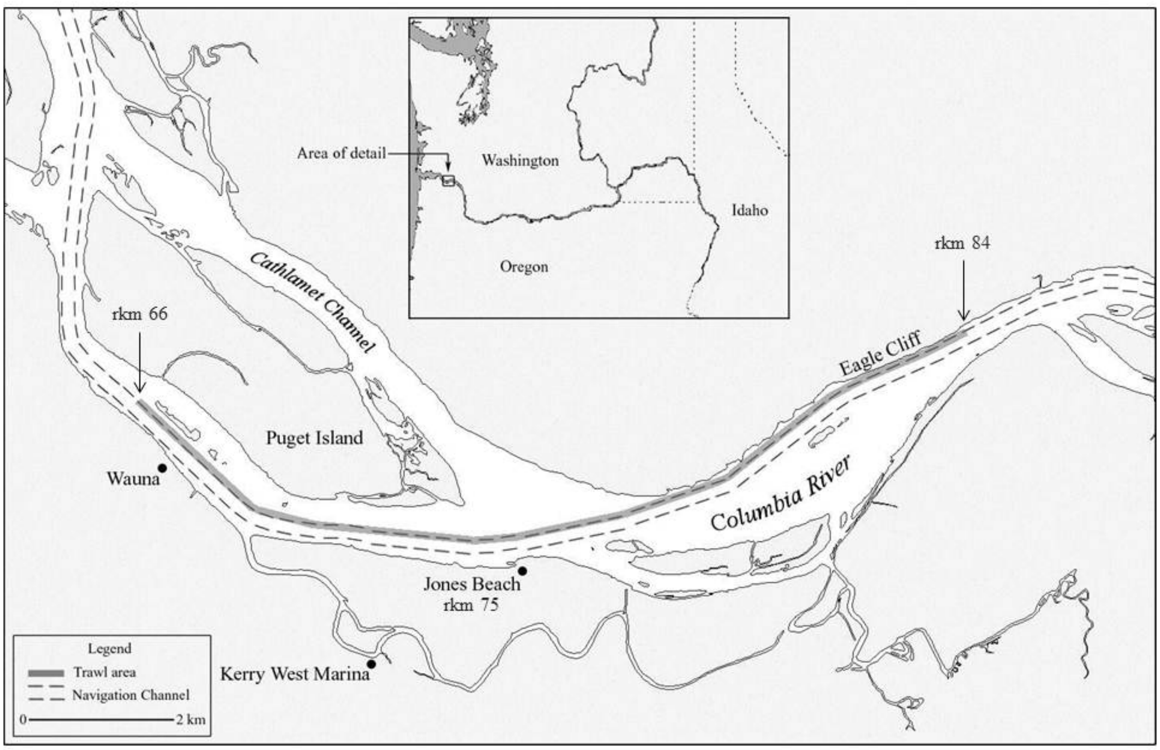

Figure 1. Trawling area adjacent to the navigation channel in the upper Columbia River estuary between rkm 66 and 84.

Study Fish

We continued to focus detection efforts on large release-groups of PIT-tagged fish detected at Bonneville Dam or transported and released just downstream from the dam. The vast majority of these fish enter the upper estuary from late April through late June. Release dates and locations of fish detected with the trawl were retrieved from the PTAGIS database (PSFMC 2013). Specific groups of tagged fish targeted for detection included over 210,000 fish released for a comparative survival study of hatchery fish, and some 178,000 fish diverted to barges for NMFS transportation studies, as well as smaller groups released for other studies. About 36,000 of the fish transported in 2013 were used in a special study at Lower Granite Dam. Because in this study were handled two or three times, we excluded them from our analysis of transported fish in the estuary.

Migrating juvenile fish released in the upper Snake River must traverse eight dams and reservoirs or be transported from one of three collector dams to reach the tailrace of Bonneville Dam. In 2013, no fish were transported from McNary Dam. Transported fish can potentially avoid passage at 7 dams and migration through approximately 461 km of river from the tailrace of Lower Granite Dam to the tailrace of Bonneville Dam (Marsh et al. 2005; 2008; 2010; 2012).

Detection numbers in the pair trawl were sufficient for analyses of timing and survival for yearling Chinook salmon and steelhead. Trawl detections of sockeye and subyearling Chinook salmon were fewer, and analyses were limited due to smaller sample sizes for these fish. We also detected PIT-tagged coho salmon *O. kisutch* and coastal cutthroat trout *O. clarki*.

Sample Period

Spring and summer sampling began on 25 March and continued through 25 July 2013. Our sample effort varied commensurate with fish availability in the estuary. At the beginning and end of the migration season we sampled with a single shift, 2-5 d week^{-1} for an average daily effort of 6 h d^{-1}. From 29 April through 6 June, we sampled with two shifts daily, both day and night, for an average daily effort of 14 h d^{-1}.

During the two-shift period, day shifts began before dawn and continued for 6-11 h, while night shifts began in early evening and continued through most of the night or until relieved by the day crew. Sampling was intended to be nearly continuous throughout the two-shift period except between 14:00 and 19:00 PDT, when we interrupted sampling for refueling and maintenance.

Trawl System Design

In 2013, sampling was conducted exclusively with the matrix-antenna trawl system (Figure 2). The fish-passage corridor was configured with three parallel antenna coils in front and three in the rear, for a total of six detection coils. Inside dimensions of individual coils measured 0.75 by 2.8 m. Front and rear components were connected by a 1.5-m length of net mesh, and the overall fish-passage opening was 2.6 by 3.0 m. The matrix antenna was attached at the rear of the trawl and suspended by buoys 0.6 m beneath the surface.

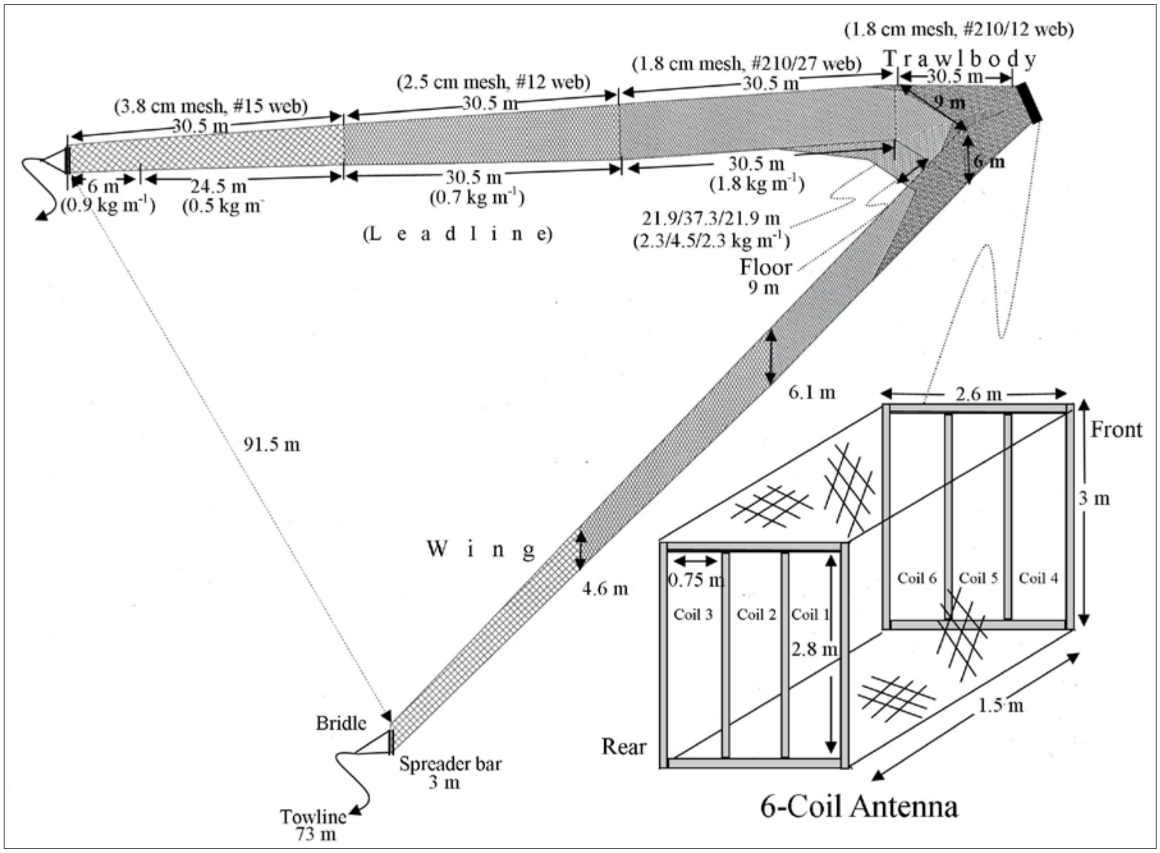

Figure 2. Basic design of the surface pair trawl used with the matrix antenna system to sample juvenile salmonids in the Columbia River estuary (rkm 75), 2013.

This configuration allowed fish collected in the trawl to exit through the antenna while remaining in the river. Each 3-coil component weighed approximately 114 kg in air and required an additional 114 kg of lead weight to suspend in the water column (total weight of front and rear components was 456 kg in air). The trawl and antenna were transported to the sample area aboard a 12.5-m tow vessel.

The basic configuration of the pair-trawl net has changed little through the years, despite changes to the PIT-tag detection apparatus (Ledgerwood et al. 2004). 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 30.5-m-long trawl body, which was modified for antenna attachment. The mouth of the trawl body had an opening 9 m wide by 6 m tall with a 9-m floor extending forward from the mouth. Sample depth was about 5.0 m due to curvature in the side-walls under tow.

We towed the pair-trawl with 73-m-long tow lines to prevent turbulence on the net from the tow vessels. After the trawl and antenna were deployed, one tow line was passed to an adjacent tow vessel. The net was towed upstream facing into the current, with a distance of about 91.5 m between the distal ends of the trawl wings. Even though volitional passage through the trawl and antenna occurred while towing with the wings extended, we continued to bring the wings of the trawl together every 17 minutes to flush debris out of the system. The majority of fish were detected during these 7-minute net-flushing periods.

Electronic Equipment and Operation

We used essentially the same electronic components and procedures as in 2006-2012. A single FS1001M multiplexing transceiver was used, which was capable of simultaneously powering, recording, and transmitting data for 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 cable. The system used a DC power source for the transceiver and antenna. Data were stored in the buffer of the transceiver and wirelessly transmitted in real-time and recorded to a computer onboard a tow vessel. Detection efficiency tests were conducted prior to the sample season to verify system performance (see below). During the season, status reports generated by the transceiver were monitored in real time to confirm performance, and each antenna coil was tested periodically using a PIT-tag attached to a telescoping pole.

The date and time of detection, tag code, coil identification number, and GPS location for each fish detected were received from the antenna and recorded automatically using the computer software program MiniMon (PSMFC 2013). Written logs were maintained for each sampling cruise noting the time and duration of net deployment, net retrieval, approximate location, and any incidence of impinged fish. 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 2013). Pair-trawl detections are designated in the PTAGIS database with site code TWX (towed array-experimental).

Detection Efficiency and Performance of Matrix Antenna

As in previous years, we used a test tape to evaluate performance of the matrix antenna detection system (Ledgerwood et al. 2005; Morris et al. 2013). For efficiency tests during deployment, we positioned a 2.5-cm diameter PVC pipe through the center of both the front and rear components of the 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. Tests were conducted independently on port, middle, and starboard coil sets. We attached PIT tags to a vinyl-coated tape measure at spacing intervals of 30, 60, and 90 cm, and at different orientations. The tape was then passed through the pipe, and detection efficiency was evaluated based on the proportion of tags on the tape that were detected during a single pass.

Impacts on Fish

We regularly inspected the cod-end of the net for debris accumulation near the antenna that could impact fish. Other sections of the net were monitored visually from a skiff, and accumulated debris was removed as necessary. During retrieval, the matrix antenna was hoisted on to a tow vessel while remaining attached to the pair-trawl. This retrieval method saved time and was possible due to the larger fish-passage opening of the matrix antenna. Previous antenna designs, such as the cylindrical antenna (0.9-m diameter) last used in 2008, allowed significant accumulations of debris in the trawl body. When using these smaller antenna designs, the trawl had to be inverted for debris removal prior to retrieval, requiring the antenna to be disconnected from the trawl (Magie et al. 2010). In contrast, the matrix antenna design allowed most debris to pass through the system, resulting in an overall reduction of debris accumulation, and less interference with sample effort. Debris that remained in the net was removed by hand through zippers in the top of the trawl body. During debris-removal activities, we recorded all impinged or trapped fish as mortalities, although most fish were released alive.

Results and Discussion

Fish Availability and Abiotic Factors Affecting Rate of Detection

In 2013, the majority of the intensive (two daily shifts) sampling period was characterized by low-to-average river flows and normal debris loads, with a brief period of above-average flow between 8 and 20 May. Mean flow volumes in the Columbia River at Bonneville Dam were about 19% lower during the two-shift sample period of 2013 (8,013 $m^3 s^{-1}$) than during the two-shift period of 2012 (9,912 $m^3 s^{-1}$; Figure 3). However, flow volume in 2012 was well above the 10-year average (8,283 $m^3 s^{-1}$).

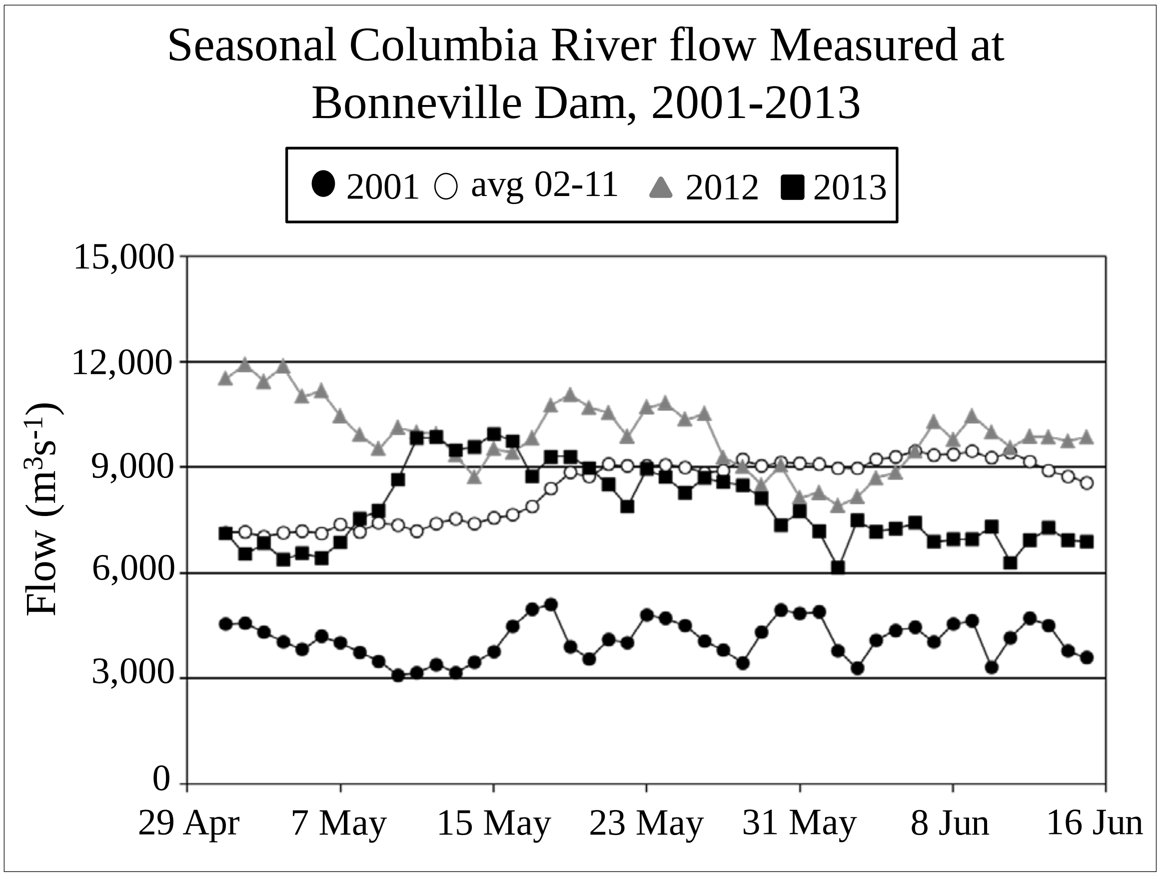

Figure 3. Columbia River flows at Bonneville Dam during the two-shift sample periods in 2012 and 2013, as compared to the average flow from 2002 to 2011. Drought-year flows for 2001 are also shown for comparison.

We estimate that our intensive sampling period in 2013 coincided with the arrival time in the estuary of 81% of yearling Chinook and 89% of steelhead passing Bonneville Dam (tagged and non-tagged) and 99% of yearling Chinook and 95% of steelhead transported for NMFS transportation studies. These numbers were similar to 2012 when, during our intensive sample period, an estimated 83% of yearling Chinook and 91% of steelhead that passed Bonneville Dam arrived in the estuary, along with 90% of transported yearling Chinook and steelhead.

Of fish passing through the estuary after we reverted to a single daily crew, 41% were subyearling Chinook salmon. This proportion was much lower than in previous years, primarily due to a significant reduction in tagging of subyearling Chinook in 2013 and an extended distribution of other species into later June due to lower flows. Subyearling life history strategies include migration during summer and fall, and a portion of these fish overwinter in freshwater and complete their juvenile migration the following spring.

In 2013 no transported yearling Chinook salmon or steelhead were released before our intensive sampling period began. After the intensive sampling period had ended, the majority of fish detected at Bonneville Dam were subyearling Chinook salmon. Transportation of subyearling Chinook continued until the end of October.

We sampled with the matrix trawl system for 889 h during 2013 and detected 22,879 PIT-tagged fish. By comparison, in 2012 we sampled for 951 h and detected 16,732 fish (Figure 4). A similar number of PIT-tagged fish were released during the spring migration in both years, but average detection rates were higher in 2013, at 26 h^{-1} than in 2012 (18 fish h^{-1}). Through years of sampling we have observed an inverse relationship between river flow volumes and trawl detection rates. Decreasing river flow volume is associated with an increased detection rate of fish previously detected at Bonneville Dam (a rough measure of sample efficiency, Morris et al. 2013).

There are a variety of factors contributing to the relationship between lower river flows and higher detection rates. First, low flows carry fish downstream slower than during higher flows. This maximizes the amount of time that a given fish is present in the sample reach and available for detection. Second, lower flows likely concentrate migrants in a smaller cross-sectional area of water. For any given fish that is present in the estuary during sampling, we expect that this narrower dispersion would increase its likelihood of passing through the trawl.

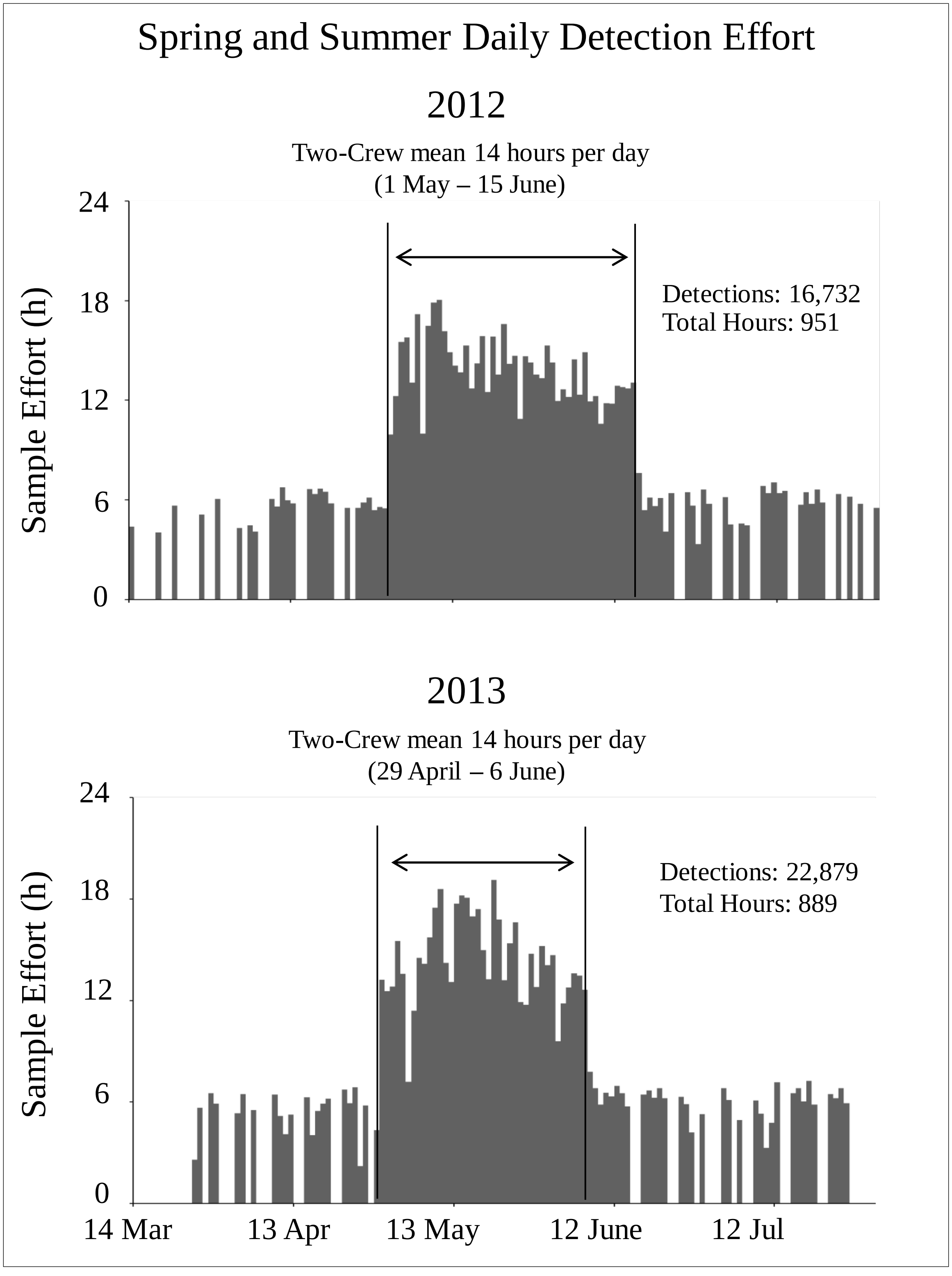

Figure 4. Daily sample effort in spring/summer 2012 and 2013 using a pair-trawl fitted with a "matrix" antenna for PIT-tag detection. Sampling was conducted near Jones Beach at Columbia River km 75 (rkm 61-83).

Lower flows also increase detection rates by increasing actual sample time in three ways. First, low flows decrease the transit time required for vessels to reach the upstream end of the sample reach, where the trawl is initially deployed. Second, low flows increase the time available for sampling with the trawl deployed before vessels drift below the downstream end of the sample reach, where the trawl must be retrieved. Finally, lower flows are typically accompanied by less debris accumulation in the trawl net. The larger fish-passage corridor of the matrix antenna provides some mitigation of this problem during higher flow years by allowing most debris to pass through the trawl, but some sample time is still lost while idling to allow for debris removal.

Antenna Performance

Estimated detection efficiencies were positively correlated with spacing between test tags, regardless of tag orientation. Of the 504 PIT-tags passed through the matrix antenna, only one test-tag spaced 30 cm apart was detected. This was the closest spacing interval tested. When spacing between tags was increased to 60 cm, detection efficiency increased to 96% for tags oriented perpendicular to the electronic field and 94% for tags at a 45-degree angle to the field. For test tags spaced 90 cm apart, reading efficiency increased to 100% for both perpendicular and angled tags. Results in 2013 were similar to previous years and showed the antenna was performing as expected.

Species Composition

In 2013 we detected a total of 22,537 juvenile salmonids of known species plus another 342 fish lacking release information in PTAGIS (Table 2; Appendix Table 1). For most identified fish, information on run-type and origin (hatchery or wild) was also available, however 165 had species data but no other information associated with their respective tags.

Of those fish detected having PIT-tag release information, 45% were spring/summer Chinook salmon, 5% were fall Chinook salmon, 41% were steelhead, 4% were sockeye, 3% were coho, less than 1% were cutthroat trout, and the remaining 1% were unknown salmonid species. Total detections by origin were 19% wild, 79% hatchery, and 2% unknown at the time of this report. These numbers may change slightly as incomplete PTAGIS records are updated by those responsible for tagging and releasing the fish.

Table 2. Species composition and origin of PIT-tagged fish detected with the trawl system in the upper Columbia River estuary near rkm 75 in 2013.

Species/run	Rear Type: Hatchery	Wild	Unknown	Total
Spring/summer Chinook salmon	8,745	1,647	8	10,400
Fall Chinook salmon*	983	56	22	1,061
Coho salmon	712	27	8	747
Steelhead	6,802	2,463	33	9,299
Sockeye salmon	912	17	94	1,023
Sea-run Cutthroat	0	7	0	7
Unknown	0	0	342	342
Grand total	18,154	4,218	507	22,879

* Includes 54 Snake River fall Chinook salmon released in 2012 that had overwintered in freshwater.

Differences in PIT-tagging strategies, hydrosystem operations, and the numbers of fish transported each year contribute to annual variations in the proportions of each species detected passing through the estuary each year (Figure 5). However, proportions by species of fish detected in 2013 were similar to proportions in recent years for all species.

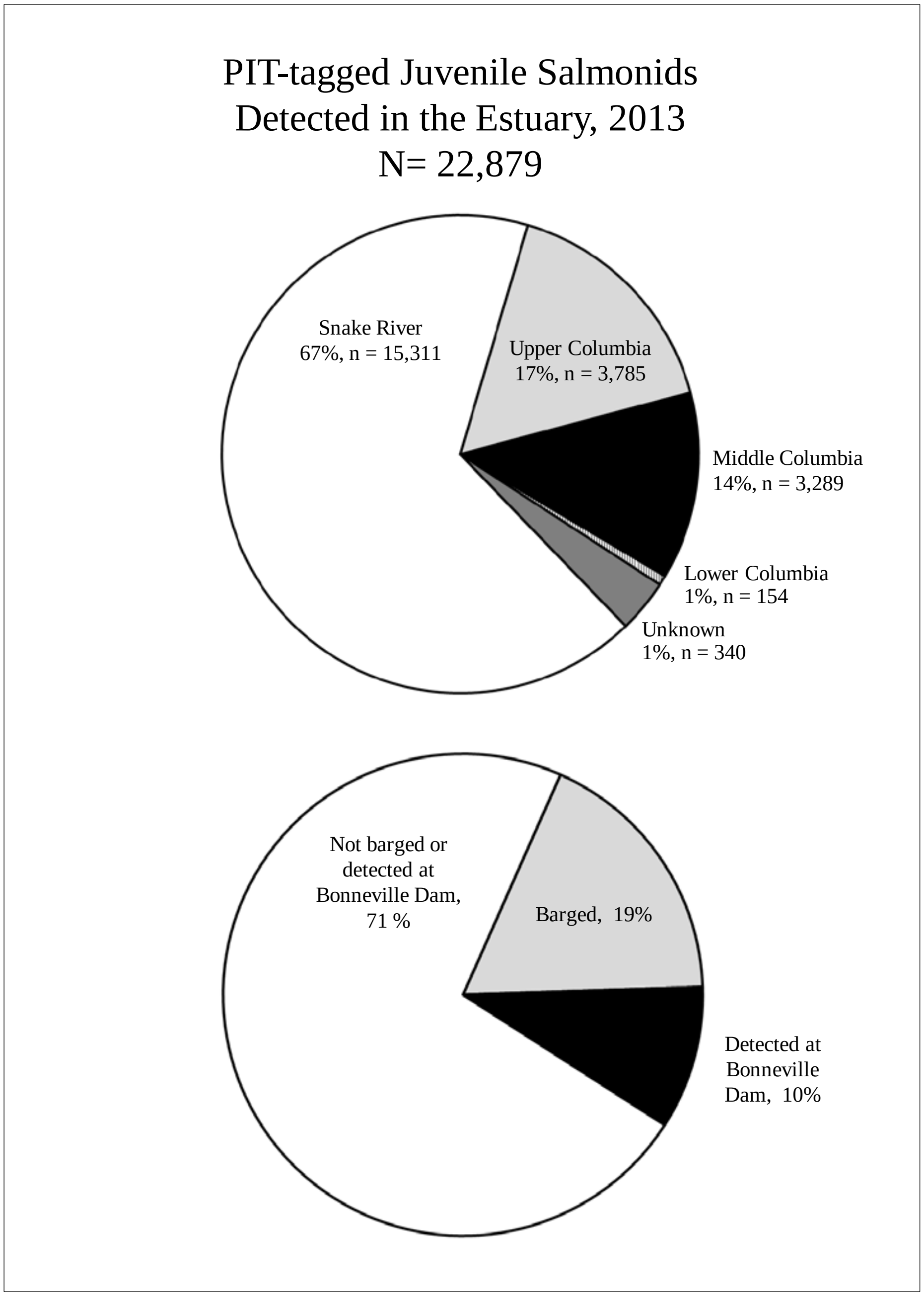

Figure 5. Proportions of fish detected in the trawl by source and migration history, 2013. Upper and mid-Columbia River sources were defined relative to McNary Dam. Fish that originated in the Columbia River below Bonneville Dam could not be transported, nor could they pass Bonneville Dam.

A proportion of juvenile fall Chinook salmon begin downstream migration in late spring, summer, or fall but suspend migration to overwinter within the hydrosystem and resume migration the following spring. These fish are said to adopt a "reservoir-type" life-history strategy (Connor et al. 2005). We detected 54 “reservoir-type” Snake River fall Chinook juveniles in the upper estuary between 29 March and 20 May 2013 (Appendix Table 2). According to release information in PTAGIS, 40 of these 54 fish had been released from the Big Canyon Creek acclimation facility on the Clearwater River (rkm 803), a tributary to the Snake River during 2012. Thirteen of the remaining 14 reservoir-type fish had been released at other locations on the Clearwater River, and one was released into the Deschutes River.

Using detection histories, we were able to determine the overwintering location for many of the reservoir-type fish. Thirty-one of the 54 fish we detected had been released in 2012 and detected at or above Bonneville dam in 2013 prior to detection in the trawl. Nine of the 31 were detected at a Snake River dam in 2013 prior to detection in the trawl. These observations indicated that the majority of reservoir-type fish we detected had overwintered in freshwater reaches far upstream, with most apparently overwintering in the Snake River.

Overwintering location for the remaining 23 reservoir-type fish could not be determined because they had not been detected in 2013 prior to detection in the trawl. However, none of these fish had been transported, and all but one were from stocks where cohort detection histories suggested overwintering in upriver reaches of the Snake River. Thus it is likely that these fish passed through the hydrosystem undetected in 2013 rather than overwintering in the estuary. These estuary detections contribute important information toward a better understanding of the life history diversity of Snake River fall Chinook salmon.

Impacts on Fish

During inspection or retrieval of the trawl we recovered juvenile salmonids that had been inadvertently impinged, injured, or killed during sampling. In 2013, we recovered 436 such salmonids from the matrix antenna system and trawl (Appendix Table 3). 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, likely because the sample gear is more visible in these areas.

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 now use a uniform color (black) of netting for the trawl body and cod-end areas, which has 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). To expedite fish passage, we flushed the net every 17 minutes and kept the trawl wings together for 5 minutes during each flush, with a 1 minute transition between opening and closing the trawl wings. Flushing also helped to clear debris and may have reduced delay, and possible fatigue, of fish pacing the net transition areas or lingering near the antenna. A majority of detections were recorded during these 7-minute net-flushing periods.

Fish appeared to move more readily through the system at night, probably because the trawl and antenna were less visible during darkness hours. Lower visibility at night also appeared to reduce the tendency of fish to pace near the entrance of the trawl body. A floor extending forward from the trawl body is meant to discourage fish from sounding to escape the trawl, but they likely sense the head rope and cork line that crosses between wings at the surface of the trawl body.

In past years, when a smaller cylindrical antenna was used with the trawl, most detections occurred during the short periods when we closed the wings to encourage fish to enter the trawl body and exit through the antennas. Since we began using the larger matrix antenna system, detections during periods when the wings are held open have increased by about 10% compared to the earlier cylindrical antennas (Magie et al. 2010). This increased volitional passage indicates that fish were more willing to approach and exit through the larger opening of the matrix antenna.

Analyses from Trawl Detection Data

Estimated Survival

Methods

Survival probabilities were 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), with detections designated as recaptures. To differentiate between fish that did not survive to a given point vs. those that passed without being detected; the model requires estimates of detection probability at the location of interest (i.e., Bonneville Dam). To estimate the probability of detection at a given point, detections downstream from this point are required. Thus, for calculating survival to Bonneville Dam, detections in the estuary are required.

For this analysis, weekly "release groups" of Snake River yearling Chinook salmon and biweekly groups for steelhead were created from fish detected passing McNary Dam during the same period. For fish originating in the upper Columbia River in 2013, detections at McNary Dam were insufficient to form weekly or biweekly groups, but these detections were used to estimate mean survival over the migration season (Faulkner et al. 2013). Similarly, for Snake and upper Columbia River sockeye salmon, estimates were limited to mean survival over the season due to small numbers of detections.

Estimates of survival probability under the CJS model are random variables, subject to sampling variability. When true survival probabilities are close to 100% and when sampling variability is high, it is possible for estimates of survival to exceed 100%. For practical purposes, these estimates should be considered equal to 100%.

Results and Discussion

Survival probabilities were estimated from McNary to John Day, John Day to Bonneville, and McNary to Bonneville Dams (Table 3). We compared weighted annual survival estimates for the years 1999-2013 for both Snake and Columbia River stocks (Figure 6). In some years, there were insufficient detections of some species for comparison between basins. We found no trends in survival over time for either basin or species.

Table 3. Average survival from the tailrace of McNary Dam to the tailrace of Bonneville Dam for weekly, biweekly, or seasonal groups of PIT-tagged salmonids by species, 2013. All estimates are hatchery and wild pooled groups, and fish were released from various locations upstream from McNary Dam. Standard error for each weighted mean estimate is shown in parenthesis.

Date of detection	Number detected at McNary Dam	McNary to John Day Dam	John Day to Bonneville Dam	McNary to Bonneville Dam
	Snake River wild and hatchery pooled groups			
Yearling Chinook				
20-26 Apr	921	0.695 (0.079)	0.781 (0.273)	0.542 (0.180)
27 Apr-3 May	5,317	0.937 (0.086)	0.872 (0.219)	0.818 (0.191)
4-10 May	23,049	1.048 (0.068)	0.849 (0.112)	0.889 (0.103)
11-17 May	12,032	0.915 (0.082)	0.867 (0.199)	0.793 (0.168)
18-24 May	2,868	0.922 (0.136)	0.750 (0.268)	0.691 (0.225)
25-31 May	1,615	0.719 (0.117)	0.554 (0.195)	0.399 (0.124)
Weighted mean		0.931 (0.054)	0.823 (0.036)	0.796 (0.064)
Steelhead				
20 Apr-3 May	4,860	0.812 (0.072)	0.833 (0.151)	0.677 (0.107)
4-17 May	5,316	0.826 (0.080)	1.217 (0.278)	1.005 (0.208)
18-31 May	1,562	0.698 (0.109)	1.563 (0.594)	1.090 (0.378)
1-14 Jun	775	0.741 (0.256)	0.677 (0.333)	0.501 (0.175)
Weighted mean		0.799 (0.025)	1.026 (0.154)	0.798 (0.112)
Sockeye				0.776 (0.106)
	Upper Columbia River wild and hatchery pooled groups			
Yearling Chinook				
Above Yakima R	134,287	0.955 (0.042)	1.073 (0.114)	1.025 (0.103)
Yakima River	83,435	0.797 (0.037)	0.954 (0.156)	0.760 (0.121)
Steelhead	88,892	0.953 (0.053)	0.955 (0.081)	0.910 (0.075)
Sockeye				0.658 (0.217)

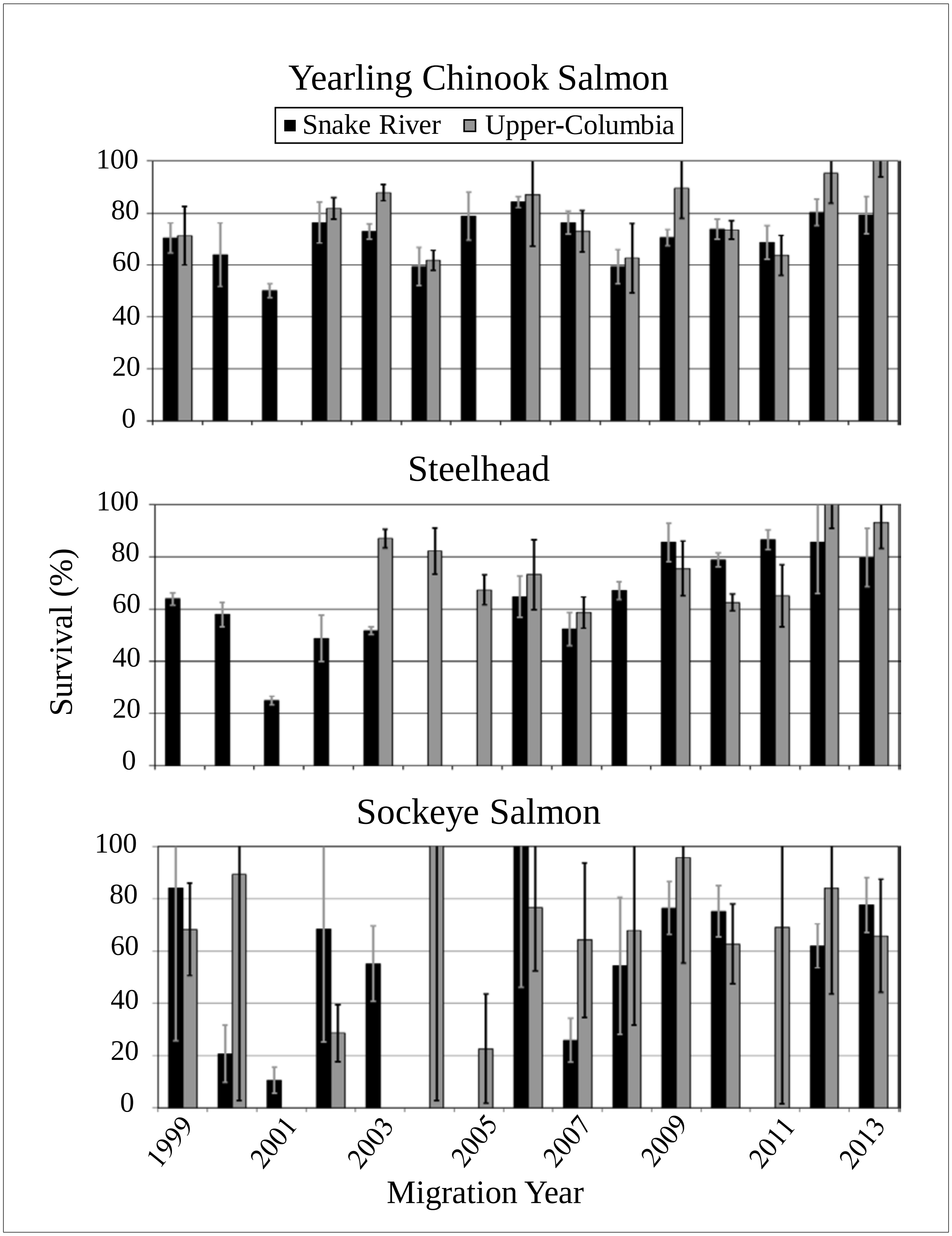

Figure 6. Weighted average annual survival and SE from the tailrace of McNary Dam to the tailrace of Bonneville Dam, for Snake and Columbia River yearling Chinook salmon, steelhead, and sockeye, 1999-2013.

For Snake River yearling Chinook salmon, estimated survival from McNary to Bonneville Dam tailrace was 79.6% in 2013 and has ranged from 50.1% in 2001 to 84.2% in 2006. For yearling Chinook originating in the upper Columbia River (upstream of the confluence with the Yakima River), the survival estimate in 2013 was the highest since estimates began in 2008 (102.5%), compared to the lowest estimate in the series in 2011 (58.4%). For yearling Chinook originating in the Yakima River and its tributaries, the survival estimate in 2013 was 76.0% and has ranged from 55.8% in 2012 to 88.3% in 2009. No estimate was possible in 2001 (a drought year) when the lowest rate of survival was estimated for Snake River yearling Chinook.

For Snake River steelhead, estimated survival from McNary to Bonneville Dam tailrace was 79.8% in 2013 and has ranged from 25.0% in 2001 to 86.6% in 2011. For upper Columbia River steelhead, survival in this reach during 2013 was 91.0% and has ranged from 106.9% in 2012 to 58.7% in 2007. No estimate was possible for upper Columbia River steelhead in 2001 when the lowest rate of survival was estimated for Snake River steelhead. Most Snake River smolts were transported in 2001 and were thus excluded from survival estimates.

In 2013, estimated survival for Snake River sockeye salmon from McNary to Bonneville Dam tailrace was 77.6%. Historically, estimated survival of these fish has ranged from 10.5% in 2001 to 111.3% in 2006. For upper Columbia River sockeye salmon, survival through this same reach was estimated at 65.8% in 2013 and has ranged from 22.6% in 2005 to 100% in 1998 and 2004. Survival estimates for sockeye stocks in all years have suffered from poor precision due to small sample sizes. Complete estimates of survival for these and other stocks are reported by Faulkner et al. (2013).

In 2012, seasonal average estimated survival through the entire hydropower system, from Lower Granite to Bonneville Dam tailrace, was 63.4% for yearling Chinook salmon and 59.7% for steelhead (Table 4). In 2013, overall hydrosystem survival estimates were 61.9% for yearling Chinook salmon and 51.5% for steelhead. Estimates for the same reach for sockeye salmon were 47.2 and 53.6% in 2012 and 2013, respectively.

The benefit of transportation for fish is expressed as the ratio of smolt-to-adult return rates (SARs) for transported vs. inriver migrant fish (T:I) in a given year. The annual T:I depends in part on conditions experienced by fish as juvenile migrants in the river and hydropower system. Higher survival for downstream juvenile migrants may be associated with higher flow volumes and faster transit times, although flow often varies widely within a single year, and seasonal average estimates of downstream survival do not reflect this variation.

However, survival probabilities for yearling Chinook salmon were much lower in 2001 (27.9%) and 2004 (39.5%) than in other years, and these two years were both characterized by extremely low river flows due to regional drought. Most fish were transported in those years because of the poor river conditions.

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, steelhead and sockeye, 1998-2013.

	Estimated seasonal average survival from Lower Granite to Bonneville Dam					
Migration	Yearling Chinook		Steelhead		Sockeye	
year	(%)	SE	(%)	SE	(%)	SE
1998	53.8	4.6	50.0	5.4	17.7	9.0
1999	55.7	4.6	44.0	1.8	54.8	36.3
2000	48.6	9.3	39.3	3.4	16.1	8.0
2001[a]	27.9	1.6	4.2	0.3	2.2	0.5
2002	57.8	6.0	26.2	5.0	34.2	21.2
2003	53.2	2.3	30.9	1.1	40.5	9.8
2004[a,b]	39.5	5.0	--	--	--	--
2005[b]	57.7	6.8	--	--	--	--
2006	64.3	1.7	45.5	5.6	82.0	45.4
2007	59.7	3.5	36.4	4.5	27.2	7.3
2008	46.5	5.2	48.0	2.7	40.4	17.9
2009	55.5	2.5	67.6	5.9	57.3	7.3
2010	56.9	3.2	60.8	2.6	54.4	7.7
2011	51.3	4.9	60.0	2.9	--	--
2012	63.4	4.2	59.7	13.8	47.2	6.2
2013	61.9	5.7	51.5	7.5	53.6	6.6

[a] Drought year when nearly all collected fish were transported rather than being returned to the river.

[b] In 2004 and 2005, the corner collector bypass structure at Bonneville Dam had no PIT-tag detection capability; as a result, detection numbers were too low for accurate survival estimates for some species in those years.

Similarly, survival estimates from the tailrace of Lower Granite Dam to the tailrace of Bonneville Dam in 2001 were exceptionally low for steelhead (4.2%) and sockeye (2.2%). However, in the drought years of both 2001 and 2004 all wild fish and most hatchery fish collected at juvenile facilities were transported, with few returned to migrate in the river.

Flow volumes at Bonneville Dam in 2013 were below average throughout the season except from 8 to 20 May, when they rose to above-average levels, peaking at 27% above the 10-year average. Flow continued to remain low to average through the end of July when sampling concluded. PIT-tag detections at Bonneville Dam increased in 2013 from lower levels in 2011 and 2012, even though basin wide tagging was significantly reduced in 2013. For example, in 2013 over 91,000 PIT-tag detections were recorded at Bonneville from releases of 1.9 million tagged fish, while in 2012 only 77,000 were recorded from releases totaling 2.6 million tagged fish.

In 2013, estimated survival from the tailrace of Lower Granite Dam to the tailrace at Bonneville Dam for yearling Chinook was the third highest in this reach since 1998. Steelhead survival in this reach was the lowest estimated since 2008, but above the long-term average. According to Faulkner et al. (2013), estimates of survival through the entire hydropower system were lower in 2013 than in recent years partly because of the low rates of survival estimated from Lower Monumental to McNary and from McNary to John Day Dam.

Relatively high survival for yearling Chinook and steelhead in recent years may be related to the operation of surface bypass structures at dams (Hockersmith et al. 2010; Axel et al. 2010, Plumb et al. 2004); these devices may particularly benefit juvenile steelhead, which tend to be more surface-oriented during migration. Low flow conditions in 2013 may have increased spillway passage because lower water velocities allow fish more time to react to conditions and may increase the attractiveness of surface bypass collectors (Faulkner et al. 2013). Surface bypass structures are currently used at five of the eight USACE dams on the lower Columbia and Snake Rivers.

The ability to estimate survival for sockeye salmon is dependent on detection rates and numbers of fish tagged each year. Recently, there has been an increased effort to tag upper Columbia and Snake River sockeye. The precision of Snake River sockeye annual survival estimates has improved since tagging effort for these stocks has increased. However, with increasing use of surface passage routes over the last few years, detection rates of these fish have remained relatively low, despite the increased tagging effort. At present, we assume sockeye survival is dependent on factors similar to those affecting survival of yearling Chinook salmon and steelhead. As tagging efforts for sockeye increase, it is increasingly important to consider development of PIT-tag detection capability for the surface bypass structures.

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 to calculate survival probabilities for fish detected at Bonneville Dam. These estimates are used in various research and management programs for endangered salmonids (Faulkner et al. 2013).

Trawl detections also allow comparison of relative detection percentages, travel speed, and other parameters between inriver migrant and transported fish groups after they comingle in the estuary and just prior to ocean entry. Annual releases of PIT tagged fish in the Columbia River basin have been near or exceeded 2 million for the past several years. Detections of these fish passing through the estuary have increased our understanding of behavior and survival during the critical freshwater-to-saltwater transition period.

Travel Time of Transported vs. Inriver Migrant Fish

Methods

We coordinated trawl system sample cruises with expected passage periods through the estuary of primarily yearling fish tagged and released for transportation and survival studies. After being collected at Lower Granite Dam (rkm 695), tagged study fish were either loaded to transport barges or returned to the river. Of fish remaining in the river, those collected at dams downstream from the release site were transported. Dams with transport facilities included Lower Granite, Little Goose (rkm 635), and Lower Monumental Dam (rkm 589). Transportation from McNary Dam (rkm 470) did not occur during our sample season. Our analysis included all transported fish detected in the trawl, regardless of the location from which they were transported.

To track fish recorded as having been diverted for transportation at any of the three transport dams, we created an independent database (Microsoft Access) using data downloaded from PTAGIS. 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 last detected at a dam on a route that ended at a transport raceway, according to monitor locations on the PTAGIS site map. Some fish had tag codes that indicated the fish was pre-designated for transport, but there was no record of detection on a transport raceway. These records were excluded from our transportation analysis, as were fish removed for biological or other samples.

The U.S. Army Corps of Engineers provided individual barge-loading dates and times for each dam throughout the 2013 transportation season (John Bailey, USACE, personal communication). By comparing barge-loading times with the last detection time of fish diverted to transport raceways, we determined the individual barge-transport trip for each fish. With this information, we were able to derive the specific date, time, and release location of each individual transported fish. Travel time and relative survival to the estuary for these fish was compared with that of fish detected at Bonneville Dam. We modified the PTAGIS information in our local database to include these migration-history data. We then created paired comparison groups of fish either released from transported barges or detected at Bonneville Dam on the same date.

For PIT-tagged yearling Chinook and steelhead, we plotted seasonal travel-time distributions of fish detected at Bonneville Dam and those of fish transported and released just downstream from the dam. Transported and inriver-migrant fish groups were plotted using the medians of daily group travel-time distributions. Travel time (in days) to the estuary was calculated for each fish on each date by subtracting time of barge release or detection at Lower Granite or Bonneville Dam from time of detection at Jones Beach.

A paired *t*-test was used to evaluate temporal differences in mean travel speed to Jones Beach between inriver migrants and transported fish. Daily median travel speeds (km d^{-1}) were calculated based on the distance traveled from barge release or dam detection to detection in the estuary, divided by travel time. Daily median travel speeds were plotted through their respective periods of availability for comparison, along with flow data based on daily average discharge rates at Bonneville Dam (m^3 s^{-1}).

Results and Discussion

Yearling Chinook Salmon and Steelhead—Seasonal median travel time (d) from the tailrace of Lower Granite Dam (rkm 695) to detection in the trawl at rkm 75 is presented for yearling Chinook salmon and steelhead (Table 5).

For yearling Chinook salmon detected during the intensive sampling period (29 April to 6 June), median travel time from Lower Granite Dam to the estuary was the fastest on record (14.1 d). Median travel time for steelhead through the same reach was slower in 2013 (11.6 d) than in 2012 (11.2 d), but the third highest since 2000. Thus, travel times from Lower Granite Dam to the estuary in 2013 were among the fastest on record for both species, even though low-to-average flow volumes were present throughout most of the migration season.

Table 5. Median travel time to detection in the upper estuary for yearling Chinook salmon and steelhead detected at Lower Granite or Bonneville Dam or released from barges just downstream from Bonneville Dam, 2000-2013. Also shown are mean flow rates at Bonneville Dam from mid-April through June (approximate spring migration periods).

	Detection at Lower Granite Dam (rkm 695) to rkm 75				Detection at Bonneville Dam (rkm 234) to rkm 75				Release from transportation barge (rkm 225) to rkm 75				
	Yearling Chinook salmon		Steelhead		Yearling Chinook salmon		Steelhead		Yearling Chinook salmon		Steelhead		
Year	Travel time (d)	Sample (n)	Travel time (d)	Sample (n)	Travel time (d)	Sample (n)	Travel time (d)	Sample (n)	Travel time (d)	Sample (n)	Travel time (d)	Sample (n)	Flow ($m^3 s^{-1}$)
2000	17.4	681	17.1	833	1.7	479	1.7	296	1.9	495	1.6	301	7,415
2001	32.9	680	30.1	44	2.3	792	2.5	59	2.9	1,329	2.3	244	3,877
2002	18.2	538	17.8	93	1.8	1,137	1.7	156	2.0	1,958	1.6	296	8,071
2003	17.0	563	16.5	95	1.8	1,721	1.7	567	2.1	2,382	1.7	435	7,120
2004	16.6	867	16.6	153	1.9	672	2.0	110	2.2	2,997	1.9	333	6,663
2005	17.3	1,183	16.9	278	1.8	81	2.0	471	2.2	2,910	1.9	400	5,776
2006	14.7	628	12.5	110	1.7	888	1.6	131	2.1	1,315	1.6	170	9,435
2007	15.7	1,196	15.6	117	1.7	1,510	1.7	362	2.2	1,096	1.7	143	6,858
2008	18.3	568	14.4	392	1.7	749	1.6	830	2.1	1,884	1.6	788	8,714
2009	18.7	1,188	15.4	1,321	1.7	1,438	1.7	892	2.1	1,681	1.6	1,325	7,871
2010	16.1	581	14.8	303	2.0	3,258	1.9	2,188	2.2	1,149	2.0	1,068	6,829
2011[a]	17.8	335	15.5	348	1.8	240	1.6	216	2.1	673	1.6	831	7,911
2011[b]	13.2	259	10.0	198	1.5	39	1.3	47	1.6	418	1.5	275	13,462
2012	15.4	755	11.2	627	1.6	485	1.5	321	2.0	567	1.5	1,116	10,056
2013	14.1	542	11.6	366	1.6	645	1.6	745	2.2	1,029	1.6	1,333	7,470

[a] Early migration period prior to the increase in river flow about 16 May.

[b] Late migration period during the high flow event beginning about 16 May.

Median travel time to the estuary from Bonneville Dam was the same in 2013 as in 2012 for yearling Chinook (1.6 d). Median travel time from Bonneville was slightly slower for steelhead in 2013 than in 2012 (1.6 vs. 1.5 d). Transported yearling Chinook salmon released just below Bonneville Dam traveled slower to the estuary in 2013 than they did in 2012 (median 2.2 d vs. 2.0 d). Transported steelhead median travel time in 2013 was also slower than in 2012 (1.6 d vs. 1.5 d).

We also compared daily differences in travel speed to the estuary relative to changing river flow volume between transported and inriver migrating fish (Figure 7). Overall, the daily mean travel speed to the estuary was significantly slower for yearling Chinook salmon released from barges (71 km d^{-1}) regardless of flow than for those traveling inriver and detected at Bonneville Dam (96 km d^{-1}; $P \leq 0.001$). Mean travel speed was also significantly slower for steelhead released from barges (93 km d^{-1}) regardless of flow than for those detected at Bonneville (100 km d^{-1}; $P \leq 0.001$) on the same day. These differences in travel speed by migration history, particularly for yearling Chinook salmon, were similar to observations from previous years.

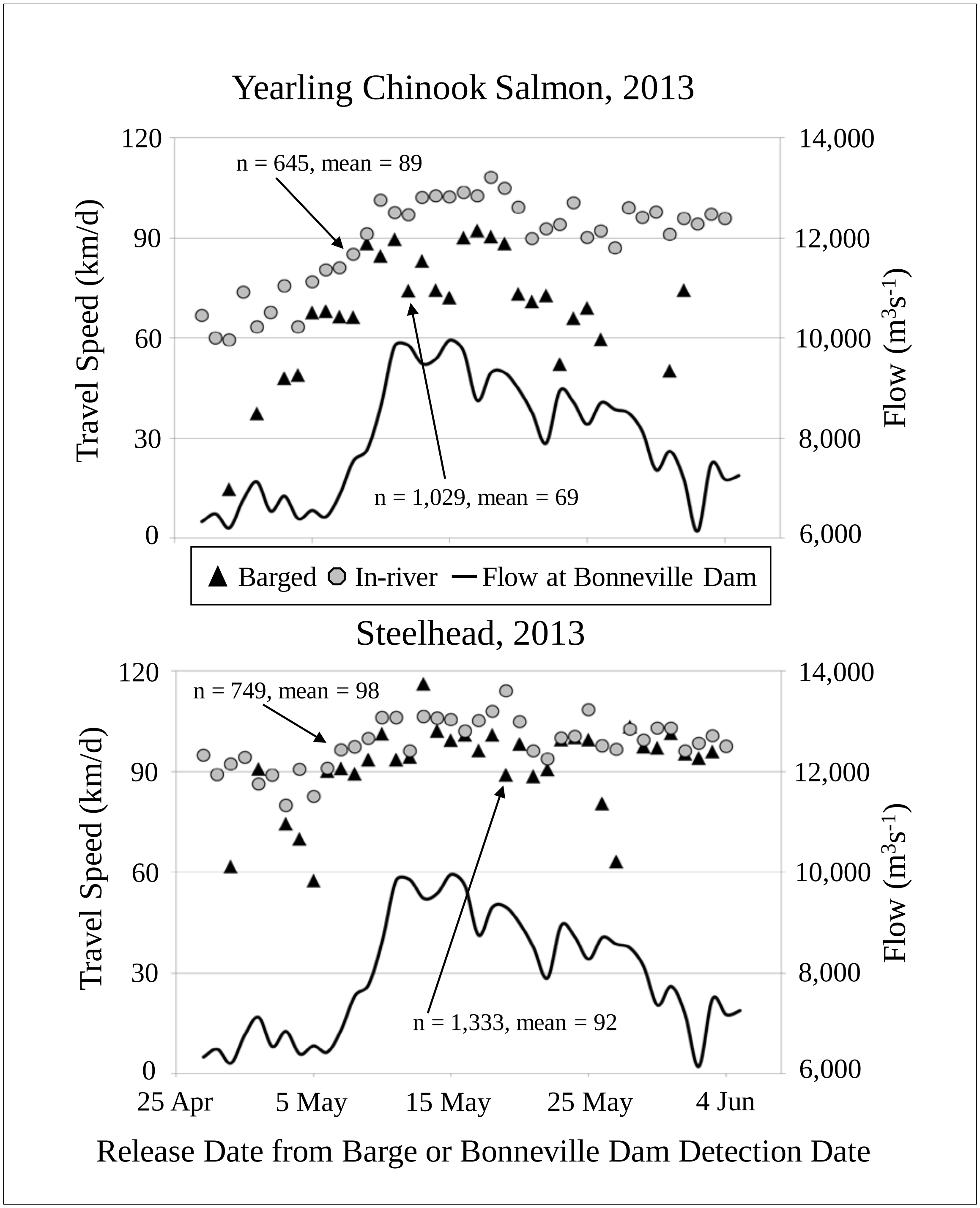

Figure 7. Daily median travel speed to the estuary of yearling Chinook salmon (top) and steelhead (bottom) following detection at Bonneville Dam or release from a barge to detection in the estuary (rkm 75), 2013. Seasonal means of daily medians are shown for comparison with flow.

Subyearling Fall Chinook Salmon—We detected 477 subyearling fall Chinook salmon, 463 of which had been released after 29 April 2013 and all were less than 120 mm fork-length at tagging. Most fall Chinook salmon released prior to 30 April were yearlings, and were greater than 120 mm FL when tagged. We detected 15 transported and 462 inriver migrant subyearling fall Chinook salmon between May and late July (Figure 8). Of all subyearlings detected by the trawl system, 45% originated in the Snake River, 31% in the Upper Columbia River (at or upstream from McNary Dam), 22% in the mid-Columbia River (between Bonneville and McNary Dam), and the remaining 2% in the Lower Columbia River (downstream from Bonneville Dam). Due to the end of a large subyearling tagging study in the Snake River, these proportions have shifted from predominately Snake River origin to a more even distribution of release sites.

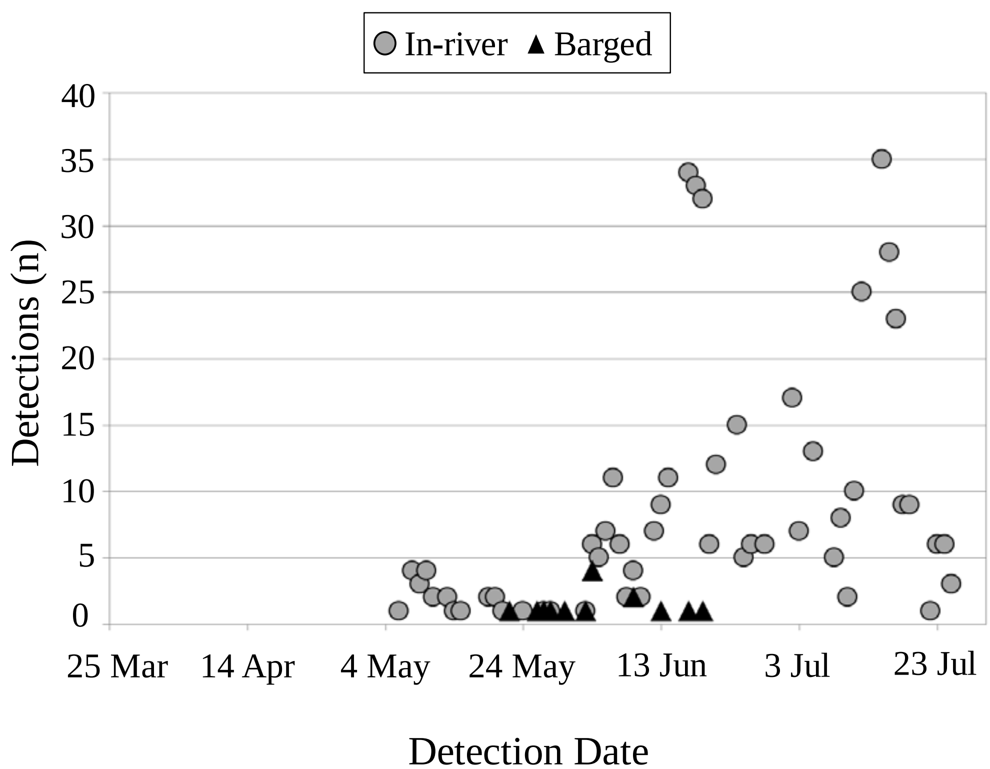

Figure 8. Temporal detection distribution for subyearling Chinook salmon in the estuary during inriver migration (n = 462) or following release from barges below Bonneville Dam (n = 15), 2013.

In prior years we have compared daily median travel speed to the estuary for subyearling fall Chinook salmon detected at Bonneville Dam (inriver migrants) with transported fish released just downstream from Bonneville Dam. In 2013, a meaningful comparison could not be made due to lack of trawl detections for both groups (17 inriver and 15 transported fish). This drop in detection numbers was due to a decrease in tagging of subyearling Chinook in the Snake River basin (over 610,000 released in 2012 and only 65,000 in 2013). Analysis in prior years has consistently shown significantly faster travel speeds for subyearling fall Chinook detected at Bonneville than for those released from transport barges (Morris et al. 2013).

Sockeye Salmon—We detected 1,023 sockeye salmon between 9 April and 2 July (Figure 9). Of these, 89% were hatchery fish, 2% were wild fish, and the remaining 9% were of unknown origin. Transported fish accounted for 459 of the 1,023 sockeye detections. Of those transported, 308 had been transported from Lower Granite Dam, 121 from Little Goose Dam, and 30 from Lower Monumental Dam. Fish released in the Snake River Basin made up 83% of our sockeye detections, while fish released in the Columbia River Basin upstream from McNary Dam made up 16%. The remaining 1% had been released to Columbia tributaries below McNary Dam or were of unknown origin. Of the 564 inriver migrant sockeye we detected, 78 had been previously detected at Bonneville Dam. Mean travel speed from Bonneville Dam to detection in the trawl was similar between sockeye detected at Bonneville Dam and transported fish released below Bonneville Dam (103 vs. 106 km d^{-1}; Figure 10).

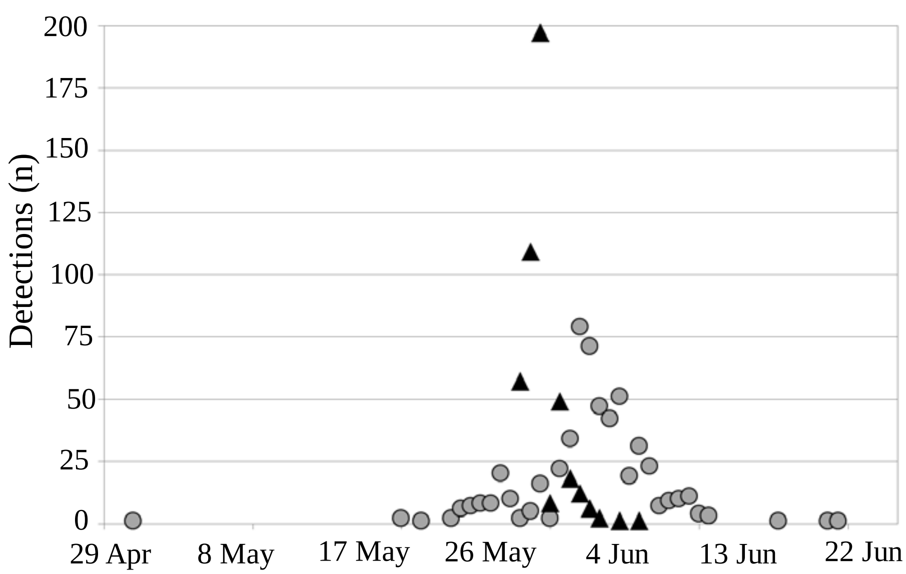

Figure 9. Temporal distribution of sockeye salmon detections in the estuary during inriver migration (n = 564, gray circles) or following release from barges below Bonneville Dam (n = 459, black triangles), 2013.

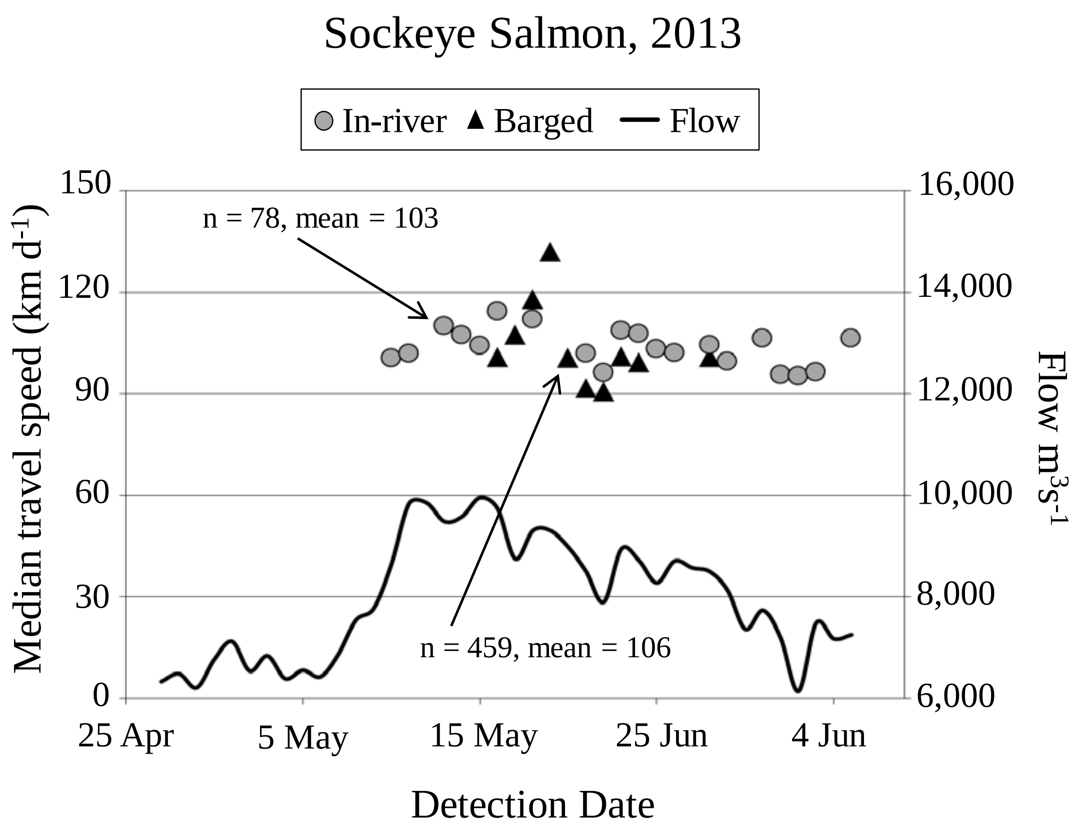

Figure 10. Daily median travel speed to the estuary for transported vs. inriver migrant sockeye salmon following detection at Bonneville Dam or release from a barge to detection in the estuary (rkm 75), 2013. Daily river flow volume at Bonneville Dam is shown for comparison.

In summary, travel speed for all migration histories and species of juvenile salmonids from the area of Bonneville Dam to the estuary was similar to that of previous moderate flow years. Travel speed from Lower Granite Dam to the estuary, however, was among the fastest on record for both yearling Chinook and steelhead. While faster travel speeds have been correlated to higher flow volumes in the past, faster speed in 2013 was likely a combination of the short high flow period in May and increased use of surface bypass structures during the lower flow periods (Faulkner et al. 2013).

Diel Detection Patterns

Methods

As in previous years, we found that wild and hatchery fish (as designated in PTAGIS) had similar trends in diel availability. Detection numbers during daylight and darkness hours were compared using a one-sample *t*-test (Zar 1999) on the daily ratios of detection numbers per hour (note: test was computed using natural log transformation to improve normality assumption, and estimated means were back-transformed). For this analysis, the number of detections and the number of minutes that the system was operated were separated into daylight and darkness-hour categories for each date during the intensive sampling period. Daily daylight/darkness detections for each species were weighted by the number of minutes that the detection system was operating during that date. For this analysis, we excluded dates when sample effort was reduced, i.e., missed or partially missed shifts. Detections of yearling Chinook salmon and steelhead were sufficient to complete this analysis; detections of sockeye and subyearling Chinook salmon were not.

Results and Discussion

During the intensive (2 shifts d^{-1}) sample period of 29 April-6 June, we detected 10,569 yearling Chinook salmon and 8,903 steelhead with the detection system operating an average of 14 h d^{-1} (Appendix Table 4). We generally stopped sampling each day between 1400 and 1900 PDT for crew changes and fueling of vessels.

Throughout the intensive sampling period, the hourly detection rates of hatchery yearling Chinook salmon were significantly higher during nighttime (20:30 to 04:30; 2.6 times higher) than during daytime hours ($P < 0.001$), although the observed seasonal difference was smaller (20 vs. 10 fish h^{-1}). The analysis assumes that the difference in hourly detection rates is constant through the season. However, for hatchery yearling Chinook salmon, the average for the first 2 weeks (lower total numbers) was around 5 times higher for nighttime detections, while the average for the rest of the season (higher total numbers) was around 2 times higher. The discrepancy is apparent from (Figure 11). Hourly detection rates of wild yearling Chinook salmon were significantly higher during nighttime hours than during daytime hours (3 vs. 2 fish h^{-1}, or 1.5 times higher, $P = 0.002$). Hourly detections rates were significantly higher for daylight hours than for darkness for both hatchery and wild steelhead (15 vs. 5 hatchery fish h^{-1}, or 3 times higher, $P < 0.001$ and 6 vs. 2 wild fish h^{-1}, $P < 0.001$).

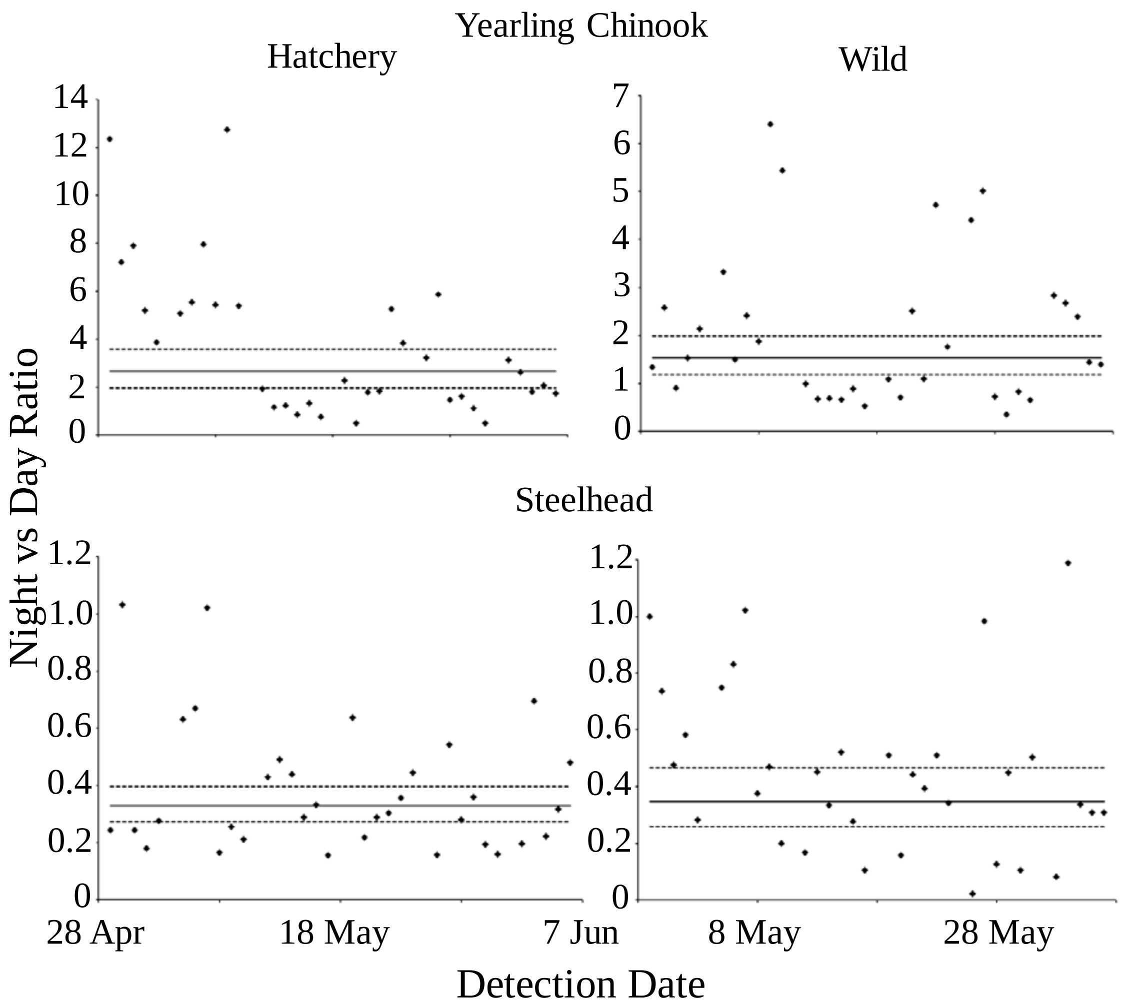

Figure 11. Daily nighttime-to-daytime detection ratios for wild and hatchery yearling Chinook and steelhead (28 April to 7 June). Daily ratios greater than 1.0 indicate a higher catch per hour in darkness hours, and values less than 1.0 indicate a higher catch per hour in daylight hours. Solid lines are estimated mean ratios, and dotted lines are estimated 95% confidence intervals. (Note that data were log-transformed for the estimation.)

In each year since 2003, hourly detection distributions have been similar between rear-types for both yearling Chinook salmon and steelhead. These numbers were similar again in 2013, so we pooled data by species and origin for a multi-year summary (Figure 12). Detection rates for yearling Chinook salmon have typically been higher, and often significantly higher, during darkness than daytime hours. Detection rates of steelhead have generally been higher during daylight hours, but often not significantly higher.

Detection numbers in 2013 were again higher during darkness for hatchery and wild Chinook salmon. For steelhead, detection rates for both hatchery and wild rearing types were higher during daylight than during darkness. The larger fish-passage opening of the matrix antenna system and its location near the surface probably resulted in less gear avoidance than in earlier years using smaller antennas, particularly during daylight hours with improved visibility.

Purse-seine sampling in this river reach has indicated peak catches for steelhead in the afternoon hours between 1400 and 1600 PDT (Ledgerwood et al. 1991). In 2013, steelhead made up 41% of total pair-trawl detections. Our practice of fueling, crew-change, and maintenance during the late-afternoon periods of high wind probably caused us to miss additional detections of steelhead. However, recurring periods of difficult weather in late afternoon would have interfered with sampling during these hours, even had we refueled at other times. Similarly, sampling at both dusk and dawn was made possible by extending the evening shift overnight until relieved by the day shift, and this strategy probably maximized detection of yearling Chinook salmon.

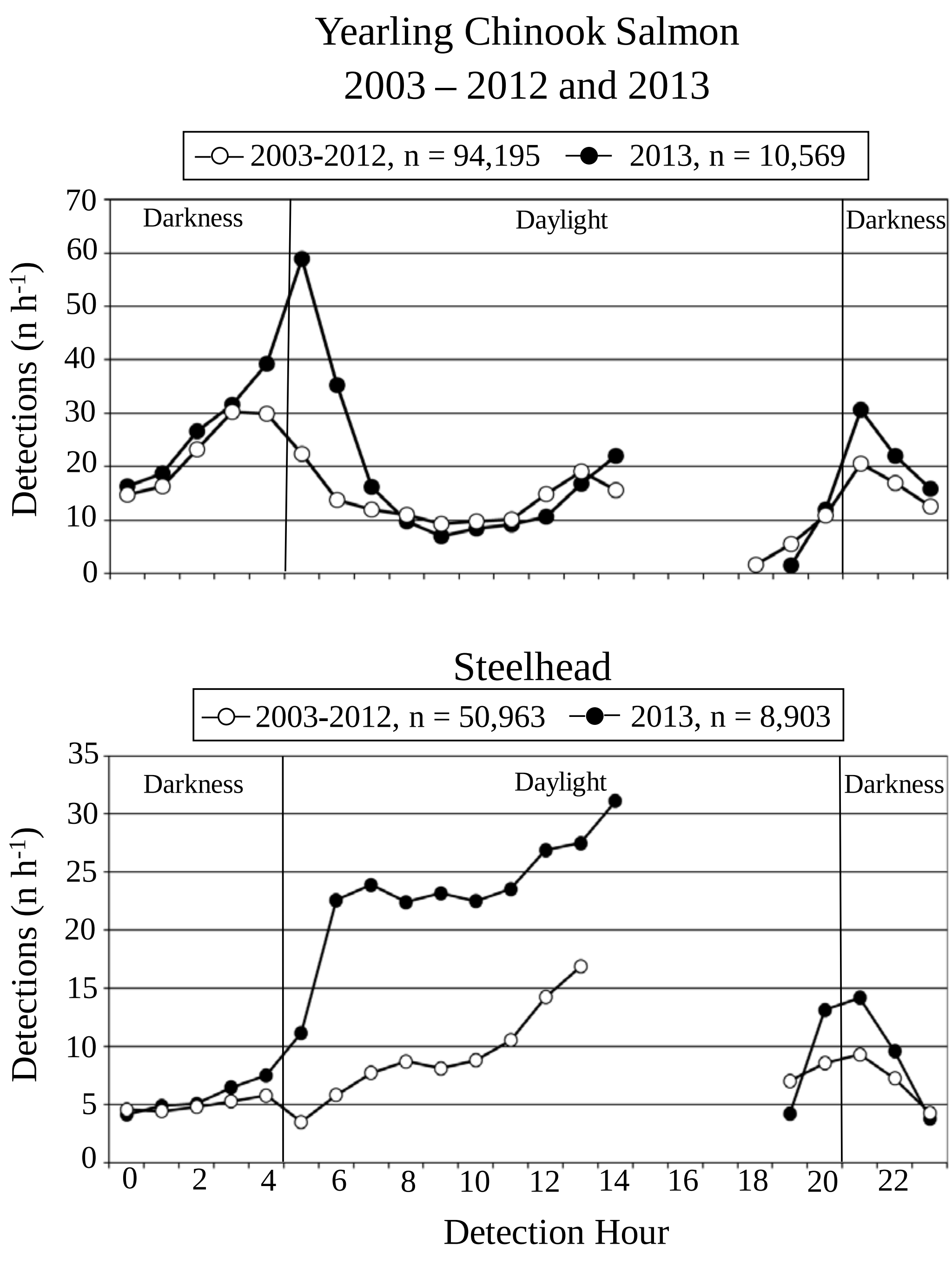

Figure 12. Average hourly detection rates of yearling Chinook salmon and steelhead during the two-shift sampling periods of 2003 through 2012, vs. 2013, using the matrix antenna system in the upper estuary near river kilometer 75.

Detection Rates of Transported vs. Inriver Migrant Fish

Methods

We compared daily detection rates in the trawl between transported fish[1] and inriver migrants previously detected at Bonneville Dam during the two-shift sample period. Detection data was evaluated 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). Daily groups of inriver migrants detected at Bonneville Dam were compared with daily groups of transported fish released from a barge on the same day. Study groups included only yearling fish released at or upstream from Lower Monumental Dam. Fish released from a barge just after midnight (3) were compared with fish detected the previous day at Bonneville Dam. 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 error distribution. Daily detection rates were then estimated as:

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

where $\hat{\beta}$ was the coefficient of the components (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 we fit the model containing interactions between treatment and date and date-squared. We then determined the amount of overdispersion relative to that assumed from a binomial distribution (Ramsey and Schafer 1997). Overdispersion was estimated as "σ," the square root of the model deviance statistic divided by the degrees of freedom. The model estimates what the observed variance is from the expected variance in the data, after accounting for the variables in the model (i.e., treatment, date, date-squared). Over-dispersion is the "difference" between the expected and the observed variances. If $\sigma > 1.0$, we adjusted the standard errors of the model coefficients by multiplying by σ

[1] Excluded from our analysis were approximately 36,000 special study fish transported from Lower Granite Dam that had been triple handled.

(Ramsey and Schafer 1997). This inversely adjusted the *z* statistic used to test the significance of the coefficients, as well as appropriately inflated estimate standard errors. Finally, if the interaction terms were not significant (likelihood ratio test $P > 0.05$), these terms were removed and we fit a reduced model.

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. One constraint was that date-squared could not be in the model unless date was included as well. 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.

The daily barged and inriver groups had similar diel distributions in the sampling area and presumably passed the sample area at similar times (Magie et al. 2011). 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 during passage from Bonneville Dam to the trawl.

Results and Discussion

Including river-run fish diverted to barges and fish tagged and transported for other studies, a total of 67,176 yearling Chinook salmon and 63,641 steelhead were transported and released upstream from our sample site during the intensive sample period. Of these fish, we detected 1,243 yearling Chinook salmon and 2,228 steelhead in the upper estuary (Appendix Tables 5-6). We detected 649 (2.7%) of the 24,045 yearling Chinook salmon released upstream from McNary Dam and detected at Bonneville Dam and 752 (3.8%) of the 19,599 steelhead released upstream from McNary Dam and detected at Bonneville Dam (Appendix Table 7).

As in previous years, a portion of both PIT-tagged inriver migrant and barged groups passed through the estuary either before or after the trawl-sampling period. In 2013, allowing 2 d for fish at Bonneville Dam to reach the sample area, we estimate that 82% of yearling Chinook and 89% of steelhead detected at Bonneville Dam and 98% of yearling Chinook and 95% of steelhead released from barges were at or near rkm 75 during the two-shift sample period (29 April-6 June). Inriver percentages in 2013 were similar to 2012 while transport percentages were higher than in 2012 because barging did not occur prior to the start of our intensive sampling period in 2013 as it had in 2012.

During the intensive sampling periods of 2012 and 2013, we average 14 sampling hours per day each year. In 2013 detection rates of both transported fish and fish detected passing Bonneville Dam were higher than in 2012 (Table 6). We believe the higher detection rates of all groups in 2013 were related to the lower flow conditions.

Table 6. Trawl detection rates of PIT-tagged fish released from barges or detected passing Bonneville Dam during the intensive sample periods, 2012 and 2013.

	Barged fish originating upstream from McNary Dam			In-river fish detected at Bonneville Dam*		
	Released	Detected		Released	Detected	
	n	n	(%)	n	n	(%)
2012						
Chinook salmon	51,685	666	1.29	28,252	486	1.72
Steelhead	49,911	1,757	3.52	12,481	325	2.60
2013						
Chinook salmon	64,730	1,243	1.92	24,045	649	2.70
Steelhead	60,660	2,228	3.67	19,599	752	3.84

* Inriver fish included only those released at or upstream from McNary Dam, although no fish were transported from McNary Dam in 2013.

For yearling Chinook salmon, logistic regression analysis showed a significant temporal interactive relationship between migration history and date (P = 0.029). The date relationship was linear on the logistic scale, as date-squared was not significant (P = 0.423), nor was there a significant interaction between migration history and date-squared (P = 0.294).

Estimated detection rates for inriver migrants decreased gradually from around 2.9% early in the season to 2.5% by early June (Figure 13, top panel). Estimated detection rates for transported yearling Chinook salmon were briefly higher than inriver migrants in late April (3.3%) but fell more sharply to 0.7% in early June The adjustment for over-dispersion was 5.12.

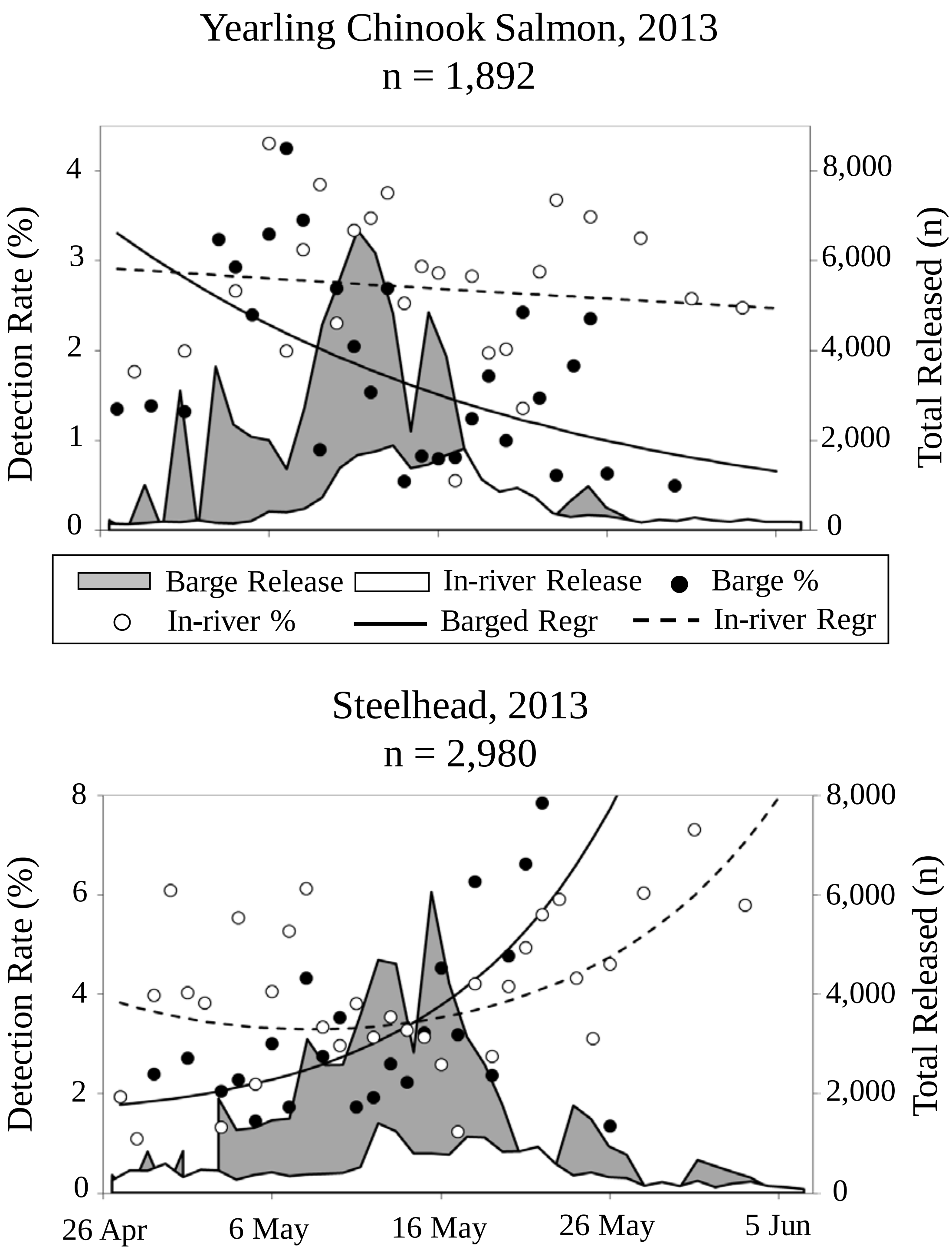

Figure 13. Logistic regression analysis of the daily detection percentage of transported and inriver migrant yearling Chinook salmon and steelhead detected at or released near Bonneville Dam on the same dates, 2013.

For steelhead, there was a significant interaction between migration history and date but not between migration history and date-squared (P = 0.001, P = 0.875, respectively). The date relationship was non-linear on the logistic scale, as date-squared was significant (P = 0.030). Estimated detection rates of inriver migrant steelhead decreased from 3.8% in late April to 3.2% in early May (Figure 13, lower panel) then rose to 7.9% by early June. Estimated detection rates for barged steelhead increased sharply from early to late season (1.8 to 18.6%) The adjustment for over-dispersion was 6.42.

Except during the early season, mean detection rate in the trawl for yearling Chinook salmon, was considerably higher for fish previously detected at Bonneville Dam than for transported migrants released below the dam. For steelhead, early season detection rates were higher for inriver fish than for transported fish but the difference was reversed after mid-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.

In summary, estuary detection rates were higher in 2013 than those in the high flow years of 2011 and 2012. Detection rates of fish passing Bonneville Dam were higher in 2013 compared to the last two years as well, but lower than in other low-to-moderate flow years like 2010. In 2011, fish guidance structures were removed from Bonneville Dam due to high debris loading and therefore fish were not being guided into the juvenile bypass system, where the majority of the PIT-tag detection occurs.

In 2012 and 2013 a management decision at Bonneville Dam to operate the Second Powerhouse turbines at the middle 1% efficiency moved some flow to the First Powerhouse and spillway, which lack PIT-tag detection capability, thus reducing overall detection rates at Bonneville Dam. Even with this management action in 2013, lower river flow contributed to an increased number of fish detected in the estuary used for estimating survival to the tailrace of Bonneville Dam. Estuary detections of fish previously detected at Bonneville Dam are fundamental to estimating survival probabilities for downstream migrating salmonids.

Development of a Flexible Antenna Detection System

During the winter of 2012 we experimented with a new transceiver system (IS1001 MTS full duplex PIT-tag transceiver, Biomark, Inc.[2]). We constructed antennas using the MTS system that were larger by a considerable magnitude than those possible using the MUX transceiver system currently used with our trawl system. We built these larger antennas primarily for use on a pile dike PIT-tag detection system targeting adult salmonids near rkm 71 (PTAGIS site code PD7, Magie et al. 2013). In 2011 and 2012, DIDSON acoustic camera observations at PD7 suggested considerable antenna avoidance by adult salmonids, we discovered that fish were passing by the antenna opening rather than passing through as desired.

The original PD7 antenna coils were similar in size to those used with our trawl system but were affixed to each other to create an antenna with overall dimensions of 2.4 m in width and 6.1 m in height. Using the new MTS transceiver, we were able to construct an antenna with a single fish-passage opening measuring 3.0 by 6.1 m. This prototype antenna was constructed using a housing made of rigid 10.1-cm diameter PVC pipe, the same housing used with the trawl and earlier pile dike detection systems. We deployed that antenna and other slightly smaller antennas (2.4 × 6.1 m) at PD7 in March 2013.

Testing during the initial deployment showed that the 3.0-m wide rigid PVC antenna appeared more fragile in the current at PD7 than the narrower antennas, and after several months of operation it developed a leak. We removed the antenna from PD7 and attempted to patch the leak. We then used the antenna to test a mobile application similar to the trawl system but with short mesh wings attached alongside each 6.1-m-long antenna side (Figure 14). The fish-passage opening of this MTS antenna was seven times larger than that of a single antenna coil used with the current trawl system. We attempted a single deployment of this antenna with wings on 14 June 2013, without PIT-detection electronics. Our goal was to evaluate the stresses on the antenna and determine deployment logistics.

[2] Reference to trade name does not imply endorsement by the National Marine Fisheries Service, NOAA.

We towed the winged-antenna at varying speeds for about 2 h. Deployment and retrieval proved cumbersome and complicated because of the rigid antenna structure. Because the antenna could not be loaded aboard the tow vessel, we towed it floating horizontally on the surface to the deployment area.

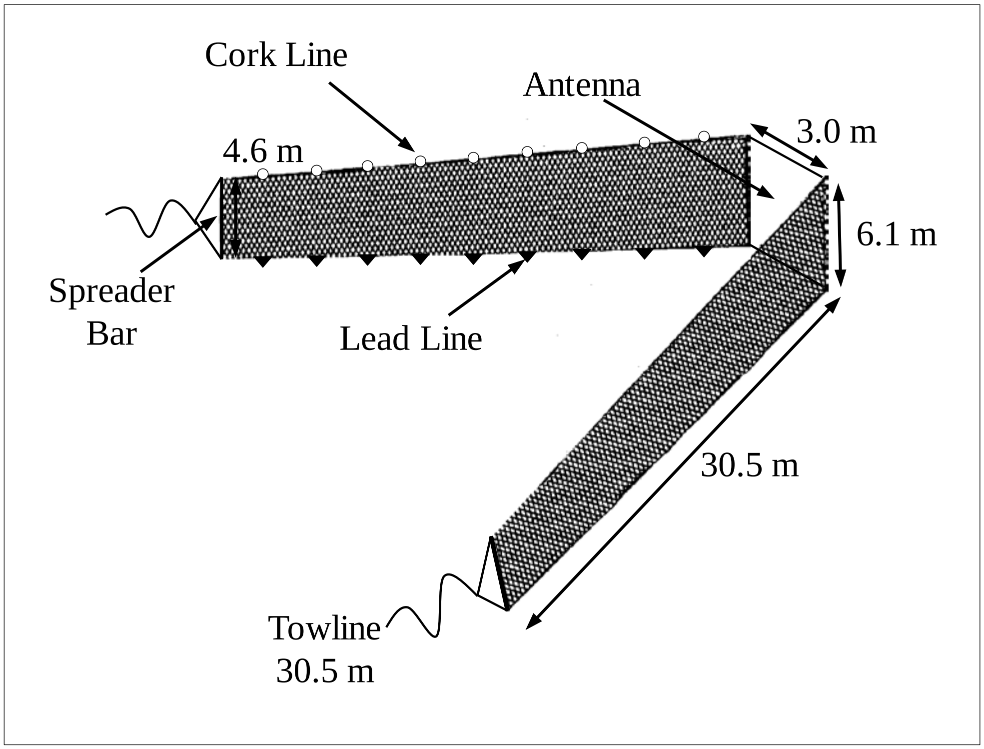

Figure 14. Basic design of the towed (3.0 × 6.1 m), PVC antenna with 2.54-cm mesh wings that was tested in June 2013.

Once in position, we attached wings to the antenna and added sufficient lead (113 kg) to the bottom of the antenna to position it vertically in the water column for testing. The wings were meant to evenly spread stress along each side of the antenna under tow, and considerable time and effort was required to properly prepare it for testing, including securing the lead weights to the bottom of the antenna (and later removing the lead).

Once completely assembled, the antenna towed reasonably well at slow speeds. However, when the tow speed was increased moderately, the antenna began to bow and vibrate excessively. At higher speeds, the antenna became contorted in the current and appeared to exceed reasonable stress limits for plastic pipe. Indeed by the end of the deployment test, cracks had developed in two corners of the housing, again compromising the antenna with water intrusion. This single test showed that we could tow an antenna of this size; however, further development was needed to address the major structural and gear-configuration concerns.

We next constructed and tested a 2.4 by 6.1 m antenna housed in 1.9-cm diameter flexible PVC hose. The flexible antenna could be easily transported with a skiff and stowed there during transit to the sample site. To prohibit overstretching, we attached a frame made of rope and 2.4-m spreader bars to the flexible antenna housing. We added a cork line to the top of the frame and lead line to the bottom. The antenna was towed horizontally and maintained in position using buoys and lead weights on either end of the spreader bars (Figure 15). The flexible design simplified deployment problems and was forgiving when under tow.

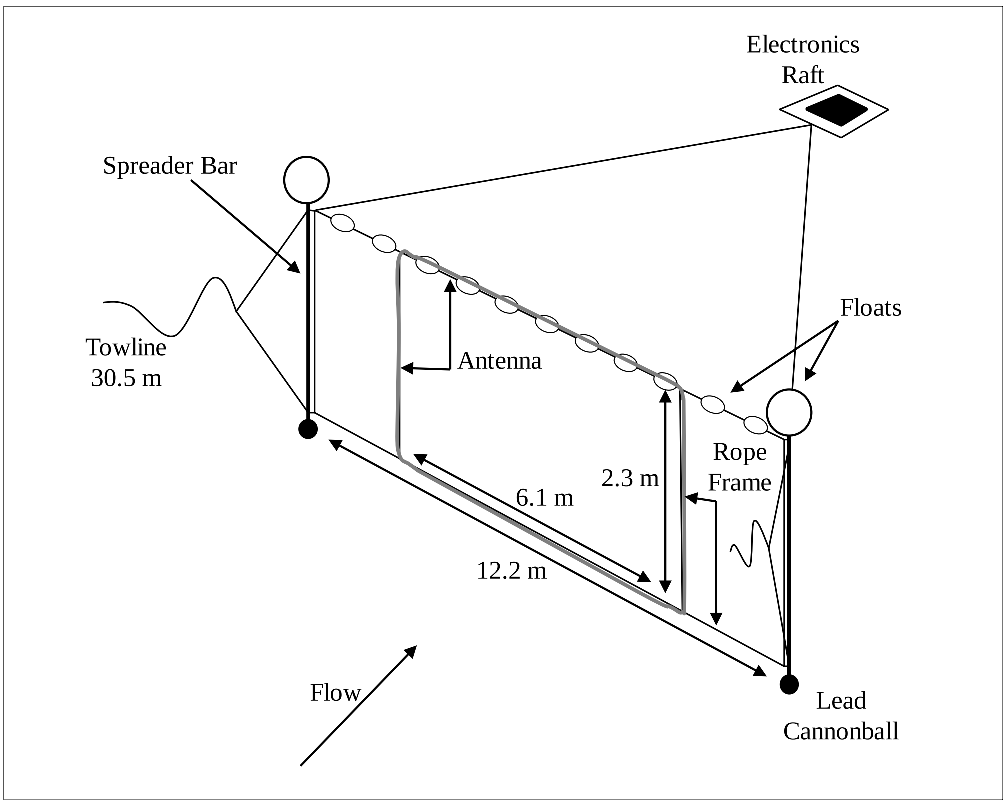

Figure 15. Basic configuration of the rope frame and 2.3- by 6.1-m flexible antenna system with electronics tested in November 2013.

On 8 November, we made a single deployment of the completed flexi-antenna mobile system. To minimize drag, no mesh wings were used and we towed the one antenna-coil configuration with two outboard powered skiffs (135 hp outboard motors). The MTS transceiver and batteries were housed on a pontoon raft (1.9 × 1.2 m) towed behind the antenna system—similar to the trawl system but without the WiFi data relay. We used a third skiff to monitor the transceiver and recorded levels of electromagnetic interference (EMI; %), current (amps), and other system values at different tow speeds (rpm). We also used a PIT tag attached to a pole to assess real-time read-ranges at each speed. Read ranges were tested near the center of the antenna.

We were concerned that the flexible housing would bow in the middle under tow and the center distortion would exceed the design criteria (2.4 m). If this were to happen, the auto-tuning capability of the MTX transceiver could fail, and detection capability in the center of the antenna would be compromised.   However, we observed that when under tow, the water pressure on the rope frame kept the width opening of the antenna constant along its length. There appeared to be little or no impact to the strength of the detection field if the antenna bowed to form a crescent horizontal shape when moving through the water.

We tested the antenna at four towing speeds: near idle and at 1,100, 1,500, and 2000 rpm (Table 7). Electronic interference (EMI) levels and amperage rates fluctuated at all speeds tested and appeared to be related to the vibration induced by the obviously oversized corks porpoising through the water. At idle speed, EMF noise levels varied between 12 and 33%, and PIT-tag read range was about 1.3 m. At 1,500 rpm, EMI noise and read-range were no different than at 1,100 rpm. At lower tow speeds, the antenna and frame glided more steadily through the water. However, at 2,000 rpm, EMI noise increased to between 20 and 50% due to vibration, and we could not read a test tag except in the center plane of the antenna. As the test tag was moved forward or rearward from the center, detection capability was immediately lost. We did not test at speeds higher than 2,000 rpm because vibration would have increased, further weakening the detection field due to EMI.

Table 7. Electromagnetic interference levels, amperage, and read-range at various speeds during deployment of the 2.4- by 6.1-m flexible antenna.

Speed (rpm)	EMI (%)	Amperage	Read range* (m)
1,100	12-33	8.7-9.6	1.3
1,500	12-33	8.8-9.5	1.3
2,000	20-50	8.7-9.5	0

* Read-range from the center plane of the antenna.

Testing of the antenna with a more streamline rope frame, smaller corks, and better security of the antenna wires within the flexible housing itself is needed. Reduction of vibration and resulting noise should allow greater towing speeds. Trading speed through the water for collection and concentration of fish, as with the trawl system, might provide an alternative to trawling with nets. If vibration induced by high-speed towing of the flex antenna through the water can be reduced or eliminated, then a multiple coil design could theoretically provide a thalweg sample similar or possibly even exceeding samples obtained with the existing estuary trawl system. We recommend further testing this flexible design and development of a multiple coil flex-antenna system. For example, an array of 6 flex antennas arranged in two rows of three would sample an 18.3-m swath of water at a sample depth of 4.9 m (similar depth as with the trawl sample). The mobility and adaptability of the flex antenna system would be adaptable to a wide variety of locations, such along a shoreline, across inner channels and small streams, and within a dam forebay or tailrace.

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Appendix

Data Tables

Appendix Table 1. Daily total sample time and detections for each salmonid species using the matrix pair trawl antenna system at Jones Beach, 2013.

Date	Time underway (h)	PIT-tag Detections (N)						
		Unknown	Chinook Salmon	Coho Salmon	Steelhead	Sockeye Salmon	Cutthroat	Total
25 Mar	2.58	0	0	0	0	0	0	0
26 Mar	5.65	0	0	0	1	0	0	1
27 Mar	0.00	--	--	--	--	--	--	--
28 Mar	6.52	0	0	0	0	0	0	0
29 Mar	5.90	0	1	0	0	0	0	1
30 Mar	0.00	--	--	--	--	--	--	--
31 Mar	0.00	--	--	--	--	--	--	--
1 Apr	0.00	--	--	--	--	--	--	--
2 Apr	5.33	0	0	0	0	0	0	0
3 Apr	6.47	0	0	0	0	0	0	0
4 Apr	0.00	--	--	--	--	--	--	0
5 Apr	5.52	0	2	0	0	0	0	2
6 Apr	0.00	--	--	--	--	--	--	--
7 Apr	0.00	--	--	--	--	--	--	--
8 Apr	0.00	--	--	--	--	--	--	--
9 Apr	6.45	0	1	0	0	1	0	2
10 Apr	5.17	0	0	0	1	0	0	1
11 Apr	4.10	0	1	0	1	0	0	2
12 Apr	5.27	0	0	0	1	0	0	1
13 Apr	0.00	--	--	--	--	--	--	--
14 Apr	0.00	--	--	--	--	--	--	--
15 Apr	6.28	0	0	0	2	0	0	2
16 Apr	4.05	1	1	0	2	0	0	4
17 Apr	5.47	1	1	0	1	0	0	3
18 Apr	5.90	0	3	1	0	0	0	4
19 Apr	6.20	0	5	0	4	0	0	9
20 Apr	0.00	--	--	--	--	--	--	--
21 Apr	0.00	--	--	--	--	--	--	--
22 Apr	6.73	0	3	1	6	0	0	10
23 Apr	5.93	0	4	0	8	0	0	12
24 Apr	6.88	0	6	0	6	0	0	12
25 Apr	2.22	1	7	0	3	0	0	11
26 Apr	5.80	0	2	0	7	0	0	9
27 Apr	0.00	--	--	--	--	--	--	--
28 Apr	4.33	0	26	0	6	0	0	32
29 Apr	13.22	3	45	0	35	0	0	83
30 Apr	12.55	1	42	0	26	0	0	69
1 May	12.82	3	47	0	70	0	0	120
2 May	15.52	6	64	0	144	0	0	214

Appendix Table 1. Continued.

Date	Time underway (h)	PIT-tag Detections (N)						
		Unknown	Chinook Salmon	Coho Salmon	Steelhead	Sockeye Salmon	Cutthroat	Total
3 May	13.58	6	83	1	97	0	0	187
4 May	7.18	3	58	1	72	0	0	134
5 May	11.38	9	168	3	148	0	0	328
6 May	14.52	10	307	3	167	2	0	489
7 May	14.17	13	392	3	154	0	0	562
8 May	15.72	13	414	4	178	1	0	610
9 May	17.47	12	331	3	87	0	0	433
10 May	18.58	12	452	5	272	0	0	741
11 May	14.23	10	547	4	259	2	1	823
12 May	13.08	3	490	8	335	6	0	842
13 May	17.73	10	1,181	19	364	7	0	1,581
14 May	18.20	6	1217	13	482	8	0	1,726
15 May	18.08	16	975	37	572	8	0	1,608
16 May	16.97	11	561	29	463	21	0	1,085
17 May	17.40	6	640	34	471	12	0	1,163
18 May	14.97	6	394	16	486	60	0	962
19 May	13.25	7	188	29	382	114	0	720
20 May	19.13	9	354	30	584	213	0	1,190
21 May	16.77	5	187	12	317	12	0	533
22 May	13.20	2	147	20	296	71	0	536
23 May	15.37	2	128	16	278	52	0	476
24 May	16.62	16	155	32	311	91	1	606
25 May	11.90	8	81	35	361	78	0	563
26 May	11.75	5	58	17	298	49	0	427
27 May	14.75	5	135	28	89	42	0	299
28 May	12.78	4	169	45	71	52	1	342
29 May	15.22	5	104	30	69	19	0	227
30 May	14.10	15	61	14	163	32	1	286
31 May	14.68	14	70	36	151	23	0	294
1 Jun	9.58	10	28	20	211	7	1	277
2 Jun	11.83	7	80	14	179	9	1	290
3 Jun	12.77	9	98	19	111	10	0	247
4 Jun	13.60	4	68	18	103	11	0	204
5 Jun	13.47	9	77	21	39	4	0	150
6 Jun	12.63	6	52	28	45	3	0	134
7 Jun	7.80	2	45	13	26	0	0	86
8 Jun	6.82	2	23	10	57	0	1	93
9 Jun	5.85	0	26	18	13	0	0	57
10 Jun	6.55	1	17	5	22	0	0	45
11 Jun	6.33	2	7	7	30	0	0	46
12 Jun	6.95	3	22	9	22	0	0	56
13 Jun	6.52	3	15	2	15	1	0	36
14 Jun	5.75	1	21	4	21	0	0	47
15 Jun	0.00	--	--	--	--	--	--	--
16 Jun	0.00	--	--	--	--	--	--	--
17 Jun	6.43	4	61	12	26	0	0	103

Appendix Table 1. Continued.

Date	Time underway (h)	PIT-tag Detections (N)						
		Unknown	Chinook Salmon	Coho Salmon	Steelhead	Sockeye Salmon	Cutthroat	Total
18 Jun	6.68	2	54		26	1	0	83
19 Jun	6.25	1	42	2	8	0	0	53
20 Jun	6.82	2	12	3	13	0	0	30
21 Jun	6.23	3	18		5	0	0	26
22 Jun	0.00	--	--	--	--	--	--	--
23 Jun	0.00	--	--	--	--	--	--	--
24 Jun	6.32	0	30	4	6	0	0	40
25 Jun	5.87	1	9	1	5	0	0	16
26 Jun	4.20	0	12	1	2	0	0	15
27 Jun	0.00	--	--	--	--	--	--	--
28 Jun	5.28	4	12	5	0	0	0	21
29 Jun	0.00	--	--	--	--	--	--	--
30 Jun	0.00	--	--	--	--	--	--	--
1 Jul	0.00	--	--	--	--	--	--	--
2 Jul	6.83	1	31	2	5	1	0	40
3 Jul	6.12	0	13	0	5	0	0	18
4 Jul	0.00	--	--	--	--	--	--	--
5 Jul	4.93	0	19	0	1	0	0	20
6 Jul	0.00	--	--	--	--	--	--	--
7 Jul	0.00	--	--	--	--	--	--	--
8 Jul	6.10	1	7	0	1	0	0	9
9 Jul	5.32	1	12	0	0	0	0	13
10 Jul	3.28	0	4	0	0	0	0	4
11 Jul	4.77	1	14	0	0	0	0	15
12 Jul	7.17	0	37	0	1	0	0	38
13 Jul	0.00	--	--	--	--	--	--	--
14 Jul	0.00	--	--	--	--	--	--	--
15 Jul	6.52	1	54	0	0	0	0	55
16 Jul	6.82	0	39	0	0	0	0	39
17 Jul	6.05	1	30	0	0	0	0	31
18 Jul	7.25	1	13	0	0	0	0	14
19 Jul	5.85	0	22	0	0	0	0	22
20 Jul	0.00	--	--	--	--	--	--	--
21 Jul	0.00	--	--	--	--	--	--	--
22 Jul	6.47	0	7	0	0	0	0	7
23 Jul	6.22	0	9	0	0	0	0	9
24 Jul	6.82	0	9	0	0	0	0	9
25 Jul	5.92	0	4	0	0	0	0	4
Total	888.61	342	11,461	747	9,299	1,023	7	22,879

Appendix Table 2. Release and consecutive observation sites and dates for the 54 subyearling Chinook salmon that were released in 2012 and detected in the estuary in 2013. Overwintering location is between the last detection site in 2012 and the first detection site in 2013.

	Release or observation	
Tag ID	Site	Date
3D9.1C2DD05A44	BCCAP-Big Canyon Cr Acclimation Facility (Clearwater R)	6-18-2012
3D9.1C2DD05A44	MCJ-McNary Dam Juvenile	5-9-2013
3D9.1C2DD05A44	TWX-Estuary Towed Array (Exp.)	5-14-2013
3D9.1C2DD11696	SNAKE3-Snake R-Clearwater R to Salmon R (km 224-303)	5-29-2012
3D9.1C2DD11696	TWX-Estuary Towed Array (Exp.)	5-13-2013
3D9.1C2DD27572	LUGUAF-Lukes Gulch Acclimation Facility, SF Clearwater R	6-13-2012
3D9.1C2DD27572	LMJ-Lower Monumental Dam Juvenile	3-23-2013
3D9.1C2DD27572	ICH-Ice Harbor Dam (Combined)	4-2-2013
3D9.1C2DD27572	MCJ-McNary Dam Juvenile	4-8-2013
3D9.1C2DD27572	JDJ-John Day Dam Juvenile	4-12-2013
3D9.1C2DD27572	TWX-Estuary Towed Array (Exp.)	4-19-2013
3D9.1C2DD66DDD	BCCAP-Big Canyon Cr Acclimation Facility (Clearwater R)	6-18-2012
3D9.1C2DD66DDD	GRJ-Lower Granite Dam Juvenile	10-11-2012
3D9.1C2DD66DDD	LMJ-Lower Monumental Dam Juvenile	4-21-2013
3D9.1C2DD66DDD	JDJ-John Day Dam Juvenile	5-4-2013
3D9.1C2DD66DDD	TWX-Estuary Towed Array (Exp.)	5-7-2013
3D9.1C2DDD7F68	SNAKE3-Snake R-Clearwater R to Salmon R (km 224-303)	6-5-2012
3D9.1C2DDD7F68	GOJ-Little Goose Dam Juvenile	3-21-2013
3D9.1C2DDD7F68	TWX-Estuary Towed Array (Exp.)	5-3-2013
3D9.1C2DDD8476	BCCAP-Big Canyon Cr Acclimation Facility (Clearwater R)	6-18-2012
3D9.1C2DDD8476	TWX-Estuary Towed Array (Exp.)	5-15-2013
3D9.1C2DDE9A70	SNAKE3-Snake R-Clearwater R to Salmon R (km 224-303)	5-24-2012
3D9.1C2DDE9A70	TWX-Estuary Towed Array (Exp.)	5-11-2013
3D9.1C2DDF2317	SNAKE3-Snake R-Clearwater R to Salmon R (km 224-303)	6-7-2012
3D9.1C2DDF2317	JDJ-John Day Dam Juvenile	4-26-2013
3D9.1C2DDF2317	BCC-BON PH2 Corner Collector	5-1-2013
3D9.1C2DDF2317	TWX-Estuary Towed Array (Exp.)	5-5-2013
3D9.1C2DE0C578	SNAKE3-Snake R-Clearwater R to Salmon R (km 224-303)	5-31-2012
3D9.1C2DE0C578	TWX-Estuary Towed Array (Exp.)	5-3-2013
3D9.1C2DE54675	BCCAP-Big Canyon Cr Acclimation Facility (Clearwater R)	6-25-2012
3D9.1C2DE54675	GOJ-Little Goose Dam Juvenile	4-9-2013
3D9.1C2DE54675	TWX-Estuary Towed Array (Exp.)	4-29-2013
3D9.1C2DE54DA2	SNAKE3-Snake R-Clearwater R to Salmon R (km 224-303)	6-7-2012
3D9.1C2DE54DA2	GOJ-Little Goose Dam Juvenile	4-18-2013
3D9.1C2DE54DA2	TWX-Estuary Towed Array (Exp.)	5-3-2013

Appendix Table 2. Continued.

Tag ID	Release or observation	
	Site	Date
3D9.1C2DE5514D	BCCAP-Big Canyon Cr Acclimation Facility (Clearwater R)	6-21-2012
3D9.1C2DE5514D	JDJ-John Day Dam Juvenile	5-12-2013
3D9.1C2DE5514D	BCC-BON PH2 Corner Collector	5-13-2013
3D9.1C2DE5514D	TWX-Estuary Towed Array (Exp.)	5-15-2013
3D9.1C2DE56B1E	BCCAP-Big Canyon Cr Acclimation Facility (Clearwater R)	6-25-2012
3D9.1C2DE56B1E	GRJ-Lower Granite Dam Juvenile	10-10-2012
3D9.1C2DE56B1E	JDJ-John Day Dam Juvenile	4-27-2013
3D9.1C2DE56B1E	TWX-Estuary Towed Array (Exp.)	5-1-2013
3D9.1C2DE594FB	BCCAP-Big Canyon Cr Acclimation Facility (Clearwater R)	6-21-2012
3D9.1C2DE594FB	GRJ-Lower Granite Dam Juvenile	7-29-2012
3D9.1C2DE594FB	LMJ-Lower Monumental Dam Juvenile	12-4-2012
3D9.1C2DE594FB	TWX-Estuary Towed Array (Exp.)	5-5-2013
3D9.1C2DE5A0E8	BCCAP-Big Canyon Cr Acclimation Facility (Clearwater R)	6-22-2012
3D9.1C2DE5A0E8	GRJ-Lower Granite Dam Juvenile	11-23-2012
3D9.1C2DE5A0E8	TWX-Estuary Towed Array (Exp.)	3-29-2013
3D9.1C2DE5BABF	BCCAP-Big Canyon Cr Acclimation Facility (Clearwater R)	6-27-2012
3D9.1C2DE5BABF	TWX-Estuary Towed Array (Exp.)	5-2-2013
3D9.1C2DE5CC58	BCCAP-Big Canyon Cr Acclimation Facility (Clearwater R)	7-6-2012
3D9.1C2DE5CC58	GRJ-Lower Granite Dam Juvenile	12-12-2012
3D9.1C2DE5CC58	TWX-Estuary Towed Array (Exp.)	5-8-2013
3D9.1C2DE5DBD7	BCCAP-Big Canyon Cr Acclimation Facility (Clearwater R)	6-29-2012
3D9.1C2DE5DBD7	JDJ-John Day Dam Juvenile	5-9-2013
3D9.1C2DE5DBD7	TWX-Estuary Towed Array (Exp.)	5-13-2013
3D9.1C2DE5EC3A	BCCAP-Big Canyon Cr Acclimation Facility (Clearwater R)	6-26-2012
3D9.1C2DE5EC3A	GRJ-Lower Granite Dam Juvenile	11-18-2012
3D9.1C2DE5EC3A	TWX-Estuary Towed Array (Exp.)	4-28-2013
3D9.1C2DE60540	BCCAP-Big Canyon Cr Acclimation Facility (Clearwater R)	7-6-2012
3D9.1C2DE60540	GRJ-Lower Granite Dam Juvenile	11-24-2012
3D9.1C2DE60540	GOJ-Little Goose Dam Juvenile	12-6-2012
3D9.1C2DE60540	TWX-Estuary Towed Array (Exp.)	5-8-2013
3D9.1C2DE61585	BCCAP-Big Canyon Cr Acclimation Facility (Clearwater R)	6-21-2012
3D9.1C2DE61585	GRJ-Lower Granite Dam Juvenile	3-19-2013
3D9.1C2DE61585	TWX-Estuary Towed Array (Exp.)	5-5-2013
3D9.1C2DE6279A	BCCAP-Big Canyon Cr Acclimation Facility (Clearwater R)	6-29-2012
3D9.1C2DE6279A	GRJ-Lower Granite Dam Juvenile	12-12-2012
3D9.1C2DE6279A	TWX-Estuary Towed Array (Exp.)	4-29-2013
3D9.1C2DE6335C	BCCAP-Big Canyon Cr Acclimation Facility (Clearwater R)	7-3-2012
3D9.1C2DE6335C	GOJ-Little Goose Dam Juvenile	3-25-2013
3D9.1C2DE6335C	JDJ-John Day Dam Juvenile	5-3-2013
3D9.1C2DE6335C	TWX-Estuary Towed Array (Exp.)	5-6-2013

Appendix Table 2. Continued.

	Release or observation	
Tag ID	Site	Date
3D9.1C2DE644A7	BCCAP-Big Canyon Cr Acclimation Facility (Clearwater R)	7-2-2012
3D9.1C2DE644A7	LMJ-Lower Monumental Dam Juvenile	4-7-2013
3D9.1C2DE644A7	TWX-Estuary Towed Array (Exp.)	4-29-2013
3D9.1C2DE65E69	BCCAP-Big Canyon Cr Acclimation Facility (Clearwater R)	7-2-2012
3D9.1C2DE65E69	GRJ-Lower Granite Dam Juvenile	11-19-2012
3D9.1C2DE65E69	GOJ-Little Goose Dam Juvenile	3-31-2013
3D9.1C2DE65E69	LMJ-Lower Monumental Dam Juvenile	5-13-2013
3D9.1C2DE65E69	TWX-Estuary Towed Array (Exp.)	5-17-2013
3D9.1C2DE65FBC	BCCAP-Big Canyon Cr Acclimation Facility (Clearwater R)	6-21-2012
3D9.1C2DE65FBC	GRJ-Lower Granite Dam Juvenile	11-9-2012
3D9.1C2DE65FBC	TWX-Estuary Towed Array (Exp.)	5-11-2013
3D9.1C2DE6671C	BCCAP-Big Canyon Cr Acclimation Facility (Clearwater R)	7-3-2012
3D9.1C2DE6671C	BCC-BON PH2 Corner Collector	5-9-2013
3D9.1C2DE6671C	TWX-Estuary Towed Array (Exp.)	5-11-2013
3D9.1C2DE68C75	BCCAP-Big Canyon Cr Acclimation Facility (Clearwater R)	6-28-2012
3D9.1C2DE68C75	GRJ-Lower Granite Dam Juvenile	9-30-2012
3D9.1C2DE68C75	JDJ-John Day Dam Juvenile	5-12-2013
3D9.1C2DE68C75	TWX-Estuary Towed Array (Exp.)	5-15-2013
3D9.1C2DE6925A	BCCAP-Big Canyon Cr Acclimation Facility (Clearwater R)	6-22-2012
3D9.1C2DE6925A	MCJ-McNary Dam Juvenile	5-1-2013
3D9.1C2DE6925A	JDJ-John Day Dam Juvenile	5-3-2013
3D9.1C2DE6925A	TWX-Estuary Towed Array (Exp.)	5-7-2013
3D9.1C2DE69590	BCCAP-Big Canyon Cr Acclimation Facility (Clearwater R)	6-25-2012
3D9.1C2DE69590	GRJ-Lower Granite Dam Juvenile	12-2-2012
3D9.1C2DE69590	TWX-Estuary Towed Array (Exp.)	4-29-2013
3D9.1C2DE69938	BCCAP-Big Canyon Cr Acclimation Facility (Clearwater R)	6-22-2012
3D9.1C2DE69938	TWX-Estuary Towed Array (Exp.)	4-22-2013
3D9.1C2DE6B0B8	BCCAP-Big Canyon Cr Acclimation Facility (Clearwater R)	7-3-2012
3D9.1C2DE6B0B8	GOJ-Little Goose Dam Juvenile	3-20-2013
3D9.1C2DE6B0B8	JDJ-John Day Dam Juvenile	4-29-2013
3D9.1C2DE6B0B8	TWX-Estuary Towed Array (Exp.)	5-16-2013
3D9.1C2DE6B7EF	BCCAP-Big Canyon Cr Acclimation Facility (Clearwater R)	7-3-2012
3D9.1C2DE6B7EF	LMJ-Lower Monumental Dam Juvenile	4-2-2013
3D9.1C2DE6B7EF	TWX-Estuary Towed Array (Exp.)	4-24-2013
3D9.1C2DE6C111	BCCAP-Big Canyon Cr Acclimation Facility (Clearwater R)	7-2-2012
3D9.1C2DE6C111	JDJ-John Day Dam Juvenile	4-17-2013
3D9.1C2DE6C111	TWX-Estuary Towed Array (Exp.)	4-25-2013
3D9.1C2DE6D501	BCCAP-Big Canyon Cr Acclimation Facility (Clearwater R)	6-25-2012
3D9.1C2DE6D501	GRJ-Lower Granite Dam Juvenile	8-22-2012
3D9.1C2DE6D501	TWX-Estuary Towed Array (Exp.)	4-29-2013

Appendix Table 2. Continued.

Tag ID	Release or observation	
	Site	Date
3D9.1C2DE6E343	BCCAP-Big Canyon Cr Acclimation Facility (Clearwater R)	6-22-2012
3D9.1C2DE6E343	GRJ-Lower Granite Dam Juvenile	11-12-2012
3D9.1C2DE6E343	TWX-Estuary Towed Array (Exp.)	5-7-2013
3D9.1C2DE6E35C	BCCAP-Big Canyon Cr Acclimation Facility (Clearwater R)	7-3-2012
3D9.1C2DE6E35C	TWX-Estuary Towed Array (Exp.)	4-30-2013
3D9.1C2DE6E873	BCCAP-Big Canyon Cr Acclimation Facility (Clearwater R)	6-22-2012
3D9.1C2DE6E873	GOJ-Little Goose Dam Juvenile	10-26-2012
3D9.1C2DE6E873	LMJ-Lower Monumental Dam Juvenile	3-26-2013
3D9.1C2DE6E873	TWX-Estuary Towed Array (Exp.)	5-2-2013
3D9.1C2DE6EB64	BCCAP-Big Canyon Cr Acclimation Facility (Clearwater R)	6-22-2012
3D9.1C2DE6EB64	TWX-Estuary Towed Array (Exp.)	5-15-2013
3D9.1C2DE6ED42	BCCAP-Big Canyon Cr Acclimation Facility (Clearwater R)	6-26-2012
3D9.1C2DE6ED42	GRJ-Lower Granite Dam Juvenile	11-3-2012
3D9.1C2DE6ED42	TWX-Estuary Towed Array (Exp.)	4-30-2013
3D9.1C2DECA083	BCCAP-Big Canyon Cr Acclimation Facility (Clearwater R)	6-27-2012
3D9.1C2DECA083	GRJ-Lower Granite Dam Juvenile	10-15-2012
3D9.1C2DECA083	MCJ-McNary Dam Juvenile	5-5-2013
3D9.1C2DECA083	TWX-Estuary Towed Array (Exp.)	5-11-2013
3D9.1C2DECC378	SNAKE3-Snake R-Clearwater R to Salmon R (km 224-303)	5-22-2012
3D9.1C2DECC378	MCJ-McNary Dam Juvenile	5-15-2013
3D9.1C2DECC378	TWX-Estuary Towed Array (Exp.)	5-20-2013
3D9.1C2DED0C8D	BCCAP-Big Canyon Cr Acclimation Facility (Clearwater R)	7-6-2012
3D9.1C2DED0C8D	TWX-Estuary Towed Array (Exp.)	5-9-2013
3D9.1C2DED1E9C	SNAKE3-Snake R-Clearwater R to Salmon R (km 224-303)	5-24-2012
3D9.1C2DED1E9C	MCJ-McNary Dam Juvenile	5-9-2013
3D9.1C2DED1E9C	TWX-Estuary Towed Array (Exp.)	5-14-2013
3D9.1C2DED5CD6	SNAKE3-Snake R-Clearwater R to Salmon R (km 224-303)	5-24-2012
3D9.1C2DED5CD6	TWX-Estuary Towed Array (Exp.)	5-14-2013
3D9.1C2DED91A8	SNAKE3-Snake R-Clearwater R to Salmon R (km 224-303)	6-5-2012
3D9.1C2DED91A8	GOJ-Little Goose Dam Juvenile	3-26-2013
3D9.1C2DED91A8	BCC-BON PH2 Corner Collector	5-18-2013
3D9.1C2DED91A8	TWX-Estuary Towed Array (Exp.)	5-19-2013
3D9.1C2DEDE3FF	SNAKE3-Snake R-Clearwater R to Salmon R (km 224-303)	5-31-2012
3D9.1C2DEDE3FF	TWX-Estuary Towed Array (Exp.)	5-4-2013
3D9.1C2DEDF2A7	SNAKE3-Snake R-Clearwater R to Salmon R (km 224-303)	6-5-2012
3D9.1C2DEDF2A7	MCJ-McNary Dam Juvenile	5-8-2013
3D9.1C2DEDF2A7	TWX-Estuary Towed Array (Exp.)	5-13-2013

Appendix Table 2. Continued.

Tag ID	Release or observation	
	Site	Date
3D9.1C2DEE2C55	BCCAP-Big Canyon Cr Acclimation Facility (Clearwater R)	7-2-2012
3D9.1C2DEE2C55	GRJ-Lower Granite Dam Juvenile	11-4-2012
3D9.1C2DEE2C55	ICH-Ice Harbor Dam (Combined)	4-29-2013
3D9.1C2DEE2C55	MCJ-McNary Dam Juvenile	5-1-2013
3D9.1C2DEE2C55	PD7-Columbia R Estuary rkm 70	5-8-2013
3D9.1C2DEE2C55	TWX-Estuary Towed Array (Exp.)	5-8-2013
3D9.1C2DEE88CE	BCCAP-Big Canyon Cr Acclimation Facility (Clearwater R)	6-29-2012
3D9.1C2DEE88CE	JDJ-John Day Dam Juvenile	5-17-2013
3D9.1C2DEE88CE	TWX-Estuary Towed Array (Exp.)	5-20-2013
3D9.1C2DEEDAD6	BCCAP-Big Canyon Cr Acclimation Facility (Clearwater R)	7-2-2012
3D9.1C2DEEDAD6	GRJ-Lower Granite Dam Juvenile	11-4-2012
3D9.1C2DEEDAD6	GOJ-Little Goose Dam Juvenile	3-31-2013
3D9.1C2DEEDAD6	BCC-BON PH2 Corner Collector	5-11-2013
3D9.1C2DEEDAD6	TWX-Estuary Towed Array (Exp.)	5-13-2013
3D9.1C2DEF0020	BCCAP-Big Canyon Cr Acclimation Facility (Clearwater R)	7-2-2012
3D9.1C2DEF0020	GRJ-Lower Granite Dam Juvenile	12-16-2012
3D9.1C2DEF0020	MCJ-McNary Dam Juvenile	5-4-2013
3D9.1C2DEF0020	BCC-BON PH2 Corner Collector	5-9-2013
3D9.1C2DEF0020	TWX-Estuary Towed Array (Exp.)	5-11-2013
3D9.1C2DEF5473	BCCAP-Big Canyon Cr Acclimation Facility (Clearwater R)	6-19-2012
3D9.1C2DEF5473	BCC-BON PH2 Corner Collector	5-13-2013
3D9.1C2DEF5473	TWX-Estuary Towed Array (Exp.)	5-14-2013
3D9.239F851AEF	DESCH1-Deschutes R-mouth to Round Butte Dam (0-177 km)	5-8-2012
3D9.239F851AEF	TWX-Estuary Towed Array (Exp.)	5-11-2013

* Site codes as defined in PTAGIS specification document.

Appendix Table 3. Combined daily total of impinged or injured fish on the matrix antenna system used in the upper Columbia River estuary, 2013. Abbreviations YCS, yearling Chinook salmon; SYCS, subyearling, Stld, steelhead.

Date	YCS	SYCS	Coho	Stld	Sockeye	Date	YCS	SYCS	Coho	Stld	Sockeye	Date	YCS	SYCS	Coho	Stld	Sockeye
25 Mar	0	0	0	0	0	25 Apr	2	0	2	1	0	26 May	0	0	0	0	0
26 Mar	1	0	0	0	0	26 Apr	1	0	0	0	0	27 May	0	0	3	0	0
27 Mar	--	--	--	--	--	27 Apr	--	--	--	--	--	28 May	0	0	2	0	1
28 Mar	0	0	0	0	0	28 Apr	0	0	0	0	0	29 May	1	0	0	0	0
29 Mar	0	0	0	0	0	29 Apr	8	0	3	2	0	30 May	3	0	2	1	2
30 Mar	--	--	--	--	--	30 Apr	88	0	12	5	7	31 May	12	0	3	2	4
31 Mar	--	--	--	--	--	1 May	2	0	1	0	0	1 Jun	5	0	2	0	0
1 Apr	--	--	--	--	--	2 May	2	0	0	0	0	2 Jun	0	0	0	0	0
2 Apr	0	0	0	0	0	3 May	2	0	0	1	0	3 Jun	3	0	4	0	3
3 Apr	0	0	0	0	0	4 May	0	0	0	0	0	4 Jun	0	0	0	0	0
4 Apr	--	--	--	--	--	5 May	0	0	0	1	0	5 Jun	2	0	0	1	1
5 Apr	0	0	0	0	0	6 May	23	2	5	4	5	6 Jun	5	1	4	1	5
6 Apr	--	--	--	--	--	7 May	0	0	1	0	0	7 Jun	4	1	2	1	4
7 Apr	--	--	--	--	--	8 May	2	0	0	0	0	8 Jun	0	0	0	0	0
8 Apr	--	--	--	--	--	9 May	1	0	0	1	0	9 Jun	0	0	0	0	0
9 Apr	0	0	0	0	0	10 May	1	0	1	0	1	10 Jun	1	0	0	0	1
10 Apr	0	0	0	0	0	11 May	0	0	0	1	1	11 Jun	0	0	0	0	0
11 Apr	0	0	0	0	0	12 May	0	0	0	0	0	12 Jun	0	0	0	0	0
12 Apr	0	0	0	0	0	13 May	1	0	0	0	2	13 Jun	0	0	0	0	0
13 Apr	--	--	--	--	--	14 May	0	0	1	0	0	14 Jun	0	0	0	0	0
14 Apr	--	--	--	--	--	15 May	0	0	0	1	1	15 Jun	--	--	--	--	--
15 Apr	0	0	0	0	0	16 May	1	0	0	0	1	16 Jun	--	--	--	--	--
16 Apr	1	0	0	0	0	17 May	3	0	1	0	1	17 Jun	0	0	0	0	0
17 Apr	1	0	0	0	0	18 May	7	0	0	1	4	18 Jun	0	0	0	0	0
18 Apr	0	0	0	0	0	19 May	4	0	2	1	3	19 Jun	0	0	0	0	0
19 Apr	3	0	0	0	0	20 May	0	0	0	0	0	20 Jun	0	0	0	0	0
20 Apr	--	--	--	--	--	21 May	0	0	0	0	1	21 Jun	0	0	0	0	0
21 Apr	--	--	--	--	--	22 May	1	0	0	0	2	22 Jun	--	--	--	--	--
22 Apr	0	0	0	0	0	23 May	10	0	2	1	5	23 Jun	--	--	--	--	--
23 Apr	1	0	1	0	0	24 May	1	0	1	0	2	24 Jun	0	0	0	0	0
24 Apr	5	0	3	1	0	25 May	2	0	2	0	3	25 Jun	0	0	0	0	0

Appendix Table 3. Continued.

Date	YCS	SYCS	Coho	Stld	Sockeye
26 Jun	0	0	0	0	0
27 Jun	--	--	--	--	--
28 Jun	0	0	0	0	0
29 Jun	--	--	--	--	--
30-Jun	--	--	--	--	--
1-Jul	--	--	--	--	--
2 Jul	0	0	0	0	0
3 Jul	0	0	0	0	0
4 Jul	--	--	--	--	--
5 Jul	0	0	0	0	0
6 Jul	--	--	--	--	--
7 Jul	--	--	--	--	--
8 Jul	0	0	0	0	0
9 Jul	0	0	0	0	0
10 Jul	0	13	1	1	0
11 Jul	0	16	2	0	0
12 Jul	0	1	0	0	0
13 Jul	--	--	--	--	--
14 Jul	--	--	--	--	--
15 Jul	0	0	0	0	0
16 Jul	0	0	0	0	0
17 Jul	0	0	0	0	0
18 Jul	0	1	0	0	0
19 Jul	0	38	0	2	0
20 Jul	--	--	--	--	--
21 Jul	--	--	--	--	--
22 Jul	0	0	0	0	0
23 Jul	0	0	0	0	0
24 Jul	0	0	0	0	0
25 Jul	0	0	0	0	0
Total	210	73	63	30	60

Appendix Table 4. Diel sampling of yearling Chinook salmon and steelhead using a PIT-tag detector surface pair-trawl at Jones Beach (rkm 75), 2013. Two-crew daily sample effort (29 April-6 June) was rounded to the nearest tenth and presented as a decimal hour.

		Yearling Chinook salmon				Steelhead			
	Sample	Detections (n)		Hourly detection rate (n/h)		Detections (n)		Hourly detection rate (n/h)	
Diel hour	effort (h)	Hatchery	Wild	Hatchery	Wild	Hatchery	Wild	Hatchery	Wild
0	34.0	470	84	13.82	2.47	110	30	3.24	0.88
1	34.0	568	71	16.71	2.09	121	45	3.56	1.32
2	26.1	613	84	23.46	3.21	95	37	3.64	1.42
3	17.0	477	62	28.00	3.64	85	25	4.99	1.47
4	14.3	489	71	34.28	4.98	83	24	5.82	1.68
5	16.1	825	120	51.40	7.48	133	46	8.29	2.87
6	30.9	938	152	30.36	4.92	525	173	16.99	5.60
7	37.5	516	92	13.75	2.45	630	267	16.79	7.12
8	36.9	290	71	7.86	1.92	558	269	15.12	7.29
9	34.6	196	46	5.67	1.33	585	216	16.93	6.25
10	37.2	249	63	6.69	1.69	608	229	16.34	6.16
11	34.9	251	70	7.19	2.01	599	223	17.16	6.39
12	28.8	233	72	8.08	2.50	590	185	20.46	6.42
13	18.7	252	62	13.50	3.32	370	143	19.82	7.66
14	15.2	269	66	17.70	4.34	354	119	23.29	7.83
15	4.1	21	4	5.10	0.97	38	5	9.23	1.21
16	0.0	--	--	--	--	--	--	--	--
17	0.0	--	--	--	--	--	--	--	--
18	0.0	--	--	--	--	--	--	--	--
19	6.5	9	1	1.39	0.15	22	5	3.40	0.77
20	32.0	300	84	9.37	2.62	317	103	9.90	3.22
21	34.0	884	158	26.00	4.65	389	93	11.44	2.74
22	34.0	668	81	19.65	2.38	248	77	7.29	2.26
23	34.0	476	61	14.00	1.79	83	46	2.44	1.35
Total	560.8	8,994	1,575			6,543	2,360		

Appendix Table 5. Number of PIT-tagged yearling Chinook salmon loaded for transport at dams and numbers detected in the estuary. Transport dates 27 Apr-15 Aug; trawl operation 25 Mar-25 Jul, intensive sampling 29 Apr-6 Jun 2013. Season totals are shown.

Release date and time (2013)		Numbers loaded by dam (n): Lower Granite	Numbers loaded by dam (n): Little Loose	Numbers loaded by dam (n): Lower Monumental	Total fish loaded (n)	Detections by transport dam (%): Lower Granite	Detections by transport dam (%): Little Loose	Detections by transport dam (%): Lower Monumental	Total trawl detections (n)	Total trawl detections (%)
4/27	9:10 pm	222	0	0	222	1.35	--	--	3	1.35
4/29	8:06 pm	417	593	0	1,010	1.20	1.52	--	14	1.39
5/1	8:40 pm	3,106	0	0	3,106	1.32	--	--	41	1.32
5/3	8:50 pm	3,607	36	0	3,643	3.19	8.33	--	118	3.24
5/4	7:10 pm	1,937	418	0	2,355	2.63	4.31	--	69	2.93
5/5	8:25 pm	1,603	481	0	2,084	2.18	3.12	--	50	2.40
5/6	8:30 pm	843	1,161	0	2,004	2.25	4.05	--	66	3.29
5/7	8:15 pm	404	959	0	1,363	3.47	4.59	--	58	4.26
5/8	7:00 pm	1,983	737	0	2,720	3.63	2.99	--	94	3.46
5/9	9:20 pm	3,213	697	663	4,573	0.72	1.29	1.36	41	0.90
5/10	8:15 pm	3,658	1,346	596	5,600	2.57	3.05	2.68	151	2.70
5/11	9:00 pm	3,095	3,042	548	6,685	2.00	1.94	2.92	137	2.05
5/12	10:15 pm	2,996	1,897	1,278	6,171	1.77	1.48	1.10	95	1.54
5/14	7:00 am	2,166	1,567	1,091	4,824	3.14	2.62	1.92	130	2.69
5/14	10:00 pm	1,356	535	313	2,204	0.66	0.37	0.32	12	0.54
5/15	8:45 pm	2,349	1,313	1,191	4,853	0.85	0.69	0.92	40	0.82
5/16	8:20 pm	2,286	717	873	3,876	0.26	1.12	1.95	31	0.80
5/17	9:55 pm	848	558	435	1,841	0.83	0.72	0.92	15	0.81
5/18	8:00 pm	493	304	249	1,046	0.81	1.64	1.61	13	1.24
5/19	7:40 pm	199	252	132	583	1.51	1.59	2.27	10	1.72
5/20	7:00 pm	161	245	94	500	1.24	1.22	0.00	5	1.00
5/21	7:05 pm	104	168	58	330	1.92	2.38	3.45	8	2.42
5/22	8:00 pm	83	148	41	272	3.61	0.68	0.00	4	1.47
5/23	9:25 pm	505	104	46	655	0.40	0.96	2.17	4	0.61
5/24	7:05 pm	871	66	44	981	1.72	1.52	4.55	18	1.83
5/25	9:10 pm	438	54	17	509	2.28	3.70	0.00	12	2.36
5/26	8:30 pm	268	47	2	317	0.37	2.13	0.00	2	0.63
5/27	9:00 pm	11	34	7	52	0.00	0.00	0.00	0	0.00

Appendix Table 5. Continued.

Release date and time (2013)		Numbers loaded by dam (n) Lower Granite	Little Loose	Lower Monumental	Total fish loaded (n)	Detections by transport dam (%) Lower Granite	Little Loose	Lower Monumental	Total trawl detections (n)	(%)
5-28	7:05 pm	12	19	2	33	0.00	0.00	0.00	0	0.00
5-29	8:40 pm	10	9	6	25	0.00	0.00	0.00	0	0.00
5-30	8:05 pm	26	16	4	46	0.00	0.00	0.00	0	0.00
5-31	9:00 pm	16	32	4	52	0.00	3.13	0.00	1	1.92
6-1	8:00 pm	53	41	4	98	1.89	0.00	0.00	1	1.02
6-2	8:50 pm	15	31	9	55	0.00	0.00	0.00	0	0.00
6-3	8:00 pm	12	12	1	25	0.00	0.00	0.00	0	0.00
6-5	4:40 am	5	12	0	17	0.00	0.00	--	0	0.00
6-6	7:55 pm	5	17	6	28	0.00	0.00	0.00	0	0.00
6-8	1:30 pm	8	13	1	22	0.00	0.00	0.00	0	0.00
6-10	7:55 pm	13	11	9	33	0.00	0.00	0.00	0	0.00
6-12	6:30 pm	22	15	10	47	9.09	0.00	0.00	2	4.26
6-14	7:30 pm	25	14	5	44	4.00	0.00	0.00	1	2.27
6-16	9:00 pm	3	14	1	18	0.00	0.00	0.00	0	0.00
6-18	7:35 pm	2	7	3	12	0.00	0.00	0.00	0	0.00
6-20	8:00 pm	1	8	1	10	0.00	0.00	0.00	0	0.00
6-22	7:45 pm	2	12	0	14	0.00	0.00	--	0	0.00
6-24	4:30 pm	1	11	4	16	0.00	9.09	0.00	1	6.25
6-26	8:00 pm	2	4	0	6	0.00	0.00	--	0	0.00
6-27	7:00 pm	3	8	0	11	0.00	0.00	--	0	0.00
6-30	8:00 pm	1	11	0	12	0.00	0.00	--	0	0.00
7-2	7:25 pm	4	17	0	21	0.00	0.00	--	0	0.00
7-4	7:30 pm	5	12	2	19	0.00	0.00	0.00	0	0.00
7-6	6:45 pm	4	8	1	13	0.00	0.00	0.00	0	0.00
7-8	6:00 pm	0	3	0	3	--	0.00	--	0	0.00
7-10	8:25 pm	0	3	1	4	--	0.00	0.00	0	0.00
7-12	7:35 pm	2	1	1	4	0.00	0.00	0.00	0	0.00
7-14	7:50 pm	1	1	0	2	0.00	0.00	--	0	0.00
7-16	8:30 pm	1	0	1	2	0.00	--	0.00	0	0.00
7-20	10:30 pm	0	1	0	1	--	0.00	--	0	0.00
Totals/means		38,943	17,398	7,669	64,010	1.88	2.15	1.56	1,239	1.94

Appendix Table 6. Number of PIT-tagged steelhead loaded for transport at dams and numbers detected in the estuary. Transport dates 27 Apr-15 Aug; trawl operation 25 Mar-25 Jul, with intensive sampling 29 Apr-6 Jun 2013. Season totals are shown.

		Numbers loaded by dam (n)			Total	Detections by transport dam (%)			Total	
Release date and time (2013)		Lower Granite	Little Loose	Lower Monumental	fish loaded (n)	Lower Granite	Little Loose	Lower Monumental	trawl detections (n)	(%)
4-27	9:10 pm	361	0	0	361	1.94	--	--	7	1.94
4-29	8:06 pm	528	306	0	834	2.84	1.63	--	20	2.40
5-1	8:40 pm	846	1	0	847	2.72	0.00	--	23	2.72
5-3	8:50 pm	1,831	70	0	1,901	1.97	4.29	--	39	2.05
5-4	7:10 pm	756	516	0	1,272	1.98	2.71	--	29	2.28
5-5	8:25 pm	949	359	0	1,308	1.26	1.95	--	19	1.45
5-6	8:30 pm	321	1,143	0	1,464	2.18	3.24	--	44	3.01
5-7	8:15 pm	458	1,041	0	1,499	0.66	2.21	--	26	1.73
5-8	7:00 pm	2,306	790	0	3,096	4.64	3.42	--	134	4.33
5-9	9:20 pm	838	894	843	2,575	3.34	2.01	2.97	71	2.76
5-10	8:15 pm	1,447	771	362	2,580	4.42	2.59	1.93	91	3.53
5-11	9:00 pm	1,864	1,350	370	3,584	1.88	1.70	1.08	62	1.73
5-12	10:15 pm	2,528	1,341	818	4,687	2.33	1.34	1.59	90	1.92
5-14	7:00 am	1,562	2077	972	4,611	2.05	2.55	3.60	120	2.60
5-14	10:00 pm	1,432	971	429	2,832	2.37	1.75	2.80	63	2.22
5-15	8:45 pm	2,995	1,894	1,164	6,053	3.17	3.38	3.09	195	3.22
5-16	8:20 pm	2,552	806	859	4,217	4.43	5.09	4.31	191	4.53
5-17	9:55 pm	1,909	793	440	3,142	3.40	3.40	1.82	100	3.18
5-18	8:00 pm	1,591	638	359	2,588	6.60	4.86	7.24	162	6.26
5-19	7:40 pm	1,106	456	209	1,771	2.44	2.63	1.44	42	2.37
5-20	7:00 pm	290	296	168	754	5.52	4.73	3.57	36	4.77
5-21	7:05 pm	241	230	133	604	6.64	5.65	8.27	40	6.62
5-22	8:00 pm	232	176	140	548	7.33	10.80	5.00	43	7.85
5-23	9:25 pm	1,480	133	147	1,760	7.84	10.53	8.84	143	8.13
5-24	7:05 pm	1,297	123	69	1,489	8.87	5.69	7.25	127	8.53
5-25	9:10 pm	761	110	69	940	1.58	1.82	2.90	16	1.70
5-26	8:30 pm	620	102	50	772	0.97	0.00	2.00	7	0.91
5-27	9:00 pm	38	72	36	146	0.00	6.94	0.00	5	3.42

Appendix Table 6. Continued.

Release date and time (2013)		Numbers loaded by dam (n)			Total fish loaded (n)	Detections by transport dam (%)			Total trawl detections	
		Lower Granite	Little Loose	Lower Monumental		Lower Granite	Little Loose	Lower Monumental	(n)	(%)
5-28	7:05 pm	74	77	43	194	6.76	19.48	11.63	25	12.89
5-29	8:40 pm	55	39	19	113	18.18	10.26	26.32	19	16.81
5-30	8:05 pm	594	61	11	666	13.64	9.84	9.09	88	13.21
5-31	9:00 pm	492	29	21	542	13.21	6.90	19.05	71	13.10
6-1	8:00 pm	331	74	19	424	7.55	12.16	5.26	35	8.25
6-2	8:50 pm	241	56	14	311	11.62	8.93	21.43	36	11.58
6-3	8:00 pm	57	39	10	106	7.02	12.82	0.00	9	8.49
6-5	4:40 am	41	18	10	69	0.00	0.00	0.00	0	0.00
6-6	7:55 pm	583	58	12	653	6.69	10.34	0.00	45	6.89
6-8	1:30 pm	429	47	12	488	3.03	4.26	8.33	16	3.28
6-10	7:55 pm	240	51	12	303	3.33	1.96	0.00	9	2.97
6-12	6:30 pm	293	57	11	361	3.07	1.75	0.00	10	2.77
6-14	7:30 pm	567	24	7	598	0.00	0.00	0.00	0	0.00
6-16	9:00 pm	403	17	2	422	2.73	5.88	0.00	12	2.84
6-18	7:35 pm	8	17	6	31	0.00	0.00	0.00	0	0.00
6-20	8:00 pm	9	19	0	28	0.00	0.00	--	0	0.00
6-22	7:45 pm	5	4	2	11	20.00	0.00	0.00	1	9.09
6-24	4:30 pm	5	9	2	16	0.00	11.11	0.00	1	6.25
6-26	8:00 pm	1	9	1	11	0.00	0.00	0.00	0	0.00
6-27	7:00 pm	1	3	3	7	0.00	0.00	0.00	0	0.00
6-30	8:00 pm	1	4	4	9	0.00	25.00	0.00	1	11.11
7-2	7:25 pm	0	13	5	18	--	0.00	0.00	0	0.00
7-4	7:30 pm	1	10	0	11	0.00	0.00	--	0	0.00
7-6	6:45 pm	1	4	1	6	0.00	0.00	100.00	1	16.67
7-8	6:00 pm	0	2	0	2	--	0.00	--	0	0.00
7-10	8:25 pm	1	2	1	4	0.00	0.00	0.00	0	0.00
7-12	7:35 pm	1	0	0	1	0.00	--	--	0	0.00
Totals/means		32,481	17,285	7,551	57,317	3.94	3.15	3.46	1,933	3.37

Appendix Table 7. Trawl system detections of PIT-tagged juvenile Chinook salmon and steelhead previously detected at Bonneville Dam, 2013.

Date detected at Bonneville	Tag detections					
	Bonneville Dam (n)		Jones Beach (n)		Bonneville and Jones Beach (%)	
	Chinook	Steelhead	Chinook	Steelhead	Chinook	Steelhead
25 Mar	4	0	0	0	0.00	--
26 Mar	1	0	0	0	0.00	--
27 Mar	1	1	0	0	0.00	0.00
28 Mar	3	1	0	0	0.00	0.00
29 Mar	3	1	0	0	0.00	0.00
30 Mar	2	0	0	0	0.00	--
31 Mar	2	4	0	0	0.00	0.00
1 Apr	5	0	0	0	0.00	--
2 Apr	5	2	0	0	0.00	0.00
3 Apr	8	5	0	0	0.00	0.00
4 Apr	9	2	0	0	0.00	0.00
5 Apr	15	6	0	0	0.00	0.00
6 Apr	24	6	0	0	0.00	0.00
7 Apr	25	8	0	0	0.00	0.00
8 Apr	38	2	0	0	0.00	0.00
9 Apr	43	9	0	0	0.00	0.00
10 Apr	52	9	0	0	0.00	0.00
11 Apr	90	11	0	0	0.00	0.00
12 Apr	546	17	2	0	0.37	0.00
13 Apr	152	20	0	1	0.00	5.00
14 Apr	146	29	0	1	0.00	3.45
15 Apr	165	9	0	0	0.00	0.00
16 Apr	142	14	1	1	0.70	7.14
17 Apr	78	22	1	0	1.28	0.00
18 Apr	68	31	0	0	0.00	0.00
19 Apr	137	45	3	0	2.19	0.00
20 Apr	270	78	2	2	0.74	2.56
21 Apr	302	66	4	1	1.32	1.52
22 Apr	344	67	1	2	0.29	2.99
23 Apr	368	102	3	0	0.82	0.00
24 Apr	352	124	1	2	0.28	1.61
25 Apr	513	151	7	0	1.36	0.00
26 Apr	445	201	5	2	1.12	1.00
27 Apr	524	317	15	7	2.86	2.21
28 Apr	608	538	11	5	1.81	0.93
29 Apr	765	545	8	22	1.05	4.04
30 Apr	1134	712	25	38	2.20	5.34
1 May	1087	384	25	19	2.30	4.95
2 May	902	520	28	18	3.10	3.46
3 May	737	504	19	6	2.58	1.19
4 May	767	307	18	17	2.35	5.54
5 May	703	390	17	10	2.42	2.56
6 May	855	465	28	17	3.27	3.66
7 May	810	398	15	22	1.85	5.53

Appendix Table 7. Continued.

Date detected at Bonneville	Tag detections					
	Bonneville Dam (n)		Jones Beach (n)		Bonneville and Jones Beach (%)	
	Chinook	Steelhead	Chinook	Steelhead	Chinook	Steelhead
8 May	905	411	23	23	2.54	5.60
9 May	1,066	536	40	25	3.75	4.66
10 May	1,696	608	36	21	2.12	3.45
11 May	1,861	713	60	28	3.22	3.93
12 May	1,951	1,651	70	54	3.59	3.27
13 May	2,040	1,472	72	51	3.53	3.46
14 May	1,505	1,107	38	35	2.52	3.16
15 May	1,517	1,018	43	35	2.83	3.44
16 May	1,717	914	48	23	2.80	2.52
17 May	1,860	1,310	10	15	0.54	1.15
18 May	1,159	1,277	33	51	2.85	3.99
19 May	872	961	17	26	1.95	2.71
20 May	964	987	20	42	2.07	4.26
21 May	763	1,082	10	52	1.31	4.81
22 May	412	673	11	39	2.67	5.79
23 May	305	419	10	26	3.28	6.21
24 May	350	481	6	19	1.71	3.95
25 May	322	369	17	11	5.28	2.98
26 May	246	349	9	15	3.66	4.30
27 May	190	202	8	4	4.21	1.98
28 May	233	328	7	19	3.00	5.79
29 May	214	211	6	15	2.80	7.11
30 May	289	356	5	31	1.73	8.71
31 May	236	152	4	6	1.69	3.95
01 Jun	198	251	9	17	4.55	6.77
02 Jun	245	312	7	24	2.86	7.69
03 Jun	192	193	2	7	1.04	3.63
04 Jun	187	163	6	8	3.21	4.91
05 Jun	194	105	5	3	2.58	2.86
06 Jun	178	149	3	2	1.69	1.34
07 Jun	240	163	2	2	0.83	1.23
08 Jun	150	139	1	3	0.67	2.16
09 Jun	174	112	0	2	0.00	1.79
10 Jun	95	57	2	1	2.11	1.75
11 Jun	138	128	1	5	0.72	3.91
12 Jun	187	139	3	3	1.60	2.16
13 Jun	203	117	0	0	0.00	0.00
14 Jun	232	100	0	0	0.00	0.00
15 Jun	235	109	1	8	0.43	7.34
16 Jun	263	96	3	2	1.14	2.08
17 Jun	164	106	4	2	2.44	1.89
18 Jun	102	66	0	1	0.00	1.52
19 Jun	205	68	3	0	1.46	0.00
20 Jun	237	44	0	0	0.00	0.00
21 Jun	343	56	0	0	0.00	0.00

Appendix Table 7. Continued.

Date detected at Bonneville	Tag detections					
	Bonneville Dam (n)		Jones Beach (n)		Bonneville and Jones Beach (%)	
	Chinook	Steelhead	Chinook	Steelhead	Chinook	Steelhead
22 Jun	143	36	0	0	0.00	0.00
23 Jun	69	29	2	1	2.90	3.45
24 Jun	138	34	1	0	0.72	0.00
25 Jun	48	23	0	0	0.00	0.00
26 Jun	177	35	2	0	1.13	0.00
27 Jun	119	17	0	0	0.00	0.00
28 Jun	79	10	0	0	0.00	0.00
29 Jun	152	7	0	0	0.00	0.00
30 Jun	108	10	1	0	0.93	0.00
01 Jul	104	16	0	0	0.00	0.00
02 Jul	129	10	0	0	0.00	0.00
03 Jul	138	10	2	0	1.45	0.00
04 Jul	227	11	0	0	0.00	0.00
05 Jul	221	11	0	0	0.00	0.00
06 Jul	230	6	1	0	0.43	0.00
07 Jul	161	17	2	0	1.24	0.00
08 Jul	186	13	0	0	0.00	0.00
09 Jul	240	8	1	0	0.42	0.00
10 Jul	240	6	0	0	0.00	0.00
11 Jul	205	5	0	0	0.00	0.00
12 Jul	285	2	2	0	0.70	0.00
13 Jul	249	3	5	0	2.01	0.00
14 Jul	185	2	1	0	0.54	0.00
15 Jul	166	1	3	0	1.81	0.00
16 Jul	130	1	1	0	0.77	0.00
17 Jul	100	2	2	0	2.00	0.00
18 Jul	71	0	0	0	0.00	--
19 Jul	64	2	0	0	0.00	0.00
20 Jul	81	0	1	0	1.23	--
21 Jul	100	1	0	0	0.00	0.00
22 Jul	94	0	1	0	1.06	--
23 Jul	94	0	0	0	0.00	--
24 Jul	79	0	0	0	0.00	--
25 Jul	79	0	0	0	0.00	--
Totals	44,976	26,711	922	950	2.05	3.56