Detection of PIT-Tagged Juvenile Salmonids in the Columbia River Estuary Using a Pair-Trawl, 2012

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Executive Summary

In 2012, we continued a 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 951 h between 14 March and 30 July and detected a total of 16,732 PIT-tagged juvenile salmonids. These detections were comprised of 20% wild and 75% hatchery-reared fish (5% were of unknown origin). The species composition of all PIT-tagged fish detected in the trawl during 2012 was 34% spring/summer Chinook salmon, 11% fall Chinook salmon, 46% steelhead, 5% sockeye, 3% coho, and 1% unknown species.

In 2012, sampling was conducted exclusively with our matrix-antenna PIT-tag detection system. 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.

High river flows through most of the migration season contributed to generally lower detection numbers in 2012. We typically detect greater numbers of fish under lower flows; for example, in 2010, a below-average flow year, we detected nearly twice as many fish (31,327). Higher flows increase fish migration speed to the estuary and disperse migrants across a greater volume of water in the sample reach, resulting in lower detection rates. High flows also reduced sample time, as crews were required to travel further upstream within the sample reach to deploy the trawl, and increased current reduces our time within the sample reach before retrieval of the trawl.

Sampling began on 14 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, we increased our sampling effort to two daily shifts operating 7 d week^{-1} during both daylight and darkness. This intensive sampling period began on 1 May and continued through 15 June. During this period we averaged 9 detections h^{-1} during daylight and 13 detections h^{-1} during darkness for yearling Chinook salmon (P = 0.089). During the same period for steelhead the trend was opposite, with 14 detections h^{-1} during daylight and 7 detections h^{-1} during darkness (P = 0.003). Sampling continued

with a single daily shift through 30 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 and we detected 1.7% of the yearling Chinook and 2.6% of the steelhead previously detected at Bonneville Dam. By comparison, during intensive sampling in 2011 the trawl was deployed for an average of 12 h/d and detected 1.8% of the yearling Chinook and 2.8% of the steelhead detected at Bonneville Dam. We also detected 1.3% of the yearling Chinook salmon and 3.5% of the steelhead transported and released below Bonneville Dam in 2012. These rates were similar to those for transported fish in 2011, when we detected 1.2% of the yearling Chinook and 2.6% of the steelhead for which we had transport release records. The detection rate of transported steelhead in 2012 was exceptional given the high flow conditions, and may represent higher post-transport survival of steelhead or a shift in diel availability related to high flows.

In 2012, 19% of the PIT-tagged fish we detected had been transported while 7% had been detected in the juvenile bypass system or corner collector at Bonneville Dam Second Powerhouse. The remaining 73% had not been transported or detected at Bonneville Dam although most had originated upstream from Bonneville.

Tagged fish are not detected at Bonneville Dam if they pass via spillways, turbines, or the First Powerhouse bypass, since none of these routes have PIT-tag detection capability. Detection rates at Bonneville were reduced when river flow was routed by managers to the First Powerhouse from 16 May until 13 June (excluding 21 to 23 May) to limit descaling and injury to sockeye observed at the Second Powerhouse. Reduced rates of detection at Bonneville resulted in smaller sample sizes from which to base estimates of survival and travel time in 2012.

In 2012, estimated survival from Lower Granite to Bonneville Dam tailrace was 63.4% for Snake River wild and hatchery yearling Chinook combined. This was higher than the 51.3% estimated in 2011. Estimated survival through this same reach for wild and hatchery combined steelhead was 59.7% in 2012, similar to the 60.0% estimated in 2011. For Snake River sockeye, estimated survival through the same reach was 47.2% in 2012; there were too few sockeye detected in 2011 for an estimate of survival through this reach.

In the reach from McNary to Bonneville Dam tailrace, estimated survival was also higher in 2012 than in 2011 for Snake River combined wild and hatchery yearling Chinook (80.2 vs. 68.7%). In the same reach for combined wild and hatchery upper Columbia River yearling Chinook, survival was higher in 2012 than in 2011 for groups released above the confluence of the Yakima River (84.5 vs. 58.4%) but lower than in

2011 for groups released in the Yakima River (55.8 vs. 68.4%). For mixed wild and hatchery Snake River steelhead, estimated survival through this reach was similar in 2012 and 2011 (85.6 and. 86.6%). For upper Columbia River hatchery and wild combined steelhead stocks, estimated survival was 101.4% in 2012 vs. 65.1% in 2011. Due to low rates of detection for upper Columbia River sockeye salmon, estimates of survival from McNary to Bonneville Dam were so imprecise in both 2012 and 2011 that no meaningful comparisons could be made (84.0% ± 40.5% in 2012 vs. 69.1% ± 67.6% in 2011).

Seasonal mean travel speed to Jones Beach was significantly faster for yearling Chinook salmon detected passing Bonneville Dam (99 km d^{-1}) than for those released from barges just below the dam (78 km d^{-1}, $P \leq 0.001$). Similar differences in travel speed between inriver migrant and barged fish were noted for steelhead (106 vs. 94 km d^{-1}, $P < 0.001$), subyearling Chinook (101 vs. 80 km d^{-1}, $P < 0.001$) and sockeye salmon (104 vs. 93 km d^{-1}, $P < 0.001$).

We detected 1,189 subyearling fall Chinook salmon in 2012, with most detected after the intensive sample period. Of these 1,189 fish, 977 originated in the Snake River basin (681 inriver migrants and 296 transported). The remaining 212 subyearling fish were Columbia River stocks. We also detected 16 fall Chinook salmon from the Snake River basin that had been released as subyearlings in 2011. Eleven of these 16 fish had overwintered in either the Snake or Columbia River above Bonneville Dam, and five had not been detected in 2012 prior to being detected in the estuary.

In 2012, we detected 843 sockeye salmon; 92% of these fish had been released into the Snake River and 8% into the Columbia River. Of these 843 fish, 91% were hatchery reared, 3% were wild, and the remaining 6% were of unknown origin. Fish migrating inriver made up 49% of the total sockeye detections (414), while the other 51% were fish that had been transported (429).

After initial testing of a prototype mobile separation by code (MSbyC) system in 2010 and 2011, we had hoped to continue testing and development in 2012. The MSbyC system was designed to sample behind the trawl in the estuary to divert fish based on PIT-tag code and route them to a holding tank. The MSbyC can potentially be used for instream monitoring or for other applications where fish sorting is needed similar to that provided by stationary SbyC systems at dams. We are developing the MSbyC systems to allow diversion of untagged fish and to provide the ability to control sample rate. This is important when sampling in locations where threatened or endangered fish may be present. Unfortunately, problems with vessel construction and stability prevented MSbyC deployment in 2012. We collaborated with marine engineers to develop drawings and cost estimates with the goal of improving the safety and functionality of the MSbyC system design.

Contents

Introduction

In 2012, 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; Magie et al. 2010; Morris et al. 2012). 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 PIT-tagged for various research projects at natal streams, hatcheries, collector dams, and other upstream locations (PSMFC 2012). When PIT-tagged fish passed through the trawl and antennas, the tag code, GPS position, and date and time of detection were 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 2.6 million Snake and Columbia River juvenile salmonids were PIT-tagged and released prior to or during the spring 2012 migration season (PSMFC 2012). During the season, a portion of these fish were detected at dams equipped with PIT-tag monitoring systems (Prentice et al. 1990a,b,c). 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 2012).

We uploaded trawl detection records to PTAGIS and downloaded information on fish we detected. This information included the species, run, tagging and release information, 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 entire hydrosystem each year since 1998.

Trawl detection data in 2012 was sufficient to conduct these comparisons for juvenile Chinook salmon *O. tshawytscha*, steelhead *O. mykiss*, and sockeye salmon *O. nerka*. In 2012, over 175,000 PIT-tagged fish were transported from dams on the Snake or Columbia River and over 75,000 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 83) and the west end of Puget Island (rkm 61; Figure 1). This is a freshwater reach characterized by frequent ship traffic, occasional severe weather, and river currents often exceeding 1.1 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.

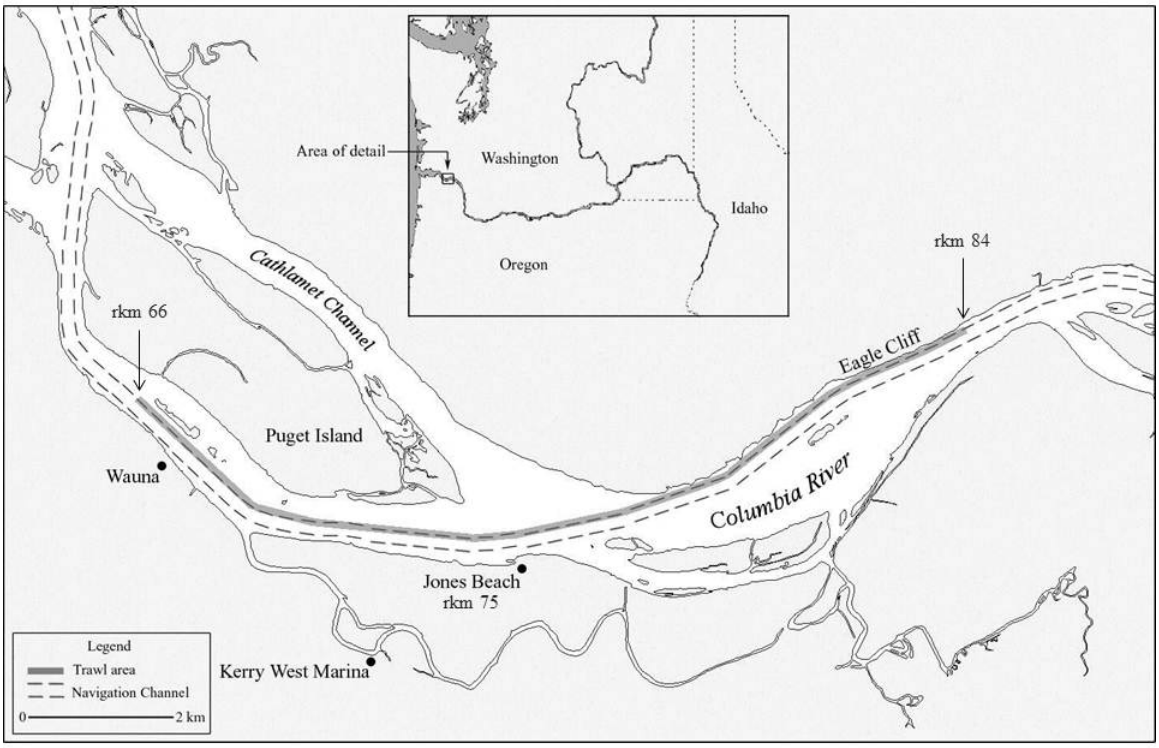

Figure 1. Trawling area adjacent to the navigation channel in the upper Columbia River estuary between rkm 61 and 83.

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 2012). Specific fish groups targeted for detection included approximately 740,000[1] fish released for NMFS transportation studies and over 215,000 fish released for a comparative survival study of hatchery fish, as well as smaller groups released for other studies. Of the 740,000 PIT-tagged fish released in the Columbia River basin for migration in 2012, over 175,000 (about 24%) were collected at dams and diverted for transportation.

In addition to the transportation study, several other studies in the Columbia River Basin released large numbers of PIT-tagged juvenile salmonids. 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 clarki*.

Sample Period

Spring and summer sampling began on 14 March and continued through 30 July 2012. Because availability of fish in the estuary varied, our sample effort varied accordingly. 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 about 6 h d^{-1}. From 1 May through 15 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 late afternoon 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 1400 and 1900 PDT, when we interrupted sampling for fueling and maintenance.

[1] Total includes 591,722 subyearling Chinook salmon released with transport beginning in mid-May

Trawl System Design

In 2012, 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.

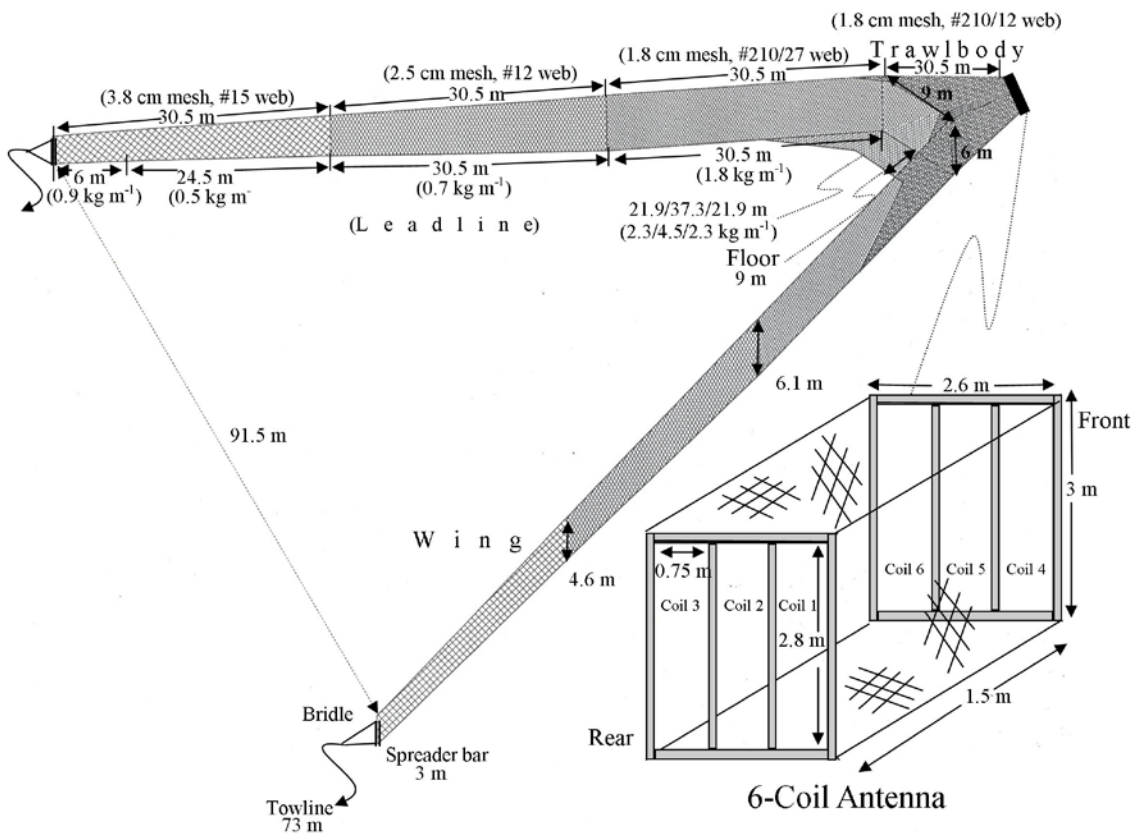

Figure 2. Basic design of the surface pair trawl used with the matrix antenna system to sample juvenile salmonids in the Columbia River estuary (rkm 75), 2012.

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 sink 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 41-ft 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 net with two 73-m-long tow lines to prevent turbulence on the net from the two tow vessels. After the trawl and antenna were deployed, one tow line was passed to an adjacent tow vessel (pair-trawling). During a typical deployment, the net was towed upstream facing into the current, with a distance of about 91.5 m between the trawl wings. Even though volitional passage through the 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 2006-2011. We used a single Digital Angel model FS1001M multiplexing transceiver, 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 then wirelessly transmitted and recorded to a computer onboard a tow vessel. Detection efficiency tests were conducted to verify performance of the system (Appendix B).

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 2012). 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 2012). Pair-trawl detections are designated in the PTAGIS database with site code TWX (towed array-experimental).

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 from net sections 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 more sustained 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

Detection Totals and Species Composition

Sampling through most of the intensive (two daily shifts) sampling period in 2012 was characterized by high river flows and heavier-than-normal debris loads. Mean flow volumes in the Columbia River at Bonneville Dam were about 16% lower during the two-shift sample period of 2012 (9,912 $m^3 s^{-1}$) than during the two-shift period of 2011 (11,801 $m^3 s^{-1}$; Figure 3). However, flow volumes in 2011 and 2012 were both well above the average flow volumes since 2002 (8,276 $m^3 s^{-1}$).

We estimate that our intensive sampling period in 2012 coincided with the arrival in the estuary of 83% of yearling Chinook and 91% of steelhead passing Bonneville Dam (tagged and non-tagged) and 90% of both yearling Chinook and steelhead transported for NMFS transportation studies (tagged and non-tagged). In contrast, we estimated that intensive sampling in 2011 coincided with 78% of yearling Chinook and 86% of Steelhead passing Bonneville and 93% of transported yearling Chinook and 87% of transported Steelhead. Of fish passing through the estuary after we reverted to a single daily crew, 82% were subyearling Chinook salmon. 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.

The proportion of PIT-tagged fish released and later detected passing Bonneville Dam was unusually low in 2012 (63% fewer detections than at Bonneville Dam in 2010). This was partially related to a management decision to direct flow away from the Second Powerhouse to reduce descaling of sockeye. This redirection of flow to the First Powerhouse occurred on 16 May and continued until 13 June, with the exception of 21-23 May. This reduced detections of PIT-tagged fish because the juvenile fish facility and corner collector are located at the Second Powerhouse, and there is no detection capability at the First Powerhouse or in the spillway.

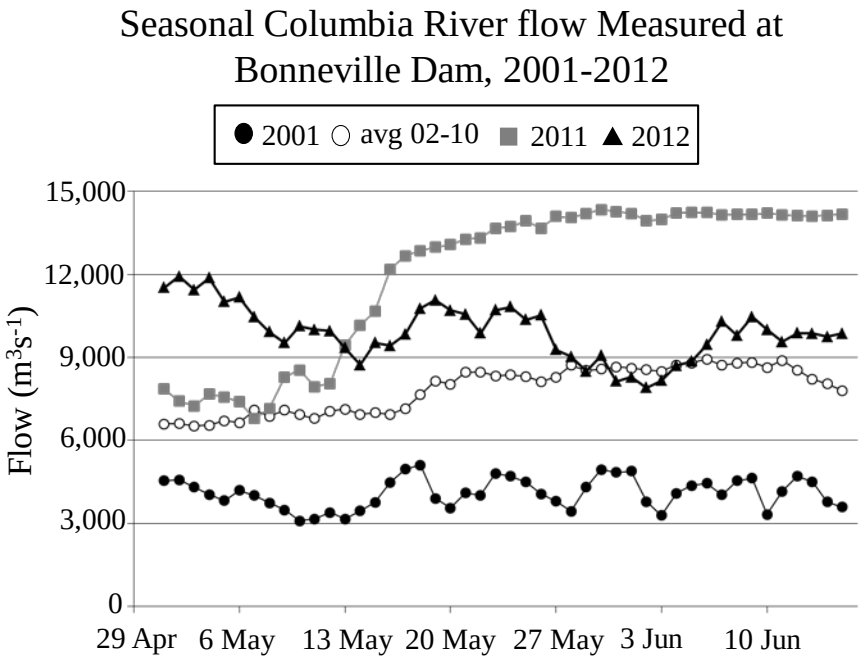

Figure 3. Columbia River flows at Bonneville Dam during the two-shift sample periods in 2011 and 2012, as compared to the average flow from 2002 to 2010. Drought-year flows for 2001 are also shown for comparison.

Three releases of transported yearling Chinook salmon and steelhead occurred before our intensive sampling period began. Very few inriver migrant fish from the transportation study were detected prior to the intensive sampling period, although these fish would not be expected in the estuary for several days or weeks after the release of transported fish. After the intensive sampling period had ended, most fish detected at Bonneville Dam were subyearling Chinook salmon, and these fish continue to migrate during summer months. Transportation of subyearling Chinook continued into October.

We sampled with the matrix trawl system for 951 h during 2012 and detected 16,732 PIT-tagged fish. By comparison, in 2011 we sampled for 671 h and detected 14,123 fish (Figure 4). A similar number of PIT-tagged fish were released during the spring migration in both years, and average detection rates were also similar, at 18 h^{-1} in 2012 vs. 21 fish h^{-1} in 2011. Since 1998, when we began intensive sampling, we have observed a strong relationship between flow volume and trawl detection rates. Increasing river flow volume is associated with decreasing detection rate of fish previously detected at Bonneville Dam (a rough measure of sample efficiency; Magie et al. 2010, Morris et al. 2012).

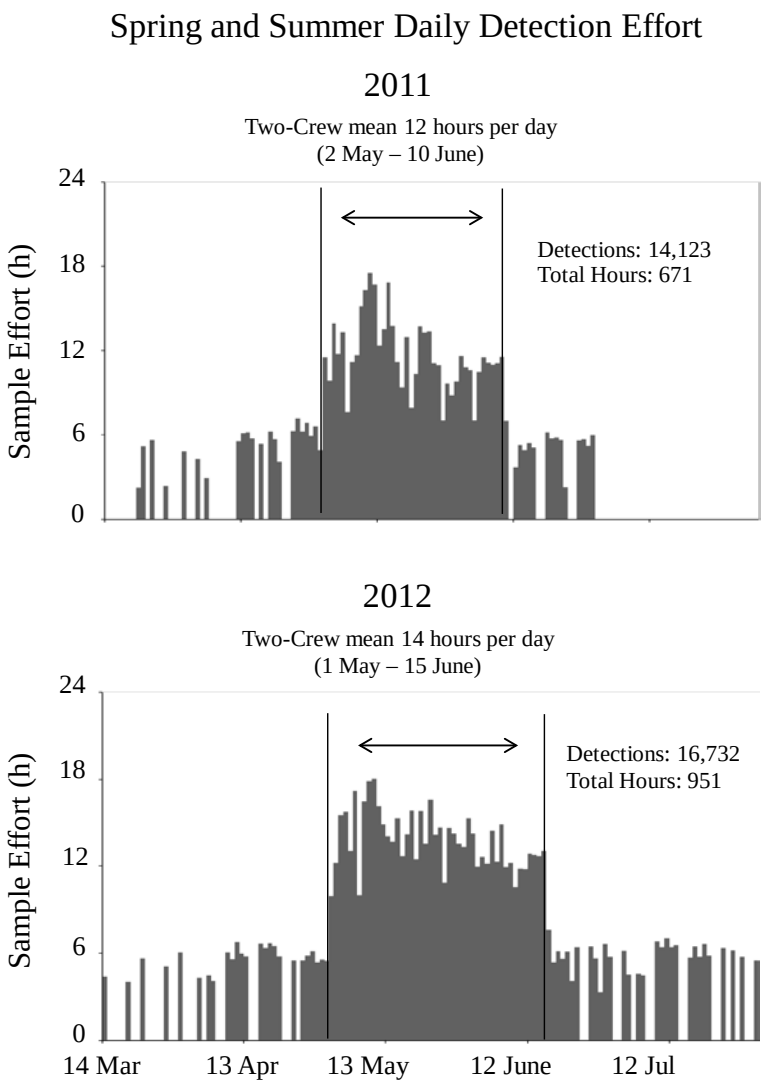

Figure 4. Daily sample effort in spring/summer 2011 and 2012 using a pair-trawl fitted with a "matrix" antenna for PIT-tag detection. Sampling was conducted near Jones Beach at Columbia River km 75 (rkm 61-83).

There are a variety of factors contributing to the relationship between higher flows and lower detection rates. First, high flows carry fish downstream more rapidly than during lower flows. This shortens the amount of time that a given fish is present in the sample reach and available for detection. Second, high flows likely disperse migrants across a greater volume of water. For any given fish that is present in the estuary during sampling, we expect that this broader dispersion would reduce its likelihood of passing through the trawl.

High flows also decrease detection rates by reducing actual sample time in three ways. First, high flows increase the transit time required for vessels to reach the upstream end of the sample reach, where the trawl is initially deployed. Second, high flows reduce 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, higher flows are typically accompanied by more debris accumulation in the trawl net. The larger fish-passage corridor of the matrix antenna provided some mitigation of this problem by allowing most debris to pass through the trawl so that less sample time was lost while idling to allow for debris removal.

In 2012 we detected a total of 16,627 juvenile salmonids of known species plus another 105 fish lacking release information in PTAGIS (Table 1; Appendix Table A1). For most identified fish, information on run-type and origin (hatchery or wild) was also available, however 645 had species data but no other information associated with their respective tags.

Table 1. Species composition and origin of PIT-tagged fish detected with the trawl system in the upper Columbia River estuary near rkm 75 in 2012.

	Rear type			
Species/run	Hatchery	Wild	Unknown	Total
Spring/summer Chinook salmon	4,273	1,103	260	5,636
Fall Chinook salmon	1,804	43	28	1,875*
Coho salmon	443	24	2	469
Steelhead	5,308	2,186	308	7,802
Sockeye salmon	769	27	47	843
Sea-run Cutthroat	0	2	0	2
Unknown	0	0	105	105
Grand total	12,597	3,385	750	16,732

* Includes 16 Snake River fall Chinook salmon released in 2011 that had overwintered in freshwater.

Of those fish detected having PIT-tag release information, 34% were spring/summer Chinook salmon, 11% were fall Chinook salmon, 46% were steelhead, 5% were sockeye, 3% were coho, and the remaining 1% were unknown salmonid species. Total detections by origin were 20% wild, 75% hatchery, and 5% unknown at the time of this report. These numbers may change slightly as incomplete PTAGIS records are updated.

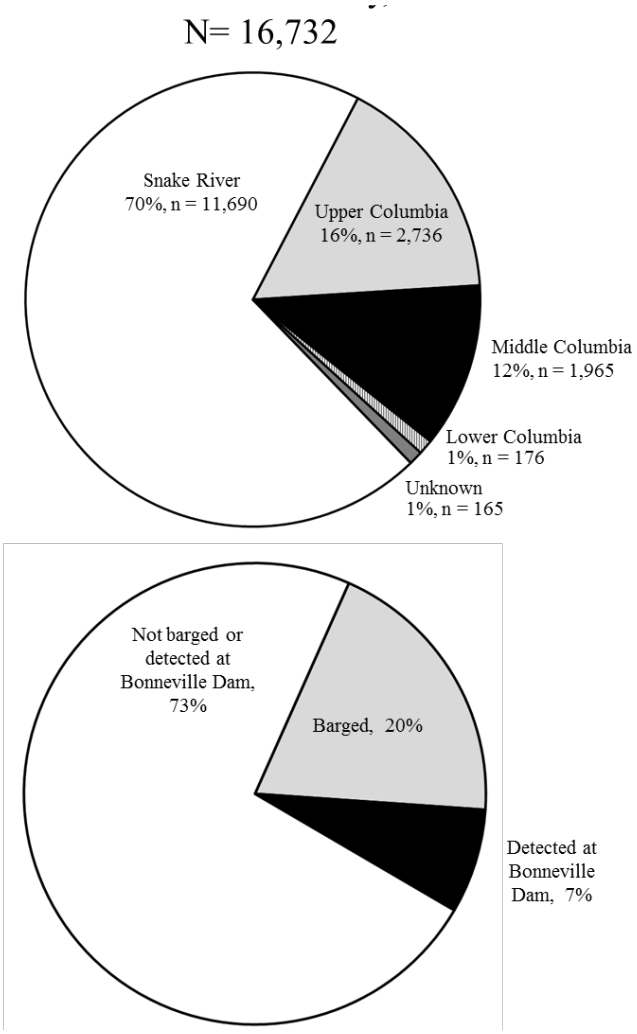

Figure 5. Proportions of fish detected in the trawl by source and migration history, 2012. Upper and mid-Columbia River sources were defined relative to McNary Dam. Fish that originated in the Columbia River below Bonneville Dam could not be transported, nor could they pass Bonneville Dam.

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). Proportions detected in 2012 were similar to recent years for all species except steelhead, which were proportionally higher.

Similar proportions of steelhead were tagged in 2011 and 2012 and similar proportions of steelhead were detected relative to yearling Chinook salmon at Bonneville Dam in both years. Though numbers of steelhead transported in both years were similar, the detection rates of those fish in 2012 were substantially higher than in 2011 (Table 2).

Table 2. Differences in estuary trawl detection rates between PIT-tagged yearling Chinook salmon and steelhead released from barges during two-crew sampling periods, 2008-2012.

	Yearling Chinook			Steelhead			
Year	Released	Detected	%	Released	Detected	%	Difference in detection rate
2008	138,826	2,363	1.70	84,109	1,602	1.90	0.20
2009	72,788	1,950	2.68	55,874	1,857	3.32	0.64
2010	43,393	1,459	3.36	43,228	1,412	3.27	-0.09
2011	78,820	978	1.24	49,633	1,286	2.59	1.35
2012	51,685	666	1.29	49,911	1,757	3.52	2.23

Reservoir-type juvenile fall Chinook salmon are defined as those that begin downstream migration in late spring, summer, or fall but suspend migration to overwinter in freshwater reservoirs or in the estuary, and resume migration the following spring (Connor et al. 2005). We detected 16 "reservoir-type" Snake River fall Chinook juveniles in the upper estuary between 11 April and 4 June 2012 (Appendix Table A2). According to release information in PTAGIS, 14 of these 16 fish had been released from the Big Canyon Creek acclimation facility on the Clearwater River (rkm 803), a tributary to the Snake River during 2011. The remaining two reservoir-type fish had been released at other locations on the Clearwater River.

Eleven of the 16 reservoir-type fish we detected had been previously detected at a Snake River dam or at McNary Dam in 2011 and subsequently detected at a dam upstream from Bonneville in 2012 before being detected in the estuary. 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 five reservoir-type fish could not be determined because they had not been detected in 2012 prior to detection in the trawl. However, none of these fish had been transported. 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 2012, we recovered 211 such salmonids from the matrix antenna system and trawl (Appendix Table A3). 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 through detection antennas, 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 fish 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 extends forward of the trawl body 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 steelhead were created from fish detected passing McNary Dam during the same week. For fish originating in the upper Columbia River in 2012, detections at McNary Dam were insufficient to form weekly groups, so these detections were used to estimate mean survival over the migration season (Faulkner et al. 2013). Similar mean seasonal estimates were made for Snake and upper Columbia River sockeye salmon 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 1999-2012 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.

For Snake River yearling Chinook salmon, estimated survival from McNary to Bonneville Dam tailrace was 80.2% in 2012 and has ranged from 50.1% in 2001 to 84.2% in 2006. For yearling Chinook originating in the Columbia River upstream of the

confluence with the Yakima River, the survival estimate in 2012 was the highest since estimates began in 2008 (84.5%), 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 2012 was the lowest since 2008 (55.8%) and the highest estimated survival for this group was in 2009 (88.3%). No estimate was possible in drought year 2001 when the lowest survival estimate occurred for Snake River yearling Chinook.

Table 3. Average survival from the tailrace of McNary Dam to the tailrace of Bonneville Dam for weekly or seasonal groups of PIT-tagged salmonids by species, 2012. 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				
27 Apr–3 May	9,265	0.905 (0.037)	1.111 (0.260)	1.005 (0.232)
4 May–10 May	9,209	0.906 (0.031)	0.826 (0.120)	0.748 (0.106)
11 May–17 May	12,417	1.040 (0.077)	0.794 (0.156)	0.826 (0.151)
1 8 May–24 May	3,504	0.854 (0.092)	0.749 (0.293)	0.640 (0.241)
25 May–31 May	1,957	0.833 (0.139)	0.869 (0.327)	0.724 (0.244)
Weighted mean		0.915 (0.023)	0.866 (0.058)	0.802 (0.051)
Steelhead				
27 Apr–3 May	3,704	0.731 (0.054)	NA	NA
4 May–10 May	2,106	0.941 (0.100)	1.141 (0.496)	1.074 (0.452)
11 May–17 May	2,238	0.915 (0.134)	1.246 (0.621)	1.140 (0.543)
18 May–24 May	1,374	0.850 (0.135)	NA	NA
25 May–31 May	793	0.712 (0.142)	0.768 (0.311)	0.546 (0.193)
Weighted mean		0.814 (0.048)	1.021 (0.148)	0.856 (0.196)
Sockeye	47,519	0.741 (0.071)	0.822 (0.151)	0.609 (0.106)
	Upper Columbia River wild and hatchery pooled groups			
Yearling Chinook				
Above Yakima R	110,764	0.845 (0.030)	1.001 (0.112)	0.845 (0.092)
Yakima River	85,754	0.866 (0.033)	0.644 (0.093)	0.558 (0.079)
Steelhead	111,094	0.875 (0.034)	1.159 (0.122)	1.014 (0.106)
Sockeye	3,231	0.837 (0.155)	1.004 (0.503)	0.840 (0.405)

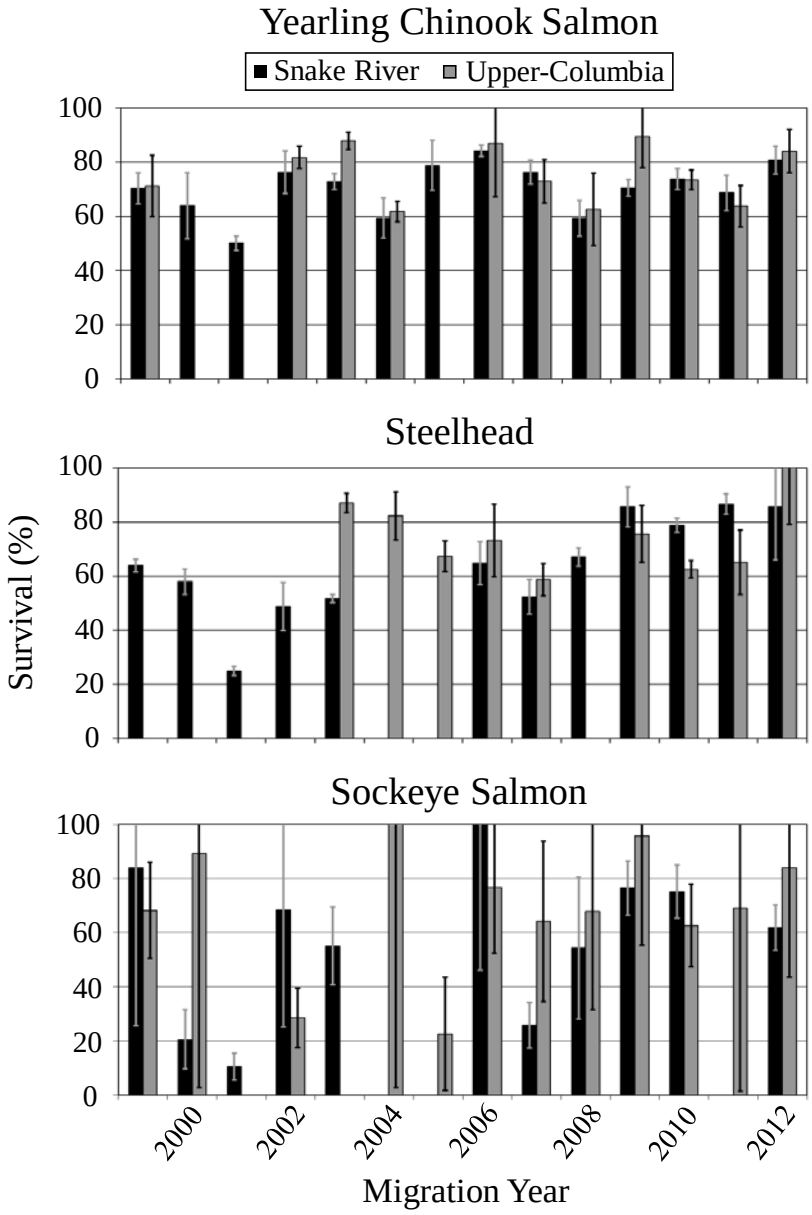

Figure 6. Weighted average annual survival and SE from the tailrace of McNary Dam to the tailrace of Bonneville Dam, for Snake and Columbia River yearling Chinook salmon, steelhead, and sockeye, 1999-2012.

For Snake River steelhead, estimated survival from McNary to Bonneville Dam tailrace was 85.6% in 2012 and has ranged from 25.0% in 2001 to 86.6% in 2011. For upper Columbia River steelhead, survival in this reach during 2012 was the highest on record (estimated over 100%). The lowest estimated survival was recorded in 2007 at 58.7%. 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 2012, estimated survival for Snake River sockeye salmon from McNary to Bonneville Dam tailrace was 61.9%. Historically, these estimates have ranged from 10.5% in 2001 to 100% in 2006. For upper Columbia River sockeye salmon, survival through this same reach was estimated at 84.0% in 2012 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 stocks are reported by Faulkner et al. (2013).

Migrating juvenile fish released in the upper Snake River must traverse eight dams and reservoirs or be transported from one of four collector dams to reach the tailrace of Bonneville Dam. Transported fish can potentially avoid passage at 7 dams and migration through approximately 461 km from the tailrace of Lower Granite Dam to the tailrace of Bonneville Dam (Marsh et al. 2005; 2008; 2010; 2012).

In 2011, seasonal average estimated survival through the entire hydropower system, from Lower Granite to Bonneville Dam tailrace, was 51.3% for yearling Chinook salmon and 60.0% for steelhead. In 2012, overall hydrosystem survival estimates were 63.4% for yearling Chinook salmon and 59.7% for steelhead, although meaningful comparison with estimates from previous years was not possible due to lack of precision in these estimates. Small sample sizes precluded any meaningful estimate of survival through the entire hydrosystem for sockeye salmon in 2011; the estimate in 2012 was 47.2% but was also too imprecise for any meaningful interpretation.

The benefit of transportation for fish, expressed as smolt-to-adult return ratios (SARs) of transported to inriver migrant fish in a given year, depends in part on conditions experienced by fish as juvenile migrants in the river and hydropower system in that same year. 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 survival estimates 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 characterized by extremely low river flows due to regional drought.

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, 1998-2012.

	Estimated seasonal average survival from Lower Granite to Bonneville Dam tailrace					
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	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*	39.5	5.0	--	--	--	--
2005*	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

* In 2004 and 2005, the corner collector bypass (BCC) structure at Bonneville Dam had no PIT-tag detection capability; as a result, detection numbers were too low for accurate estimates 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, no wild fish and few hatchery fish were returned to the river from juvenile facilities at dams to migrate in the river. As is normal for most years, all transport study fish were barged and released downstream from Bonneville Dam (Marsh et al. 2005, 2010).

Flow volumes at Bonneville Dam in 2012 were well above average for the second consecutive year. Flow peaked early in the migration period and remained 30-40% above average until the end of May when river flows historically peak. Flow continued to remain high through the end of July when sampling concluded. This year marked the second consecutive year of low PIT-tag detections at Bonneville Dam. For example, in 2010 over 207,000 PIT-tag detections were recorded at Bonneville, while only 60,000 were recorded in 2011 and 77,000 were recorded in 2012.

From 16 May to 13 June, flow was routed away from the Second Powerhouse and through the First Powerhouse due to observed descaling of juvenile sockeye salmon at the Second Powerhouse. During this time detections at Bonneville Dam were significantly reduced, and this resulted in decreased precision of survival estimates in

2012 (Faulkner et al. 2013). Use of surface bypass devices allowed large proportions of migrating salmonids to pass dams via spillways, which likely increased passage survival at these dams; however at present, most surface-passage routes lack PIT-tag detection capability. High flows in 2012 further increased spill volumes which also increased total dissolved gas levels in the river. Historically this has raised concern about smolt mortality due to gas trauma (Faulkner et al. 2012).

In 2012, estimated survival for steelhead from the tailrace of Lower Granite Dam to the tailrace at Bonneville Dam was similar to estimates in 2009 and 2010, which were the second and third highest estimated survival years for this reach since 1998. High survival for 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 particularly benefit juvenile steelhead, which tend to be more surface-oriented during migration. 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 heavily 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 of transported fish 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 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 operations with the expected passage through the estuary of primarily yearling fish tagged and released for NMFS transportation studies. After being tagged at Lower Granite Dam (rkm 695), transportation 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 until August 2012, after our sampling in the estuary had concluded. 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 four 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 2012 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 transported fish released from barges and fish detected at Bonneville Dam on the same date.

For PIT-tagged yearling or subyearling 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.

One-way ANOVA 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). Again in 2012, fish facilities at dams throughout the basin were affected by impacts of high flows. High flows in April resulted in an earlier migration through Snake River dams that largely occurred prior to the beginning of fish transportation on 2 May. In mid-season, managers at Bonneville Dam were forced to route fish away from detection systems located exclusively at the Second Powerhouse, thus fewer PIT-tagged fish previously detected passing Bonneville Dam were available in the estuary to establish daily travel speed estimates.

We prepare seasonal summaries of travel time distributions to allow for multi-year comparisons. In 2011, record high flows occurred after 16 May thus we separated the data at that date because of the magnitude of change to travel speed estimates related to the high flow period. Flow volumes in 2012, while high, were relatively consistent during the spring migration period therefore a temporal split in the data like 2011 was not necessary.

Table 5. Median travel time to the upper estuary (rkm 75) in days for yearling Chinook salmon and steelhead detected at Lower Granite Dam, at Bonneville Dam, or released from barges just downstream from Bonneville Dam, 2000-2012. 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)				Detection at Bonneville Dam (rkm 234)				Release from transportation barge (rkm 225)				
	Yearling Chinook salmon		Steelhead		Yearling Chinook salmon		Steelhead		Yearling Chinook salmon		Steelhead		
Year	Travel time (d)	Sample (n)	Travel time (d)	Sample (n)	Travel time (d)	Sample (n)	Travel time (d)	Sample (n)	Travel time (d)	Sample (n)	Travel time (d)	Sample (n)	Flow ($m^3 s^{-1}$)
2000	17.4	681	17.1	833	1.7	479	1.7	296	1.9	495	1.6	301	7,415
2001	32.9	680	30.1	44	2.3	792	2.5	59	2.9	1,329	2.3	244	3,877
2002	18.2	538	17.8	93	1.8	1,137	1.7	156	2.0	1,958	1.6	296	8,071
2003	17.0	563	16.5	95	1.8	1,721	1.7	567	2.1	2,382	1.7	435	7,120
2004	16.6	867	16.6	153	1.9	672	2.0	110	2.2	2,997	1.9	333	6,663
2005	17.3	1,183	16.9	278	1.8	81	2.0	471	2.2	2,910	1.9	400	5,776
2006	14.7	628	12.5	110	1.7	888	1.6	131	2.1	1,315	1.6	170	9,435
2007	15.7	1,196	15.6	117	1.7	1,510	1.7	362	2.2	1,096	1.7	143	6,858
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

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.

Through the first month of our intensive sampling period in 2012, river flow volume measure at Bonneville Dam was approximately 40% higher than average. Flow at Bonneville dropped closer to average levels at the end of May for a short time before again rising to above-average levels. This flow pattern resulted in some of the fastest travel times to the estuary on record for inriver migrant fish detected at Lower Granite or Bonneville Dam, and for transported fish released just below Bonneville dam.

For yearling Chinook salmon, median travel time from Lower Granite Dam to the estuary was faster in 2012 than during the 2011 period of normal flow (15.4 d vs. 17.8 d, respectively), but slower than during the 2011 period of high flow after 16 May (13.2 d). Median travel time for steelhead through the same reach in 2012 was similar, with a mean of 11.2 d, which was faster than the normal flow and slower than the high-flow period in 2011 (15.5 and 10.0 d, respectively). Thus in general, travel times from Lower Granite Dam to the estuary in 2012 were among the fastest on record for both species presumably due to the high flow volumes present throughout most of the migration period.

Median travel time to the estuary from Bonneville Dam was faster in 2012 than during the period prior to high flows in 2011 for yearling Chinook (1.6 vs. 1.8 d), however, it was slightly slower than during the high flow period of 2011 (1.5 d). Median travel time from Bonneville was also faster for steelhead in 2012 than the early season of 2011 (1.5 vs. 1.6 d), but slower than the median travel time during the high flow period in 2011 (1.3 d). With the exception of the high flow period of 2011, steelhead travel times from Bonneville Dam to the estuary in 2012 were the fastest on record.

Transported yearling Chinook salmon released just below Bonneville Dam traveled faster to the estuary in 2012 than they did during the period prior to high flows in 2011 (median 2.0 d vs. 2.1 d), but slower than during the high flow period of 2011 (1.6 d). Steelhead median travel time in 2012 (1.5 d) was similar to the period prior to the high flows (1.6 d) and during the high flows in 2011 (1.5 d).

We also compared daily differences in travel speed to the estuary between transported and inriver migrating fish (Figure 7). Mean travel speed to the estuary was significantly slower for yearling Chinook salmon released from barges (78 km d^{-1}) than for those traveling inriver and detected at Bonneville Dam (99 km d^{-1}; $P \leq 0.001$). Mean travel speed was also significantly slower for steelhead released from barges (94 km d^{-1}) than for those detected at Bonneville (106 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.

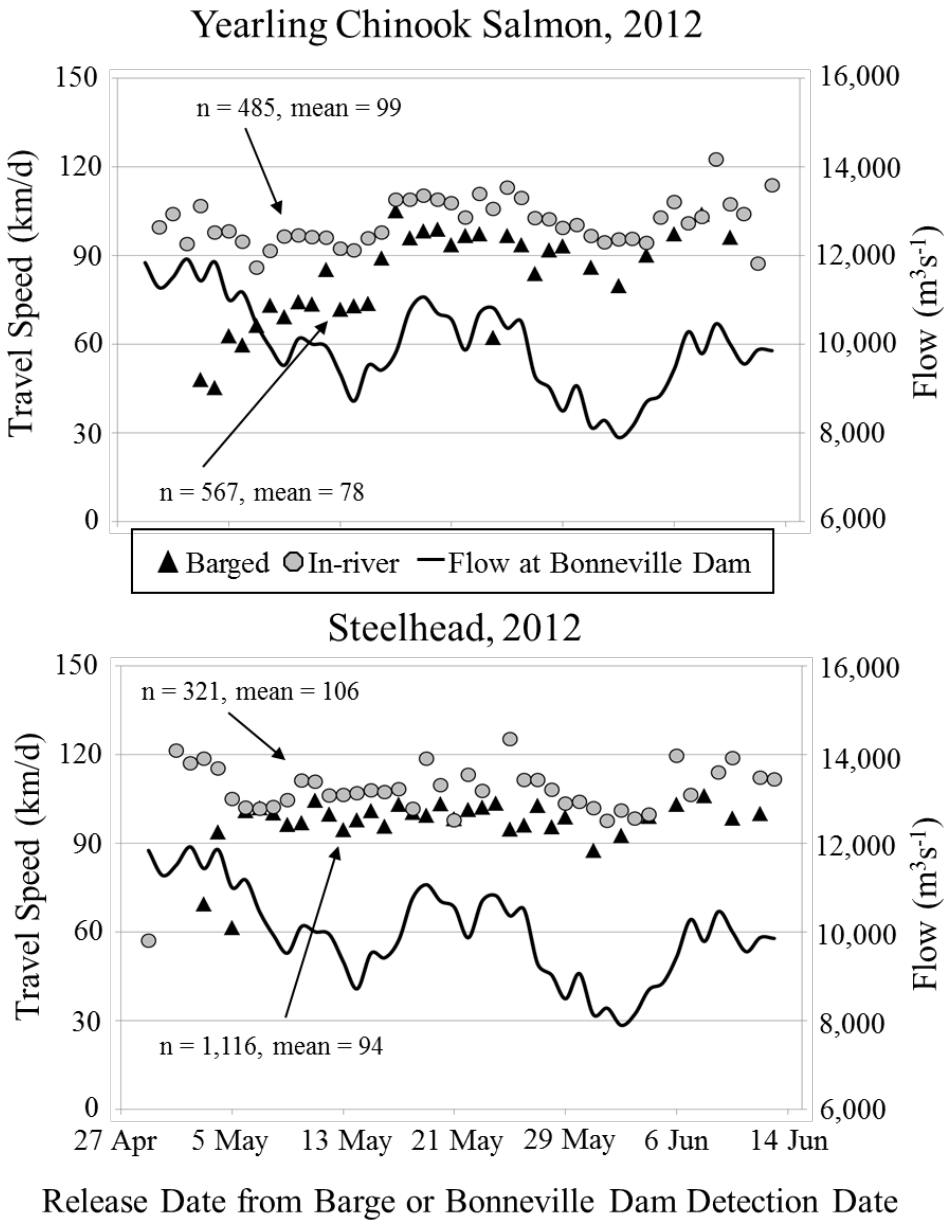

Figure 7. Daily median travel speed to the estuary of yearling Chinook salmon (top) and steelhead (bottom) following detection at Bonneville Dam or release from a barge to detection in the estuary (rkm 75), 2012. Seasonal means are shown for comparison.

Subyearling Fall Chinook Salmon—We detected 1,189 subyearling fall Chinook salmon, nearly all of which had been tagged and released after 30 April 2012 and 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 296 transported and 893 inriver migrant subyearling fall Chinook salmon between May and late July (Figure 8). The majority of these fish had originated in the Snake River. Of all subyearlings detected by the trawl system, 82% originated in the Snake River, 8% in the Upper Columbia River (at or upstream from McNary Dam), 9% in the mid-Columbia River (between Bonneville and McNary Dam), and the remaining 1% in the Lower Columbia River (downstream from Bonneville Dam). The difference in detection numbers between Snake and upper Columbia River stocks likely reflected variation in regional tagging effort rather than different detection rates in the estuary.

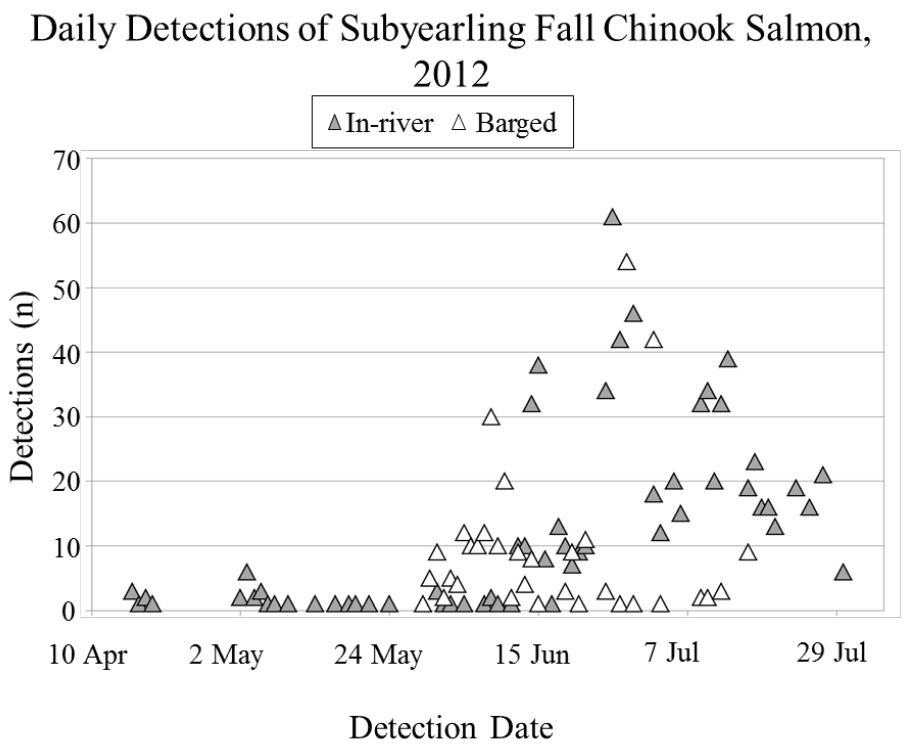

Figure 8. Temporal detection distribution for subyearling Chinook salmon in the estuary during inriver migration or following release from barges below Bonneville Dam, 2012.

We 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. Daily median travel speeds for both groups increased with increasing river flow during 2012 (Figure 9). Subyearling Chinook salmon migrating inriver and detected at Bonneville Dam traveled significantly faster than those transported and released below Bonneville Dam during the same period (101 vs. 80 km d^{-1}; $P \leq 0.001$). 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. 2012).

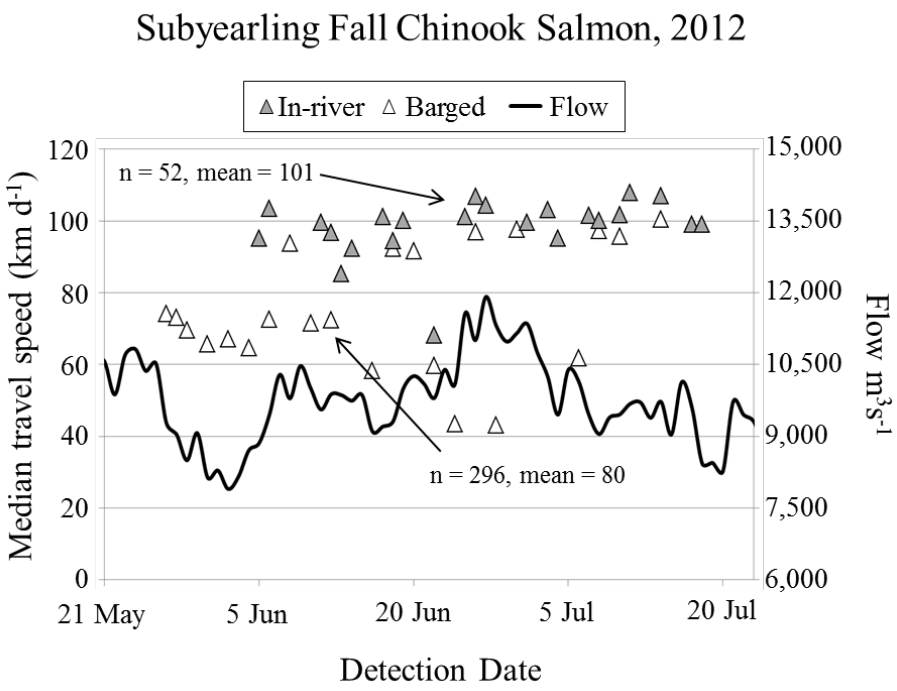

Figure 9. Daily median travel speed to the estuary for transported vs. inriver migrant subyearling Chinook salmon, 2012. Daily river flow volume at Bonneville Dam is shown for comparison.

Sockeye Salmon—We detected 843 sockeye salmon between 2 May and 21 June (Figure 10). These fish had been released from two sites on the Snake River and four sites on the mainstem Columbia River. Of these 843 sockeye, 91% were hatchery fish, 3% were wild fish, and the remaining 6% were of unknown origin. Transported fish accounted for 429 of the 843 sockeye detections. Of the 414 inriver migrant sockeye we detected, only 58 had been previously detected at Bonneville Dam.

Of the 429 transported sockeye detected, 182 had been transported from Lower Granite Dam, 178 from Little Goose Dam, and 69 from Lower Monumental Dam. Sockeye released upstream from McNary Dam on the Columbia River made up 8% of our sockeye detections, while releases from the Snake River made up 92%. We detected one fish that had been released between McNary and Bonneville Dam (Deschutes River). Mean travel speed from Bonneville Dam to detection in the trawl was significantly faster for sockeye migrating inriver and detected at Bonneville Dam than transported fish released below Bonneville (104 vs. 93 km d^{-1}; $P \leq 0.001$; Figure 11),

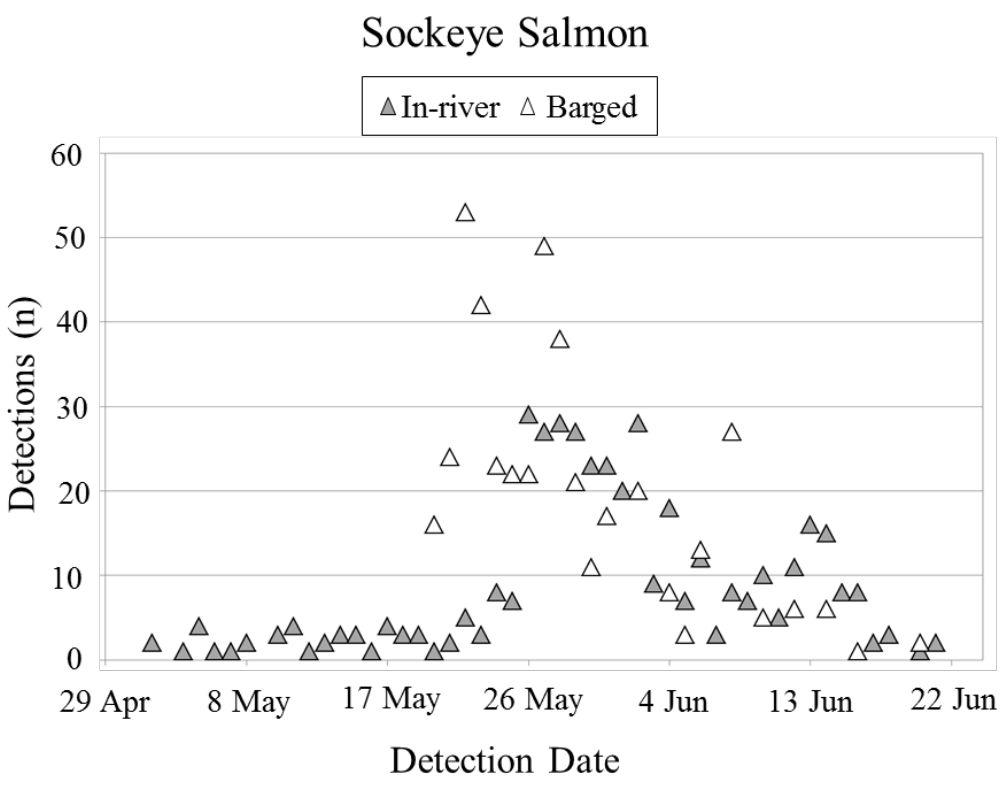

Figure 10. Temporal distribution for PIT-tagged sockeye salmon in the estuary, 2012.

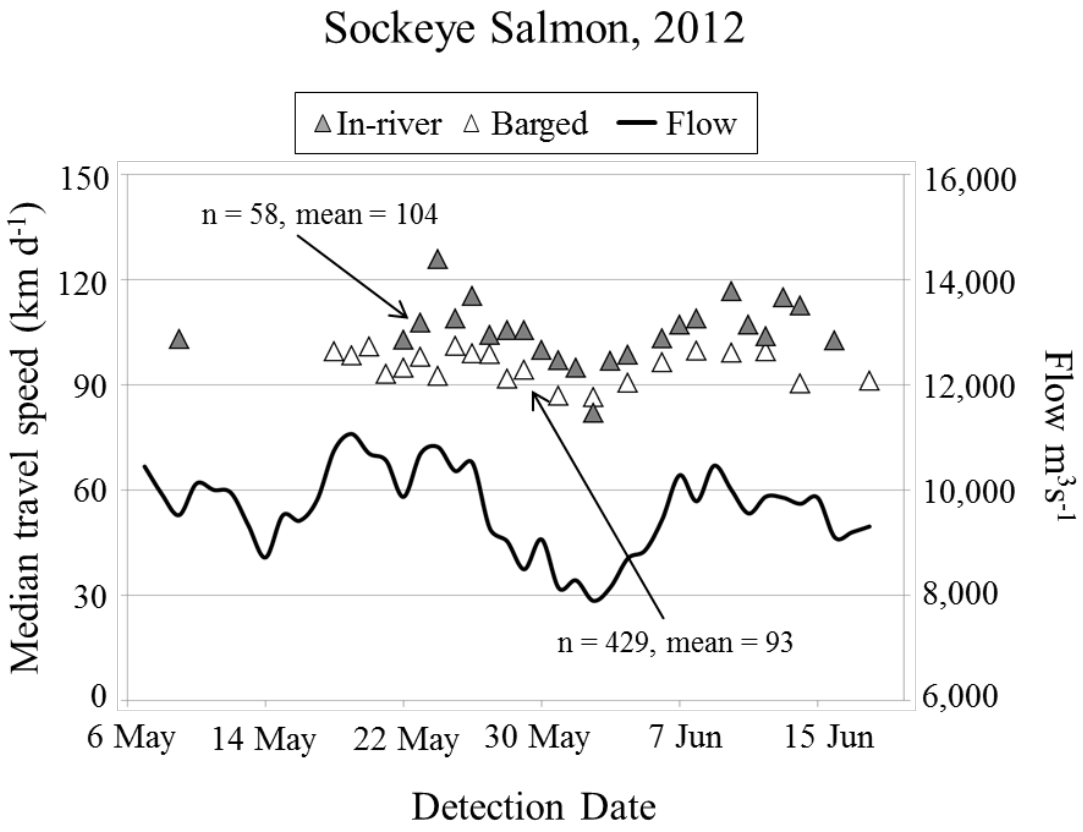

Figure 11. Daily median travel speed to the estuary for transported vs. inriver migrant Sockeye salmon, 2012. Daily river flow volume at Bonneville Dam is shown for comparison.

In summary, travel speed from the area of Bonneville Dam to the estuary was among the fastest on record for all fish groups in 2012, and these faster speeds appear directly correlated to the higher flow volumes. During our intensive sample period overall flow volumes averaged 9,912 $m^3 s^{-1}$ in 2012. These flows were only 16% lower than the record high flow levels recorded in 2011, and were well above the average over the past 10 years. Both daily and seasonal travel speeds of fish are strongly correlated with river flow volume.

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. Diel availability during the intensive sampling period was determined for each species by weighting the average hourly detection rates by respective numbers of hatchery and wild fish detected. For this analysis, we excluded hourly periods when sample effort was minimal, i.e., the afternoon refueling period between day and evening shifts.

Detection numbers during daylight and darkness hours were compared using a one-way ANOVA (Zar 1999). For this analysis, the number of detections per hour and the number of minutes that the system was operated each hour were separated into daylight- and darkness-hour categories. Hourly detections for each species were weighted by the number of minutes that the detection system was operating during that hour. 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 1 May-15 June, we detected 5,802 yearling Chinook salmon and 7,047 steelhead with the detection system operating an average of 14 h d^{-1} (Appendix Table A4). We generally stopped sampling each day between 1400 and 1900 PDT for crew changes and fueling of vessels.

Hourly detection rates of hatchery yearling Chinook salmon were greater during nighttime (2030 to 0430) than during daytime hours (11 vs. 7 fish h^{-1}, $P = 0.065$). However, hourly detection rates of wild yearling Chinook salmon were the same during nighttime and daytime hours (2 vs. 2 fish h^{-1}, $P = 0.326$). Hourly detections rates were significantly different between darkness and daylight hours for both hatchery and wild steelhead (5 vs. 10 hatchery fish h^{-1}, $P = 0.005$ and 2 vs. 4 wild fish h^{-1}, $P = 0.007$).

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 2012, so we pooled data by species and origin for a multi-year analysis (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 2012 were again higher during darkness for hatchery Chinook salmon, but showed no correlation to light conditions for 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 nearer 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 (Ledgerwood et al. 1991). In 2012, steelhead made up 46% of total pair-trawl detections, the highest this proportion has ever been. 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.

Diel analyses showed that detection rates for steelhead during morning daylight hours were 2-3 times higher than the average over the past 9 years. Detection rates for yearling Chinook were below the 9-year average for every hour in 2012. The higher relative proportion of steelhead detections over yearling Chinook salmon in the estuary in 2012 was not observed for fish detected passing Bonneville Dam. There were similar proportions of steelhead and yearling Chinook tagged in 2012 as in recent years, and similar proportions were transported (presented earlier).

High flow throughout the entire intensive sampling period in 2012, rather than later in the season as in 2011, increased the travel speed of transported steelhead to the estuary in 2012. Our afternoon shut downs for refueling and maintenance no doubt lowered detections of steelhead passing through the estuary in early afternoon, particularly in 2011 before flows increased (Figure 13). While it is also possible that transported steelhead had higher post-transport survival in 2012, it appears that earlier diel availability of transported steelhead at rkm 75 due to high early season flows in 2012 was the main influence on our detection numbers.

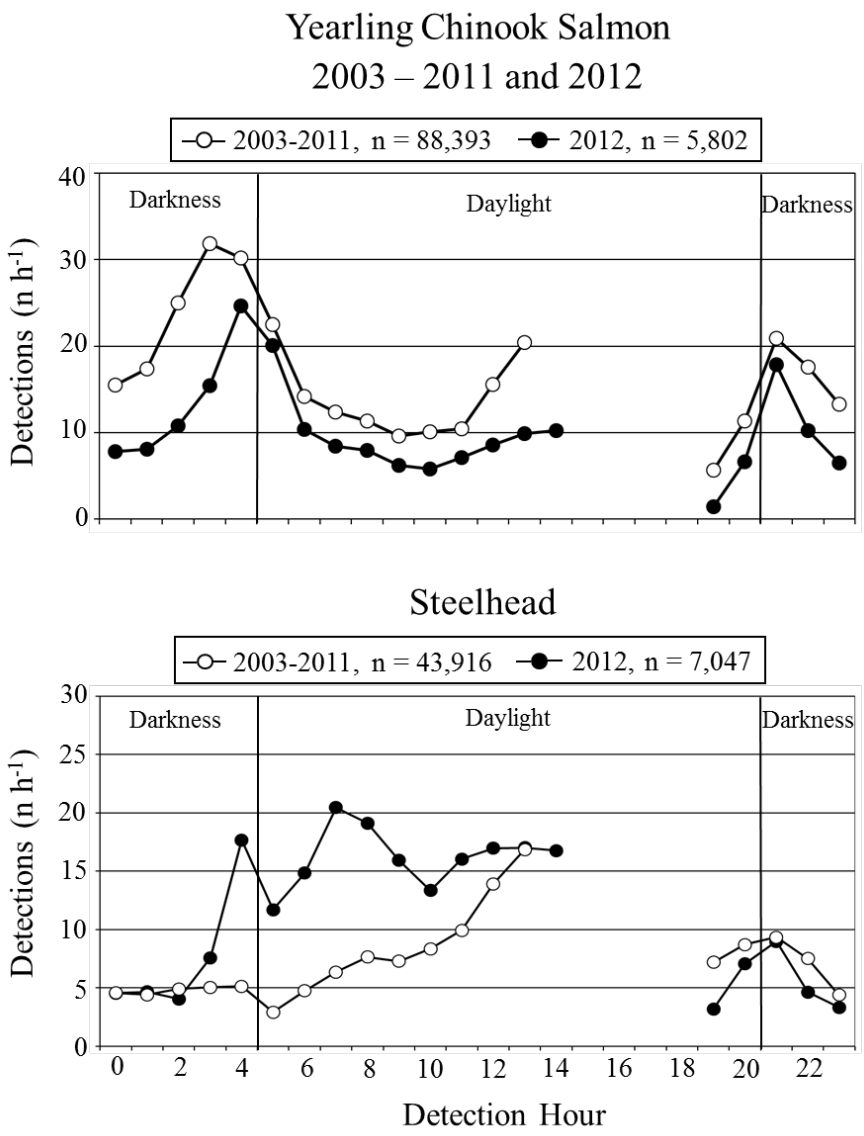

Figure 12. Average hourly detection rates of yearling Chinook salmon and steelhead during the two-shift sampling periods of 2003 through 2011, versus 2012, using the matrix antenna system in the upper estuary near river kilometer 75.

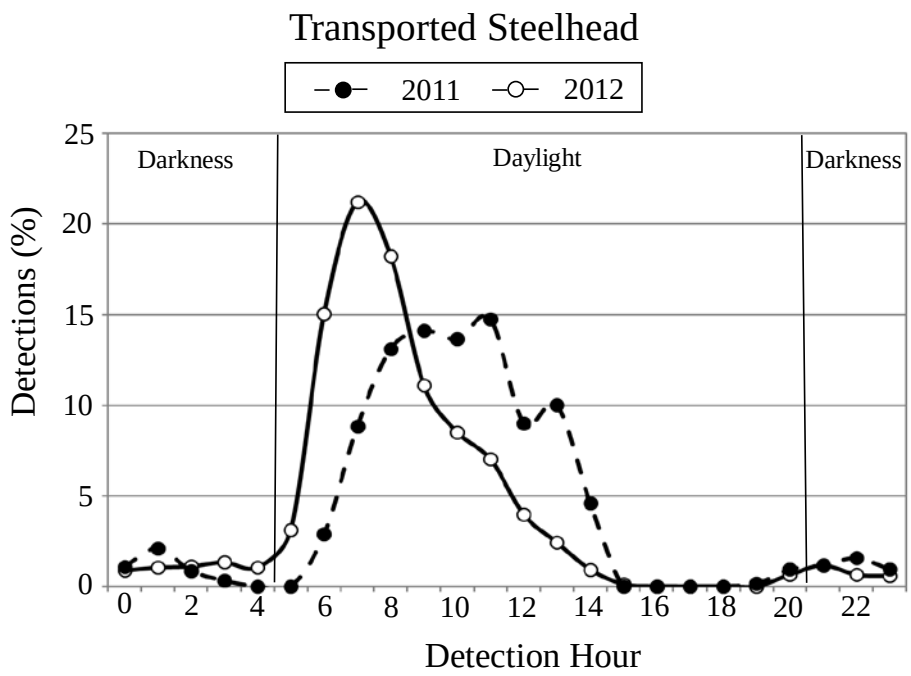

Figure 13. Hourly detection proportions for transported steelhead during intensive day/night sampling periods, 2011 and 2012.

Detection Rates of Transported vs. Inriver Migrant Fish

Methods

We compared daily detection rates in the trawl between transported fish 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. During 2012, approximately 86,000 yearling Chinook salmon, 592,000 subyearling Chinook salmon, and 62,000 steelhead were PIT-tagged and released for NMFS Snake River fish transportation studies. Including river-run fish diverted to barges and fish tagged and transported for other studies, a total of 51,685 yearling Chinook salmon and 49,911 steelhead were transported and released upstream from our sample site during the intensive sample period.

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

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

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. If $\sigma > 1.0$, we adjusted the standard errors of the model coefficients by multiplying by σ (Ramsey and Schafer 1997). This inversely adjusted the *z* statistic used to test the

significance of the coefficients, as well as appropriately inflated estimate standard errors. Finally, if the interaction terms were not significant (likelihood ratio test $P > 0.10$), 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, depending on the data situation.

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

Of the fish transported and released downstream from Bonneville Dam, we detected 666 yearling Chinook salmon and 1,757 steelhead in the upper estuary (Table 6; Appendix Tables A5-6). We detected 486 (1.7%) of the 28,252 yearling Chinook salmon released upstream from McNary Dam and detected at Bonneville Dam and 325 (2.6%) of the 12,481 steelhead detected at Bonneville Dam (Appendix Table A7).

As in previous years, a portion of both PIT-tagged barged and inriver migrant groups passed through the estuary either before or after the trawl-sampling period. In 2012, allowing 2 d for fish at Bonneville Dam to reach the sample area, we estimate that 90% of yearling Chinook and 90% of steelhead released from barges and 83% of yearling Chinook and 91% of steelhead detected at Bonneville Dam were at or near rkm 75 during the two-shift sample period (1 May-15 June). These percentages were higher than in 2011, despite three early-season index barge releases that occurred prior to the start of our intensive sampling period in 2012 when few inriver migrant fish had reached the estuary. There were also large numbers of subyearling Chinook salmon that were PIT-tagged and released after our intensive sample period, which targeted primarily yearling migrants.

During the intensive sampling period, the trawl was deployed for an average of 14 h/d, and detected 1.7% of the yearling Chinook salmon and 2.6% of the steelhead previously detected at Bonneville Dam. By comparison, the trawl was deployed for an average of 12 h/d during intensive sampling in 2011, and detected 1.8% of the yearling Chinook and 2.8% of the steelhead detected at Bonneville Dam. In 2012, we also detected 1.3% of the yearling Chinook salmon transported and released downstream from Bonneville Dam (vs. 1.2% in 2011), and 3.5% of steelhead transported and released downstream from Bonneville Dam (vs. 2.6% in 2010). The increased detection rate of transported steelhead in 2012 was exceptional given the high flow conditions. We attributed this increase primarily to a shift in the diel availability of transported steelhead, (Figure 13) from higher numbers passing the sample area during active sampling rather than during our afternoon shut-down period for re-fueling and maintenance.

Table 6. Trawl detection rates of PIT-tagged fish released from barges or detected passing Bonneville Dam during the intensive sample period, 1 May-15 June 2012.

	Barged fish released downstream from Bonneville Dam			Inriver fish detected at Bonneville Dam*		
	Released	Detected	%	Released	Detected	%
Chinook salmon	51,685	666	1.29	28,252	486	1.72
Steelhead	49,911	1,757	3.52	12,481	325	2.60

* Selected to include only those PIT-tagged fish released at or upstream from McNary Dam, i.e., subject to fish transportation but not transported.

Logistic regression analysis showed a significant relationship between detection rate and both date and migration history (P = 0.001and 0.016, respectively) for yearling Chinook salmon. The date relationship was linear on the logistic scale as date-squared was not significant (P = 0.145). Also, there was no significant interaction between migration history and date or date-squared (P = 0.258 and P = 0.618, respectively).

Estimated detection rates for inriver migrants increased gradually from around 1.3% early in the season to 1.7% by mid-May and 2.6% by early-to-mid-June (Figure 14, top panel). Estimated detection rates for transported yearling Chinook salmon were lower but with a similar temporal trend (i.e., 1.0% early in the season, increased to 1.3% by mid-May, and continued to increase to 2.1% by the second week of June). The adjustment for over-dispersion was 2.36.

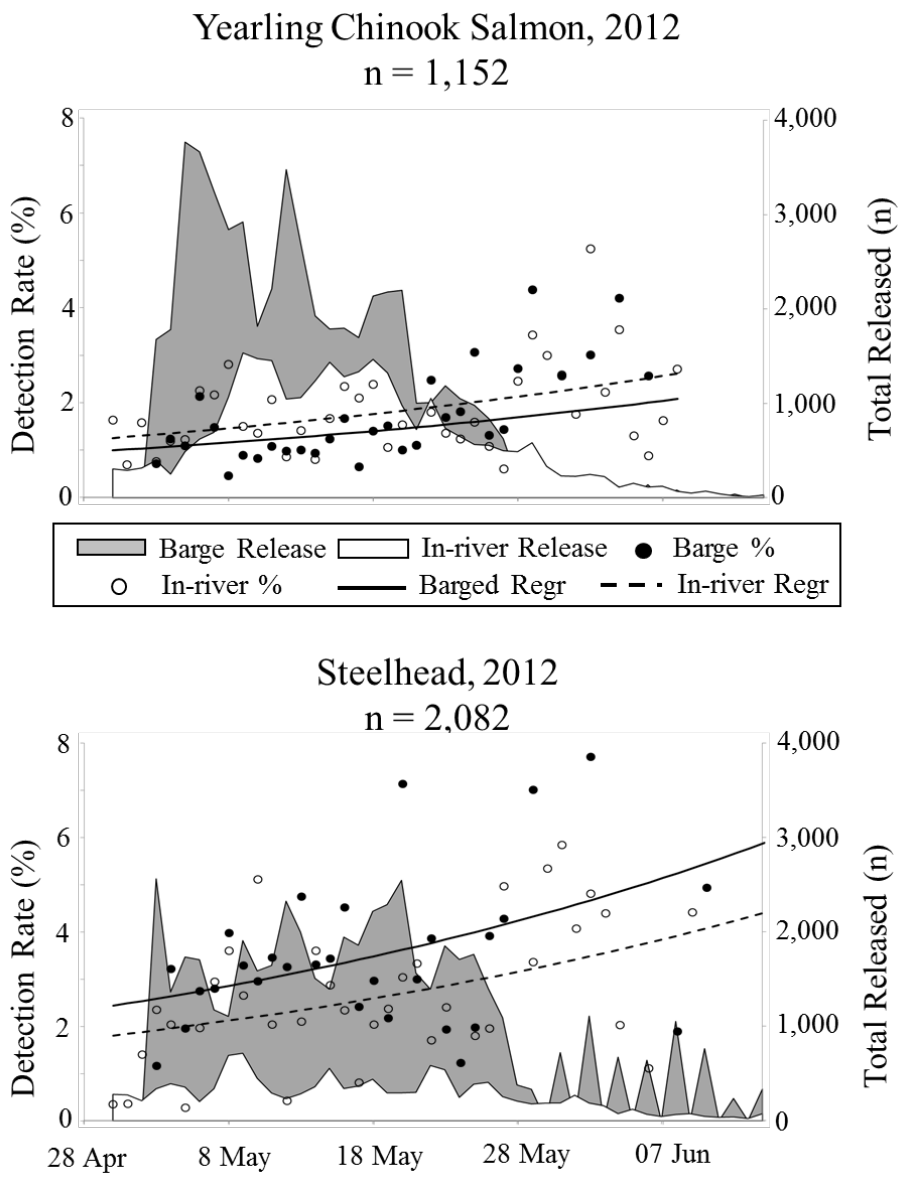

Figure 14. Logistic regression analysis of the daily detection percentage of transported and inriver migrant yearling Chinook salmon and steelhead detected at or released near Bonneville Dam on the same dates, 2012.

For steelhead, logistic regression analysis for detection rate showed no significant interaction between migration history and date or date-squared, and no significant effect for date-squared (P = 0.804, 0.880, and 0.500, respectively). There was a significant effect for date of barge release or date detected at Bonneville Dam and for migration history, ($P \leq 0.001$, P = 0.057, respectively). Estimated detection rates of both barged and inriver migrant steelhead increased steadily from early to late season (Figure 14, lower panel). Detection rates of inriver migrants rose from 1.9% in early May to 2.4% by mid-May and 4.4% by mid-June. Higher detection rates of transported steelhead were estimated at 2.5% in early May, 3.3% in mid-May, and 5.9% at the end of intensive sampling in mid-June. The adjustment for over-dispersion was 6.61.

For yearling Chinook salmon, mean detection rate in the trawl was 26% higher for transported fish released below Bonneville Dam than for inriver migrants detected at the dam, and the difference was statistically significant. The opposite was true for steelhead, with a mean detection rate for transported fish that was 34% higher than that for inriver migrant. It is possible that the lower detection rates for transported yearling Chinook salmon represent higher mortality following release from the barges than following detection at Bonneville Dam. As presented above, we believe a shift in diel availability for transported steelhead, away from the afternoon refueling period, affected these comparisons in 2012.

In summary, the precision of our relative survival analysis of both barged and inriver migrating fish based on estuary detection rates was reduced by lower detection rates due to high flows for the second consecutive year. Estuary detection rates in 2012 were similar to those in 2011, but considerably lower than 2010 when detection rates for fish previously detected at Bonneville Dam averaged 3.7% for yearling Chinook salmon and 4.1% for steelhead. Similarly, detections of fish passing at Bonneville Dam were again low in 2012 compared to previous years (63% lower than numbers detected in 2010). The management decision at Bonneville Dam to move flow from the Second Powerhouse to the First Powerhouse, where there is no PIT-tag detection capability, reduced detection rates at Bonneville Dam. This in turn reduced the number of fish detected in the estuary that could be used for estimates of survival to Bonneville Dam tailrace. Estuary detections of fish previously detected at Bonneville are fundamental to estimating survival probabilities for downstream migrating salmonids.

Mobile Separation-by-Code System

In 2012, we continued efforts to develop a prototype Mobile Separation by Code (MSbyC) system for use in the estuary attached to our trawl (Figure 15; Magie et al. 2011, Morris et al. 2012). The MSbyC system will potentially allow diversion of specific PIT-tagged fish based on tag code.[2] Field testing of the MSbyC vessel in 2010 and 2011 proved the concept, and for a few brief deployments we successfully diverted fish exiting the trawl to a holding tank. The components adapted for mobile application were similar to those of stationary SbyC systems at dams (Downing et al. 2001).

Our goal is to develop a system that will not only divert PIT-tagged fish, but also allow diversion of non-tagged juvenile migrants and control over the number fish sampled, regardless of fish density at the time of sampling. This system offers a mechanism to control sample size regardless of changing fish densities. In contrast, traditional sampling methods such as a beach or purse-seine reflect changes in fish density but collect many more (or fewer) fish than needed for study objectives.

In 2012, we intended to use the prototype MSbyC system to collect weekly samples of fish with known migration histories (barged vs. inriver migrants) and to monitor the species composition of non-tagged fish passing through the estuary. However, vessel stability and structural concerns precluded all sampling with the MSbyC system. Instead, we consulted with marine architects and safety engineers to design a new vessel more suited to safely transport the SbyC equipment.

The plans produced include consolidating numerous generators and pumps into one power source, using a common fuel source, adding propulsion and steerage, with added deck space for fish processing (Appendix Figure C). The new platform for MSbyC would have much improved maneuverability and potential to use in other areas beyond the estuary but awaits a funding source for construction.

[2] The M4 software being developed for regional separation by code (Ref.) remains in development and older Multimon software still in use at dams was not installed for our MSbyC. During prototype testing of MSbyC we controlled electronic gates to divert all PIT-tagged fish and post-processing of fish in the sample tank used to identify specific groups of fish and migration history.

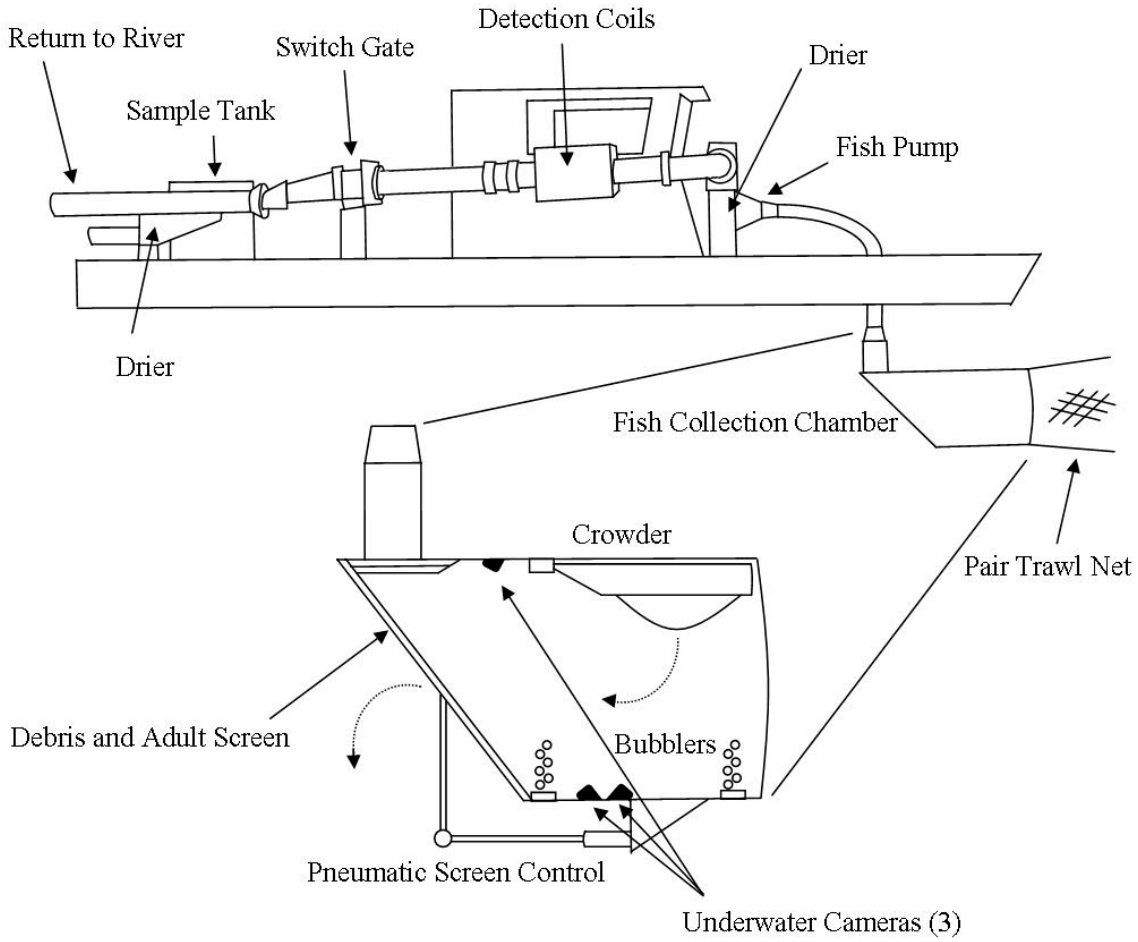

Figure 15. Diagram of the mobile system designed to divert fish by PIT-tag code after passing through the trawl.

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Appendix A: Data Tables

Appendix Table A1. Daily total sample time and detections for each salmonid species using the matrix pair trawl antenna system at Jones Beach, 2012.

		PIT-tag Detections (N)						
Date	Sample Time (h)	Unknown	Chinook Salmon	Coho Salmon	Steelhead	Sockeye Salmon	Cutthroat	Total
14 Mar	4.40	0	0	0	0	0	0	0
15 Mar	0.00	--	--	--	--	--	--	--
16 Mar	0.00	--	--	--	--	--	--	--
17 Mar	0.00	--	--	--	--	--	--	--
18 Mar	0.00	--	--	--	--	--	--	--
19 Mar	4.05	0	1	0	0	0	0	1
20 Mar	0.00	--	--	--	--	--	--	--
21 Mar	0.00	--	--	--	--	--	--	--
22 Mar	5.65	0	0	0	0	0	0	0
23 Mar	0.00	--	--	--	--	--	--	--
24 Mar	0.00	--	--	--	--	--	--	--
25 Mar	0.00	--	--	--	--	--	--	--
26 Mar	0.00	--	--	--	--	--	--	--
27 Mar	5.12	0	0	0	0	0	0	0
28 Mar	0.00	--	--	--	--	--	--	--
29 Mar	0.00	--	--	--	--	--	--	--
30 Mar	6.05	0	1	0	0	0	0	1
31 Mar	0.00	--	--	--	--	--	--	--
1 Apr	0.00	--	--	--	--	--	--	--
2 Apr	0.00	--	--	--	--	--	--	--
3 Apr	4.30	0	0	0	0	0	0	0
4 Apr	0.00	--	--	--	--	--	--	--
5 Apr	4.47	0	0	0	0	0	0	0
6 Apr	4.08	0	0	0	1	0	0	1
7 Apr	0.00	--	--	--	--	--	--	--
8 Apr	0.00	--	--	--	--	--	--	--
9 Apr	6.07	0	1	0	1	0	0	2
10 Apr	5.60	0	0	0	2	0	0	2
11 Apr	6.75	0	3	0	1	0	0	4
12 Apr	5.97	0	0	0	0	0	0	0
13 Apr	5.80	0	3	0	0	0	0	3
14 Apr	0.00	--	--	--	--	--	--	--
15 Apr	0.00	--	--	--	--	--	--	--
16 Apr	6.65	0	3	0	5	0	0	8
17 Apr	6.37	0	2	0	2	0	0	4
18 Apr	6.68	0	6	0	3	0	0	9
19 Apr	6.50	0	6	0	2	0	0	8
20 Apr	5.78	0	0	0	1	0	0	1
21 Apr	0.00	--	--	--	--	--	--	--
22 Apr	0.00	--	--	--	--	--	--	--
23 Apr	5.52	0	0	0	7	0	0	7
24 Apr	0.00	--	--	--	--	--	--	--
25 Apr	5.52	0	2	0	21	0	0	23

Appendix Table A1. Continued.

Date	Sample Time (h)	PIT-tag Detections (N) Unknown	Chinook Salmon	Coho Salmon	Steelhead	Sockeye Salmon	Cutthroat	Total
26 Apr	5.85	0	8	0	48	0	0	56
27 Apr	6.13	0	18	0	33	0	0	51
28 Apr	5.38	0	32	0	44	0	0	76
29 Apr	5.58	1	33	0	31	0	0	65
30 Apr	5.48	0	34	0	56	0	0	90
1 May	9.93	0	45	0	61	0	0	106
2 May	12.25	3	127	3	101	2	0	236
3 May	15.52	2	258	1	197	0	0	458
4 May	15.77	4	218	0	209	1	0	432
5 May	13.05	1	231	1	282	4	0	519
6 May	17.18	3	233	3	334	1	0	574
7 May	10.00	3	121	0	167	1	0	292
8 May	16.47	4	239	1	211	2	0	457
9 May	17.88	5	293	2	316	0	0	616
10 May	18.05	2	329	1	277	3	0	612
11 May	16.17	1	171	0	276	4	0	452
12 May	14.88	3	156	1	235	1	0	396
13 May	14.08	0	116	3	167	2	0	288
14 May	13.68	5	131	4	237	3	0	380
15 May	15.28	2	155	1	260	3	0	421
16 May	12.70	4	157	7	175	1	0	344
17 May	14.22	3	192	1	212	4	0	412
18 May	15.87	6	263	5	244	3	0	521
19 May	12.50	2	215	7	153	3	0	380
20 May	15.83	8	355	11	265	17	0	656
21 May	13.53	2	225	7	184	26	0	444
22 May	16.60	3	297	30	338	58	0	726
23 May	14.20	1	127	15	209	45	0	397
24 May	14.67	2	172	30	299	31	1	535
25 May	10.88	1	81	13	155	29	0	279
26 May	14.65	2	98	18	119	51	0	288
27 May	14.27	1	120	23	177	76	0	397
28 May	13.53	0	73	20	130	66	0	289
29 May	13.32	2	88	17	111	48	0	266
30 May	15.30	7	119	23	147	34	0	330
31 May	14.27	0	124	29	122	40	0	315
1 Jun	11.97	1	90	22	59	20	0	192
2 Jun	12.65	3	78	13	116	48	0	258
3 Jun	12.20	0	59	12	65	9	0	145
4 Jun	14.47	0	88	10	175	26	0	299
5 Jun	12.33	1	48	8	52	10	0	119
6 Jun	14.90	1	74	20	130	25	1	251
7 Jun	11.92	1	32	7	41	3	0	84
8 Jun	12.25	0	53	10	52	35	0	150
9 Jun	10.58	1	35	6	22	7	0	71
10 Jun	11.82	0	27	10	56	15	0	108
11 Jun	11.80	0	13	5	23	5	0	46
12 Jun	12.88	0	28	6	50	17	0	101
13 Jun	12.80	0	18	10	39	16	0	83

Appendix Table A1. Continued.

		PIT-tag Detections (N)						
Date	Sample Time (h)	Unknown	Chinook Salmon	Coho Salmon	Steelhead	Sockeye Salmon	Cutthroat	Total
14 Jun	12.72	2	50	12	67	21	0	152
15 Jun	13.05	2	45	10	37	8	0	102
16 Jun	7.63	0	9	7	37	9	0	62
17 Jun	5.38	0	3	2	9	2	0	16
18 Jun	6.13	2	18	7	51	3	0	81
19 Jun	5.63	0	17	3	18	0	0	38
20 Jun	6.12	0	19	3	20	3	0	45
21 Jun	4.10	0	12	0	7	2	0	21
22 Jun	6.42	2	24	3	9	0	0	38
23 Jun	0.00	--	--	--	--	--	--	--
24 Jun	0.00	--	--	--	--	--	--	--
25 Jun	6.45	0	49	2	8	0	0	59
26 Jun	5.67	3	67	3	13	0	0	86
27 Jun	3.35	0	51	0	4	0	0	55
28 Jun	6.62	0	211	0	5	0	0	216
29 Jun	5.75	0	52	1	1	0	0	54
30 Jun	0.00	--	--	--	--	--	--	--
1 Jul	0.00	--	--	--	--	--	--	--
2 Jul	6.17	0	61	0	1	0	0	62
3 Jul	4.53	0	18	0	0	0	0	18
4 Jul	0.00	--	--	--	--	--	--	--
5 Jul	4.58	0	25	0	1	0	0	26
6 Jul	4.48	0	16	0	0	0	0	16
7 Jul	0.00	--	--	--	--	--	--	--
8 Jul	0.00	--	--	--	--	--	--	--
9 Jul	6.83	0	52	0	0	0	0	52
10 Jul	6.42	0	50	0	0	0	0	50
11 Jul	7.05	1	28	0	2	0	0	31
12 Jul	6.40	1	48	0	1	0	0	50
13 Jul	6.53	0	56	0	1	0	0	57
14 Jul	0.00	--	--	--	--	--	--	--
15 Jul	0.00	--	--	--	--	--	--	--
16 Jul	5.72	0	33	0	0	0	0	33
17 Jul	6.47	0	36	0	1	0	0	37
18 Jul	5.75	0	18	0	0	0	0	18
19 Jul	6.62	0	24	0	1	0	0	25
20 Jul	5.83	0	18	0	0	0	0	18
21 Jul	0.00	--	--	--	--	--	--	--
22 Jul	0.00	--	--	--	--	--	--	--
23 Jul	6.37	1	26	0	0	0	0	27
24 Jul	0.00	--	--	--	--	--	--	--
25 Jul	6.18	0	20	0	0	0	0	20
26 Jul	0.00	--	--	--	--	--	--	--
27 Jul	5.77	0	22	0	0	0	0	22
28 Jul	0.00	--	--	--	--	--	--	--
29 Jul	0.00	--	--	--	--	--	--	--
30 Jul	5.52	0	8	0	0	0	0	8
Total	951.08	105	7,511	469	7,802	843	2	16,732

Appendix Table A2. Release and consecutive observation sites and dates for the 16 subyearling Chinook salmon that were released in 2011 and detected in the estuary in 2012. Overwintering location is between the last detection site in 2011 and the first detection site in 2012.

Tag ID	Release / Observation Site*	Release / Observation Date
3D9.1C2D49E05B	CLWR	8/10/2011 15:11
3D9.1C2D49E05B	GRJ	4/23/2012 17:35
3D9.1C2D49E05B	GOJ	4/25/2012 18:46
3D9.1C2D49E05B	TWX	6/4/2012 12:17
3D9.1C2D49E83A	CLWR	7/25/2011 10:30
3D9.1C2D49E83A	GRJ	8/21/2011 12:24
3D9.1C2D49E83A	LMJ	4/5/2012 16:10
3D9.1C2D49E83A	TWX	5/6/2012 12:55
3D9.1C2DC1F5B9	BCCAP	7/1/2011 12:20
3D9.1C2DC1F5B9	GRJ	9/22/2011 05:07
3D9.1C2DC1F5B9	GOJ	4/1/2012 00:22
3D9.1C2DC1F5B9	LMJ	4/13/2012 19:59
3D9.1C2DC1F5B9	JDJ	5/5/2012 05:24
3D9.1C2DC1F5B9	TWX	5/9/2012 06:14
3D9.1C2DC22872	BCCAP	6/29/2011 15:45
3D9.1C2DC22872	GRJ	4/29/2012 18:21
3D9.1C2DC22872	GOJ	5/4/2012 19:13
3D9.1C2DC22872	TWX	5/8/2012 23:21
3D9.1C2DC40F78	BCCAP	7/6/2011 17:15
3D9.1C2DC40F78	GOJ	4/6/2012 09:03
3D9.1C2DC40F78	LMJ	4/20/2012 21:03
3D9.1C2DC40F78	JDJ	4/27/2012 15:59
3D9.1C2DC40F78	TWX	4/30/2012 11:21
3D9.1C2DC5444E	BCCAP	7/7/2011 17:00
3D9.1C2DC5444E	GRJ	12/9/2011 08:41
3D9.1C2DC5444E	GOJ	4/5/2012 08:34
3D9.1C2DC5444E	TWX	4/27/2012 11:00
3D9.1C2DC56C81	BCCAP	6/30/2011 15:15
3D9.1C2DC56C81	GRJ	11/19/2011 21:06
3D9.1C2DC56C81	TWX	4/11/2012 10:25
3D9.1C2DC59316	BCCAP	6/29/2011 15:45
3D9.1C2DC59316	GRJ	4/20/2012 18:55
3D9.1C2DC59316	TWX	5/1/2012 08:51
3D9.1C2DC5AC7F	BCCAP	7/6/2011 17:15
3D9.1C2DC5AC7F	TWX	5/8/2012 13:05
3D9.1C2DC5E7D4	BCCAP	7/6/2011 17:15
3D9.1C2DC5E7D4	GOJ	4/1/2012 07:53
3D9.1C2DC5E7D4	TWX	4/19/2012 10:09

Appendix Table A2. Continued.

Tag ID	Release / Observation Site*	Release / Observation Date
3D9.1C2DC6E453	BCCAP	7/5/2011 16:25
3D9.1C2DC6E453	GRJ	11/23/2011 11:25
3D9.1C2DC6E453	LMJ	4/25/2012 02:47
3D9.1C2DC6E453	TWX	5/4/2012 08:46
3D9.1C2DC6E5F4	BCCAP	6/20/2011 16:20
3D9.1C2DC6E5F4	TWX	5/5/2012 09:48
3D9.1C2DC72E81	BCCAP	7/8/2011 18:35
3D9.1C2DC72E81	GOJ	4/18/2012 03:54
3D9.1C2DC72E81	TWX	5/2/2012 20:53
3D9.1C2DC79074	BCCAP	7/7/2011 17:00
3D9.1C2DC79074	TWX	5/18/2012 23:09
3D9.1C2DC7E02B	BCCAP	6/21/2011 13:35
3D9.1C2DC7E02B	GOJ	11/28/2011 19:14
3D9.1C2DC7E02B	TWX	5/15/2012 06:30
3D9.1C2DCA9BA9	BCCAP	7/6/2011 17:15
3D9.1C2DCA9BA9	LMJ	4/17/2012 21:22
3D9.1C2DCA9BA9	TWX	4/29/2012 09:46

* Site codes as defined in PTAGIS specification document.

Appendix Table A3. Combined daily total of impinged or injured fish on the matrix antenna system used in the upper Columbia River estuary, 2012.

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

Appendix Table A3. Continued.

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

Appendix Table A3. Continued.

	Chinook Salmon				
Date	Yearling	Subyearling	Coho	Steelhead	Sockeye
18 Jun	0	1	0	0	0
19 Jun	0	0	0	0	0
20 Jun	0	0	0	0	0
21 Jun	0	1	0	0	0
22 Jun	0	1	0	0	0
23 Jun	--	--	--	--	--
24 Jun	--	--	--	--	--
25 Jun	1	1	0	0	0
26 Jun	0	0	0	0	0
27 Jun	0	0	0	0	0
28 Jun	1	1	0	0	0
29 Jun	0	0	0	0	0
30 Jun	--	--	--	--	--
1 Jul	--	--	--	--	--
2 Jul	0	0	0	0	0
3 Jul	0	0	0	0	0
4 Jul	--	--	--	--	--
5 Jul	0	0	0	0	0
6 Jul	1	1	0	0	1
7 Jul	--	--	--	--	--
8 Jul	--	--	--	--	--
9 Jul	0	0	0	0	0
10 Jul	0	0	0	0	0
11 Jul	0	0	0	0	0
12 Jul	0	0	0	0	0
13 Jul	1	6	2	1	2
14 Jul	--	--	--	--	--
15 Jul	--	--	--	--	--
16 Jul	0	1	0	0	0
17 Jul	1	2	1	0	1
18 Jul	1	5	1	1	2
19 Jul	0	2	0	0	0
20 Jul	0	0	0	0	0
21 Jul	--	--	--	--	--
22 Jul	--	--	--	--	--
23 Jul	0	0	0	0	0
24 Jul	--	--	--	--	--
25 Jul	0	1	0	0	0
26 Jul	--	--	--	--	--
27 Jul	0	0	0	0	0
28 Jul	--	--	--	--	--
29 Jul	--	--	--	--	--
30 Jul	0	0	0	0	0
Total	120	24	27	6	34

Appendix Table A4. Diel sampling of yearling Chinook salmon and steelhead using a PIT-tag detector surface pair-trawl at Jones Beach (rkm 75), 2012. Two-crew daily sample effort (1 May-15 June) was rounded to the nearest tenth and presented as a decimal hour.

		Yearling Chinook salmon				Steelhead			
Diel		n		n/h		n		n/h	
hour	Effort (h)	Hatchery	Wild	Hatchery	Wild	Hatchery	Wild	Hatchery	Wild
0	45.1	303	48	6.7	1.1	140	65	3.1	1.4
1	44.9	308	55	6.9	1.2	126	83	2.8	1.8
2	29.2	262	52	9.0	1.8	73	45	2.5	1.5
3	13.4	169	37	12.7	2.8	76	25	5.7	1.9
4	5.3	108	22	20.5	4.2	75	18	14.2	3.4
5	8.5	140	30	16.5	3.5	69	30	8.1	3.5
6	35.6	296	74	8.3	2.1	355	173	10.0	4.9
7	44.4	306	68	6.9	1.5	619	289	13.9	6.5
8	43.9	271	77	6.2	1.8	589	250	13.4	5.7
9	43.1	205	61	4.8	1.4	503	183	11.7	4.2
10	42.0	204	40	4.9	1.0	398	162	9.5	3.9
11	40.3	223	63	5.5	1.6	451	195	11.2	4.8
12	27.5	187	48	6.8	1.7	358	109	13.0	4.0
13	19.2	156	34	8.1	1.8	240	87	12.5	4.5
14	10.1	81	22	8.0	2.2	138	31	13.7	3.1
15	3.0	23	5	7.6	1.6	31	4	10.2	1.3
16	0.0	--	--	--	--	--	--	--	--
17	0.0	--	--	--	--	--	--	--	--
18	0.0	--	--	--	--	--	--	--	--
19	7.2	8	2	1.1	0.3	17	6	2.4	0.8
20	38.4	203	51	5.3	1.3	188	83	4.9	2.2
21	45.0	671	132	14.9	2.9	289	115	6.4	2.6
22	45.0	388	73	8.6	1.6	139	69	3.1	1.5
23	45.5	246	50	5.4	1.1	102	49	2.2	1.1
Total	636	4,758	1,044			4,976	2,071		

Appendix Table A5. Number of PIT-tagged yearling Chinook salmon loaded for transport at dams and numbers detected in the estuary. LGR, Lower Granite; LGO, Little Goose; LMN, Lower Monumental. Transport dates 13 Apr - 24 Jul; trawl operation 14 Mar - 30 Jul, with intensive sampling 1 May - 15 Jun 2012. Season totals are shown.

Release date and	Numbers loaded at each dam and total fish loaded (n)				Percent detected from each dam and total numbers detected (n)				
time	LGR	LGO	LMN	n	LGR	LGO	LMN	n	(%)
4/13/12 8:35 PM	1,223	0	0	1,223	0.08	--	--	1	0.08
4/20/12 7:00 PM	1,703	0	0	1,703	0.06	--	--	1	0.06
4/27/12 6:50 PM	2,064	0	0	2,064	0.44	--	--	9	0.44
5/3/12 7:15 PM	1,678	0	0	1,678	0.72	--	--	12	0.72
5/4/12 3:17 PM	1,449	334	0	1,783	0.90	2.69	--	22	1.23
5/5/12 8:15 PM	1,557	2,213	0	3,770	1.22	0.99	--	41	1.09
5/6/12 9:05 PM	1,505	1,454	707	3,666	1.99	2.27	2.12	78	2.13
5/7/12 9:10 PM	506	1,449	1293	3,248	2.37	1.31	1.31	48	1.48
5/8/12 7:30 PM	487	1,562	793	2,842	0.21	0.51	0.50	13	0.46
5/9/12 9:10 PM	874	1,381	668	2,923	0.69	1.16	0.60	26	0.89
5/10/12 8:45 PM	746	639	432	1,817	0.54	0.47	1.85	15	0.83
5/11/12 9:15 PM	902	767	546	2,215	1.00	0.65	1.83	24	1.08
5/12/12 9:35 PM	1,553	1,394	531	3,478	1.03	0.79	1.32	34	0.98
5/13/12 8:30 PM	1,328	1,101	266	2,695	1.13	0.82	1.13	27	1.00
5/14/12 8:50 PM	962	680	285	1,927	0.94	1.03	0.70	18	0.93
5/15/12 8:45 PM	831	674	284	1,789	1.32	1.34	0.70	22	1.23
5/16/12 7:45 PM	1,044	492	262	1,798	1.92	1.22	1.53	30	1.67
5/17/12 8:50 PM	1,092	397	209	1,698	0.37	0.76	1.91	11	0.65
5/18/12 9:20 PM	1,341	486	311	2,138	1.04	2.26	1.61	30	1.40
5/19/12 8:30 PM	1,301	613	267	2,181	1.38	1.96	1.12	33	1.51
5/20/12 7:05 PM	1,048	766	385	2,199	0.76	1.31	1.04	22	1.00
5/21/12 8:05 PM	290	507	206	1,003	1.72	0.59	1.46	11	1.10
5/22/12 8:30 PM	252	537	220	1,009	1.98	2.98	1.82	25	2.48
5/23/12 8:35 PM	582	358	247	1,187	1.20	2.79	1.21	20	1.68
5/24/12 8:00 PM	505	388	159	1,052	2.97	1.03	0	19	1.81
5/25/12 8:15 PM	581	242	158	981	3.44	3.31	1.27	30	3.06
5/26/12 8:00 PM	555	165	120	840	1.08	1.82	1.67	11	1.31

Appendix Table A5. Continued.

	Numbers loaded at each dam and total fish loaded (n)				Percent detected from each dam and total numbers detected (n)				
	LGR	LGO	LMN	n	LGR	LGO	LMN	n	(%)
5/27/12 8:30 PM	469	104	53	626	1.49	1.92	0	9	1.44
5/28/12 7:20 PM	78	81	25	184	3.85	0	8.00	5	2.72
5/29/12 8:40 PM	51	88	21	160	5.88	3.41	4.76	7	4.38
5/31/12 7:00 PM	57	113	25	195	3.51	1.77	4.00	5	2.56
6/2/12 7:30 PM	44	74	15	133	2.27	4.05	0	4	3.01
6/4/12 8:00 PM	43	55	21	119	4.65	5.45	0	5	4.20
6/6/12 8:20 PM	27	85	27	139	7.41	5.88	0	7	5.04
6/8/12 7:50 PM	43	20	20	83	2.33	0	0	1	1.20
6/10/12 8:30 PM	30	27	1	58	0	3.70	0	1	1.72
6/12/12 7:10 PM	11	23	5	39	0	0	0	0	0
6/14/12 8:30 PM	12	14	6	32	0	0	0	0	0
6/16/12 7:40 PM	16	34	6	56	0	0	0	0	0
6/18/12 8:00 PM	27	35	2	64	3.70	0	0	1	1.56
6/20/12 6:50 PM	25	19	3	47	0	0	0	0	0
6/22/12 6:45 PM	21	35	9	65	0	0	0	0	0
6/24/12 8:45 PM	15	9	5	29	0	0	0	0	0
6/26/12 7:30 PM	17	10	5	32	0	0	0	0	0
6/28/12 7:00 PM	9	16	7	32	0	0	0	0	0
6/30/12 7:05 PM	7	8	4	19	0	0	0	0	0
7/2/12 8:25 PM	6	6	5	17	0	0	0	0	0
7/4/12 9:00 PM	6	2	0	8	0	0	--	0	0
7/6/12 8:10 PM	8	8	2	18	0	0	0	0	0
7/8/12 9:25 PM	6	7	1	14	0	0	0	0	0
7/10/12 8:10 PM	2	5	0	7	0	0	--	0	0
7/12/12 8:40 PM	8	4	0	12	0	0	--	0	0
7/14/12 7:10 PM	0	2	1	3	--	0	0	0	0
7/16/12 8:20 PM	2	4	0	6	0	0	--	0	0
7/18/12 7:30 PM	2	3	0	5	0	0	--	0	0
7/20/12 8:50 PM	2	2	1	5	0	0	0	0	0
7/24/12 8:40 PM	2	0	0	2	0	--	--	0	0
Totals/means	29,005	19,492	8,619	57,116	1.08	1.31	1.28	678	1.19

Appendix Table A6. Number of PIT-tagged steelhead loaded for transport at dams and numbers detected in the estuary. LGR, Lower Granite; LGO, Little Goose; LMN, Lower Monumental. Transport dates 13 Apr-22 Jul; trawl operation 14 Mar-30 Jul, with intensive sampling 1 May-15 Jun 2011. Season totals are shown.

Release date and time	Numbers loaded at each dam and total fish loaded (n)				Percent detected from each dam and total numbers detected (n)				
	LGR	LGO	LMN	n	LGR	LGO	LMN	n	(%)
4/13/12 8:35 PM	1,227	0	0	1,227	0.41	--	--	5	0.41
4/20/12 7:00 PM	1,403	0	0	1,403	0.07	--	--	1	0.07
4/27/12 6:50 PM	1,996	0	0	1,996	0.25	--	--	5	0.25
5/3/12 7:15 PM	2,564	0	0	2,564	1.17	--	--	30	1.17
5/4/12 3:17 PM	1,295	69	0	1,364	3.24	2.90	--	44	3.23
5/5/12 8:15 PM	1,305	430	0	1,735	1.53	3.26	--	34	1.96
5/6/12 9:05 PM	1,113	451	142	1,706	2.70	3.33	1.41	47	2.75
5/7/12 9:10 PM	366	434	375	1,175	2.46	3.23	2.67	33	2.81
5/8/12 7:30 PM	397	328	381	1,106	4.28	3.66	3.94	44	3.98
5/9/12 9:10 PM	1,218	387	304	1,909	3.53	3.10	2.63	63	3.30
5/10/12 8:45 PM	1,091	246	251	1,588	2.93	2.03	3.98	47	2.96
5/11/12 9:15 PM	1,157	264	225	1,646	3.46	2.65	4.44	57	3.46
5/12/12 9:35 PM	1,509	511	307	2,327	3.64	2.74	2.28	76	3.27
5/13/12 8:30 PM	1,342	423	234	1,999	5.14	4.02	3.85	95	4.75
5/14/12 8:50 PM	870	295	344	1,509	3.22	3.05	3.78	50	3.31
5/15/12 8:45 PM	766	294	336	1,396	3.79	3.06	2.98	48	3.44
5/16/12 7:45 PM	1,333	362	251	1,946	5.40	2.49	2.79	88	4.52
5/17/12 8:50 PM	1,320	300	240	1,860	2.20	3.33	2.50	45	2.42
5/18/12 9:20 PM	1,480	424	315	2,219	3.58	1.65	1.90	66	2.97
5/19/12 8:30 PM	1,554	481	255	2,290	2.32	2.08	1.57	50	2.18
5/20/12 7:05 PM	1,286	779	483	2,548	6.30	8.73	6.83	182	7.14
5/21/12 8:05 PM	616	549	399	1,564	2.92	3.64	2.26	47	3.01
5/22/12 8:30 PM	611	286	497	1,394	4.26	4.20	3.22	54	3.87
5/23/12 8:35 PM	1,136	425	292	1,853	2.29	1.41	1.37	36	1.94
5/24/12 8:00 PM	1,050	439	220	1,709	1.43	0.46	1.82	21	1.23

Appendix Table A6. Continued.

Release date and time	Numbers loaded at each dam and total fish loaded (n)				Percent detected from each dam and total numbers detected (n)				
	LGR	LGO	LMN	n	LGR	LGO	LMN	n	(%)
5/25/12 8:15 PM	1,296	271	196	1,763	2.39	0.74	1.02	35	1.99
5/26/12 8:00 PM	1,045	229	129	1,403	4.31	3.93	0.78	55	3.92
5/27/12 8:30 PM	837	82	173	1,092	2.87	4.88	2.89	33	3.02
5/28/12 7:20 PM	162	100	117	379	10.49	9.00	3.42	30	7.92
5/29/12 8:40 PM	144	113	76	333	11.11	8.85	6.58	31	9.31
5/31/12 7:00 PM	443	173	106	722	6.09	5.78	5.66	43	5.96
6/2/12 7:30 PM	880	163	66	1,109	9.09	6.75	12.12	99	8.93
6/4/12 8:00 PM	427	163	84	674	10.30	8.59	4.76	62	9.20
6/6/12 8:20 PM	337	164	140	641	6.23	1.83	1.43	26	4.06
6/8/12 7:50 PM	689	233	131	1,053	2.18	2.15	0	20	1.90
6/10/12 8:30 PM	573	118	73	764	3.49	5.08	1.37	27	3.53
6/12/12 7:10 PM	40	149	47	236	7.50	10.07	6.38	21	8.90
6/14/12 8:30 PM	238	61	36	335	6.30	3.28	2.78	18	5.37
6/16/12 7:40 PM	184	68	39	291	11.96	10.29	10.26	33	11.34
6/18/12 8:00 PM	91	67	29	187	4.40	5.97	3.45	9	4.81
6/20/12 6:50 PM	36	38	29	103	2.78	2.63	0	2	1.94
6/22/12 6:45 PM	42	48	17	107	2.38	0	0	1	0.93
6/24/12 8:45 PM	10	18	14	42	0	5.56	7.14	2	4.76
6/26/12 7:30 PM	8	14	7	29	0	0	0	0	0
6/28/12 7:00 PM	5	7	7	19	0	0	0	0	0
6/30/12 7:05 PM	3	11	9	23	0	0	11.11	1	4.35
7/2/12 8:25 PM	0	2	1	3	--	0	0	0	0
7/4/12 9:00 PM	2	1	0	3	0	0	--	0	0
7/6/12 8:10 PM	0	1	0	1	--	0	--	0	0
7/8/12 9:25 PM	1	2	2	5	0	0	0	0	0
7/10/12 8:10 PM	1	1	1	3	0	0	0	0	0
7/12/12 8:40 PM	1	1	0	2	0	0	--	0	0
7/14/12 7:10 PM	0	2	1	3	--	0	0	0	0
7/18/12 7:30 PM	0	1	0	1	--	0	--	0	0
7/22/12 5:50 PM	0	1	0	1	--	0	--	0	0
Totals/means	37,500	10,479	7,381	55,360	3.19	3.69	3.14	1816	3.28

Appendix Table A7. Trawl system detections of PIT-tagged juvenile Chinook salmon and steelhead previously detected at Bonneville Dam, 2012.

	Bonneville Dam detections		Jones Beach detections		Bonneville detections seen at Jones Beach (%)	
Detection date at Bonneville Dam	Chinook salmon (n)	Steelhead (n)	Chinook salmon (n)	Steelhead (n)	Chinook salmon (%)	Steelhead (%)
14 Mar	0	0	0	0	--	--
15 Mar	2	0	0	0	0.00	--
16 Mar	38	0	0	0	0.00	--
17 Mar	78	1	0	0	0.00	0.00
18 Mar	84	0	0	0	0.00	--
19 Mar	59	1	0	0	0.00	0.00
20 Mar	23	1	0	0	0.00	0.00
21 Mar	24	0	0	0	0.00	--
22 Mar	16	2	0	0	0.00	0.00
23 Mar	17	1	0	0	0.00	0.00
24 Mar	15	1	0	0	0.00	0.00
25 Mar	5	0	0	0	0.00	--
26 Mar	6	1	0	0	0.00	0.00
27 Mar	9	2	0	0	0.00	0.00
28 Mar	11	2	0	0	0.00	0.00
29 Mar	5	1	0	0	0.00	0.00
30 Mar	3	2	0	0	0.00	0.00
31 Mar	14	1	0	0	0.00	0.00
1 Apr	7	2	0	0	0.00	0.00
2 Apr	6	3	0	0	0.00	0.00
3 Apr	8	1	0	0	0.00	0.00
4 Apr	3	1	0	0	0.00	0.00
5 Apr	4	5	0	0	0.00	0.00
6 Apr	9	1	1	0	11.11	0.00
7 Apr	16	3	0	0	0.00	0.00
8 Apr	12	4	0	0	0.00	0.00
9 Apr	8	3	0	0	0.00	0.00
10 Apr	9	4	0	0	0.00	0.00
11 Apr	67	3	0	0	0.00	0.00
12 Apr	152	5	0	0	0.00	0.00
13 Apr	120	3	0	0	0.00	0.00
14 Apr	279	11	1	2	0.36	18.18
15 Apr	26	11	0	0	0.00	0.00
16 Apr	33	9	0	0	0.00	0.00
17 Apr	249	13	2	0	0.80	0.00
18 Apr	343	17	0	0	0.00	0.00
19 Apr	381	5	4	0	1.05	0.00
20 Apr	216	25	0	0	0.00	0.00
21 Apr	276	43	0	2	0.00	4.65
22 Apr	352	63	3	0	0.85	0.00
23 Apr	506	89	4	0	0.79	0.00
24 Apr	419	254	4	1	0.95	0.39
25 Apr	396	159	0	0	0.00	0.00
26 Apr	250	105	0	0	0.00	0.00
27 Apr	227	47	0	0	0.00	0.00
28 Apr	286	79	1	0	0.35	0.00

Appendix Table A7. Continued.

Detection date at Bonneville Dam	Bonneville Dam detections		Jones Beach detections		Bonneville detections seen at Jones Beach (%)	
	Chinook salmon (n)	Steelhead (n)	Chinook salmon (n)	Steelhead (n)	Chinook salmon (%)	Steelhead (%)
29 Apr	510	108	1	1	0.20	0.93
30 Apr	579	193	10	0	1.73	0.00
01 May	513	293	5	1	0.97	0.34
02 May	471	221	7	3	1.49	1.36
03 May	567	370	7	8	1.23	2.16
04 May	393	426	4	10	1.02	2.35
05 May	638	411	6	1	0.94	0.24
06 May	766	235	17	6	2.22	2.55
07 May	854	397	16	12	1.87	3.02
08 May	1,293	836	32	30	2.47	3.59
09 May	1,811	999	24	28	1.33	2.80
10 May	1,739	636	22	28	1.27	4.40
11 May	1,688	429	31	10	1.84	2.33
12 May	1,256	350	11	5	0.88	1.43
13 May	1,267	451	18	17	1.42	3.77
14 May	1,451	523	12	15	0.83	2.87
15 May	1,683	767	27	24	1.60	3.13
16 May	1,424	501	30	16	2.11	3.19
17 May	1,516	504	29	8	1.91	1.59
18 May	1,585	562	36	11	2.27	1.96
19 May	1,395	368	17	11	1.22	2.99
20 May	1,019	332	15	10	1.47	3.01
21 May	754	334	8	13	1.06	3.89
22 May	1,093	661	19	12	1.74	1.82
23 May	764	593	10	14	1.31	2.36
24 May	673	282	9	0	1.34	0.00
25 May	589	438	9	7	1.53	1.60
26 May	565	472	6	9	1.06	1.91
27 May	517	311	3	5	0.58	1.61
28 May	507	260	12	19	2.37	7.31
29 May	608	254	20	12	3.29	4.72
30 May	355	230	11	14	3.10	6.09
31 May	250	234	6	16	2.40	6.84
01 Jun	243	330	5	16	2.06	4.85
02 Jun	252	246	13	12	5.16	4.88
03 Jun	233	218	5	13	2.15	5.96
04 Jun	117	107	4	7	3.42	6.54
05 Jun	160	168	3	1	1.88	0.60
06 Jun	117	100	2	2	1.71	2.00
07 Jun	129	60	2	2	1.55	3.33
08 Jun	79	80	2	0	2.53	0.00
09 Jun	57	93	1	4	1.75	4.30
10 Jun	107	67	1	2	0.93	2.99
11 Jun	81	46	2	2	2.47	4.35
12 Jun	63	51	2	3	3.17	5.88
13 Jun	87	31	2	2	2.30	6.45
14 Jun	187	90	4	4	2.14	4.44

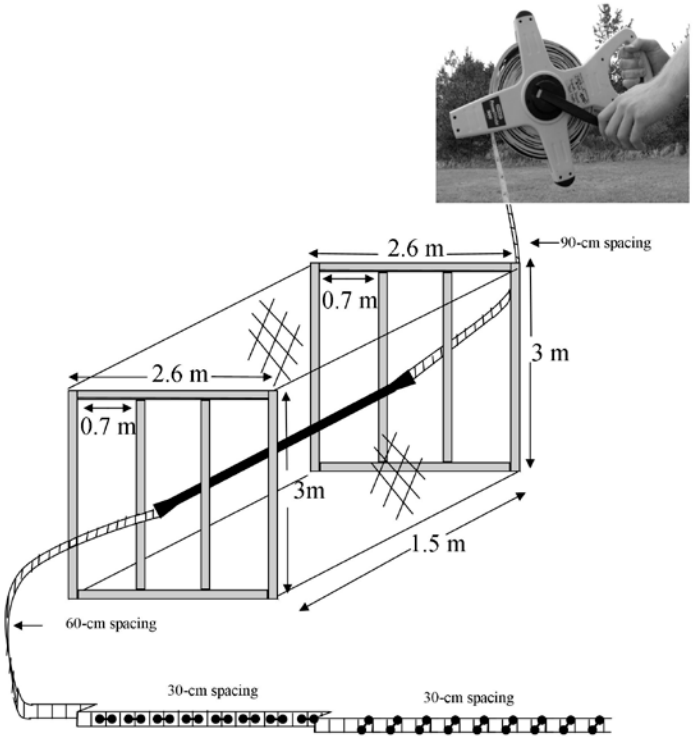
Appendix Table A7. Continued.

Detection date at Bonneville Dam	Bonneville Dam detections		Jones Beach detections		Bonneville detections seen at Jones Beach (%)	
	Chinook salmon (n)	Steelhead (n)	Chinook salmon (n)	Steelhead (n)	Chinook salmon (%)	Steelhead (%)
15 Jun	300	55	0	1	0.00	1.82
16 Jun	267	65	0	3	0.00	4.62
17 Jun	291	62	1	2	0.34	3.23
18 Jun	267	33	1	2	0.37	6.06
19 Jun	449	35	1	0	0.22	0.00
20 Jun	484	24	2	2	0.41	8.33
21 Jun	466	26	0	1	0.00	3.85
22 Jun	499	32	1	0	0.20	0.00
23 Jun	344	12	0	0	0.00	0.00
24 Jun	502	30	1	0	0.20	0.00
25 Jun	604	25	2	0	0.33	0.00
26 Jun	535	11	13	0	2.43	0.00
27 Jun	710	9	6	0	0.85	0.00
28 Jun	589	8	0	0	0.00	0.00
29 Jun	440	15	0	0	0.00	0.00
30 Jun	298	11	1	0	0.34	0.00
01 Jul	262	4	2	0	0.76	0.00
02 Jul	416	10	0	0	0.00	0.00
03 Jul	405	10	3	1	0.74	10.00
04 Jul	473	5	1	0	0.21	0.00
05 Jul	674	7	0	0	0.00	0.00
06 Jul	396	6	0	0	0.00	0.00
07 Jul	404	3	3	0	0.74	0.00
08 Jul	349	2	1	0	0.29	0.00
09 Jul	337	1	2	0	0.59	0.00
10 Jul	333	2	3	1	0.90	50.00
11 Jul	348	3	5	0	1.44	0.00
12 Jul	372	1	0	0	0.00	0.00
13 Jul	285	0	0	0	0.00	--
14 Jul	223	3	1	0	0.45	0.00
15 Jul	234	4	0	0	0.00	0.00
16 Jul	183	0	1	0	0.55	--
17 Jul	216	2	4	0	1.85	0.00
18 Jul	219	2	1	0	0.46	0.00
19 Jul	314	2	0	0	0.00	0.00
20 Jul	218	4	0	0	0.00	0.00
21 Jul	139	1	0	0	0.00	0.00
22 Jul	188	5	0	0	0.00	0.00
23 Jul	199	1	0	0	0.00	0.00
24 Jul	154	0	1	0	0.65	--
25 Jul	213	0	0	0	0.00	--
26 Jul	128	2	0	0	0.00	0.00
27 Jul	79	0	0	0	0.00	--
28 Jul	81	3	0	0	0.00	0.00
29 Jul	82	2	0	0	0.00	0.00
30 Jul	34	0	0	0	0.00	--
Totals	53,077	17,190	615	464	1.16	2.70

Appendix B: Detection Efficiency and Performance of Matrix Antenna

Methods

As in previous years, we used a test tape to evaluate electronic performance of the matrix detection system (Ledgerwood et al. 2005). For efficiency tests during deployment, we positioned a 2.5-cm diameter PVC pipe through the center of both the front and rear component of the matrix antenna. The pipe extended beyond the reading range of the electronic fields (at least 0.5 m) of both the front and rear antenna components. A vinyl-coated tape measure with PIT-tags attached at known spacing intervals and orientations 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 (Appendix Figure B1).



Appendix Figure B1. Schematic depicting test tags on a vinyl tape measure, threaded through a PVC pipe in the center of the inner matrix antenna coils to evaluate antenna detection efficiency. PIT-tags were oriented at 0 and 45 degrees to the direction of travel and spaced at intervals of 30, 60, and 90 cm.

In 2009, we developed an additional procedure to evaluate the matrix antenna in a dry environment. In 2012, dry tests were conducted in an enclosed facility and were similar to in-water tests, except that pulleys mounted to the ceiling were used to guide the test tape through the antenna components.

Detection efficiency tests also help to better understand the impact of tag collisions (signal cancelation due to multiple tags simultaneously energized within the detection field) in order to optimize antenna performance (Appendix Table B1). The test tape used in 2012 was configured with 6 separate groups of 9 tags. Spacing and orientation of tags were consistent within each group, but differed between groups. The 6 groups were comprised of tag sets oriented at two different angles relative to the antenna detection field (0 and 45 degrees) with tags sets at each angle spaced 30, 60, and 90 cm apart. Both the first and last tag in each group were omitted from analysis because the spacing before and after these tags was not equal.

We expected results from efficiency tests to show greater rates of detection with improved alignment, orientation, and proximity to the electronic field. Accounting for some variation in each of these factors, the tape tests allowed rigorous tests of antenna efficiency. The angles and orientations used on the tape did not reflect those of actual PIT-tagged fish, which generally do not pass through the exact center of the coils but closer to the sides where detection efficiency is much higher.

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

Appendix Table B1. Configuration of SST PIT-tags on a vinyl-tape measure used to test antenna performance in 2012.

Position on tape measure (ft)	Orientation (°)	Distance from previous tag (ft)[a]	PIT-tag code[b]
5	45	0	3D9.1C2CC4AE3F
6	45	1	3D9.1C2CC45A80
7	45	1	3D9.1C2CC42A83
8	45	1	3D9.1C2CC42AAA
9	45	1	3D9.1C2CC8107D
10	45	1	3D9.1C2CC711DF
11	45	1	3D9.1C2CC48B0F
12	45	1	3D9.1C2CC4E48C
13	45	1	3D9.1C2CC47161
21	0	8	3D9.1C2CC43D0C
22	0	1	3D9.1C2CC42A98
23	0	1	3D9.1C2CC4D578
24	0	1	3D9.1C2CC4625D
25	0	1	3D9.1C2CC440E7
26	0	1	3D9.1C2CC46137
27	0	1	3D9.1C2CC7008A
28	0	1	3D9.1C2CC81379
29	0	1	3D9.1C2CC6F306
37	45	8	3D9.1C2CC817E9
39	45	2	3D9.1C2CC4A641
41	45	2	3D9.1C2CC4B83D
43	45	2	3D9.1C2CC4E762
45	45	2	3D9.1C2CC6F1E5
47	45	2	3D9.1C2CC46298
49	45	2	3D9.1C2CC4C92B
51	45	2	3D9.1C2CC4E9E0
53	45	2	3D9.257C6C4FF9
61	0	8	3D9.1C2CC4D3C5
63	0	2	3D9.1C2CC4CE33
65	0	2	3D9.1C2CC4393C
67	0	2	3D9.1C2CC45743
69	0	2	3D9.1C2CC4DE17
71	0	2	3D9.1C2CC43EB4
73	0	2	3D9.1C2CC713DC
75	0	2	3D9.1C2CC4C630

Appendix Table B1. Continued.

Position on tape measure (ft)	Orientation (°)	Distance from previous tag (ft)[a]	PIT-tag code[b]
77	0	2	3D9.1C2CC4EFEB
85	45	8	3D9.1C2CC70808
88	45	3	3D9.1C2CC49929
91	45	3	3D9.1C2CC6F33E
94	45	3	3D9.1C2CC4AF9E
97	45	3	3D9.1C2CC43C37
100	45	3	3D9.1C2CC4634A
103	45	3	3D9.1C2CC44376
106	45	3	3D9.1C2CC4928D
109	45	3	3D9.1C2CC6FECC
117	0	8	3D9.1C2CC4C79D
120	0	3	3D9.1C2CC4B62B
123	0	3	3D9.1C2CC44382
126	0	3	3D9.1C2CC43F9D
129	0	3	3D9.257C6C3570
132	0	3	3D9.1C2CC49BCA
135	0	3	3D9.257C6C0723
138	0	3	3D9.1C2CC46225
141	0	3	3D9.257C6C0B80

[a] Distance from previous tag as measured in the direction from 17 to 125 ft

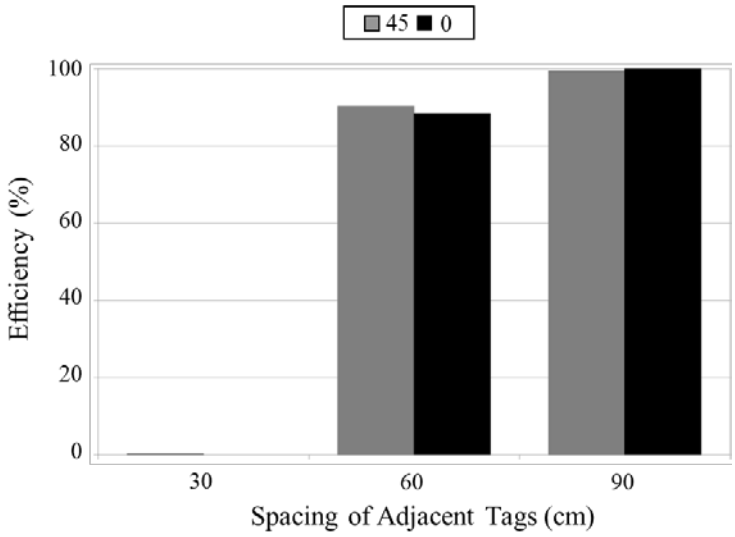
[b] PIT-tags were tested after each antenna evaluation with a hand-held reader and replaced as needed

Results and Discussion

Antenna Performance

Detection Efficiency—Detection efficiencies were positively correlated with spacing between tags, regardless of tag orientation. According to PTAGIS, 97% of the PIT-tagged fish released into the basin for migration in 2012 were tagged with SST tags, which have longer read ranges than the older ST tags (PSMFC 2012). About 93% of trawl detections in 2012 were SST tags, 5% were ST tags, and the remaining 2% were a variety of tag types from new tag manufacturers. We tested detection efficiency using SST tags in 2012.

The 6-coil matrix antenna recorded only one test-tag spaced 30 cm apart in either orientation, out of the 504 PIT-tags passed through the antenna. This was the closest spacing interval tested, (Appendix Figure B2). When spacing between tags was increased to 60 cm, detection efficiency increased to 88% for tags oriented perpendicular to the electronic field and 90% 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 tags and angled tags.



Appendix Figure B2. Detection rate/read efficiency of the matrix antenna during 2012. Efficiency was determined by targeting 42 of 54 PIT-tags attached to a vinyl tape and passed through the antenna six times. Various spacing intervals between tags and tag orientations to the electronic field were used. Results reflect the combined performance (42 tag codes per pass × 6 passes = 252 possible detections).

Antenna Efficiency—Similar to previous years, tag-reading efficiency tests for the individual antenna coils and for the matrix system overall were conducted *in situ* prior to sampling operations. The tests are used to evaluate technological 'upgrades' and general performance of our system. The tests must be conducted on the weakest part of the antenna field to show any differences in orientation or spacing. When similar tests are conducted slightly closer to the edges of the antennas (more optimal read area) read efficiencies are nearly 100%. These results with the matrix antenna system are shown with results from earlier tests of the 0.9-m-diameter cylindrical antenna for comparison (Appendix Table B2).

Appendix Table B2. Comparison of antenna detection efficiencies of a test PIT-tag tape passed through the 0.9-m diameter cylindrical antenna and the matrix antenna.

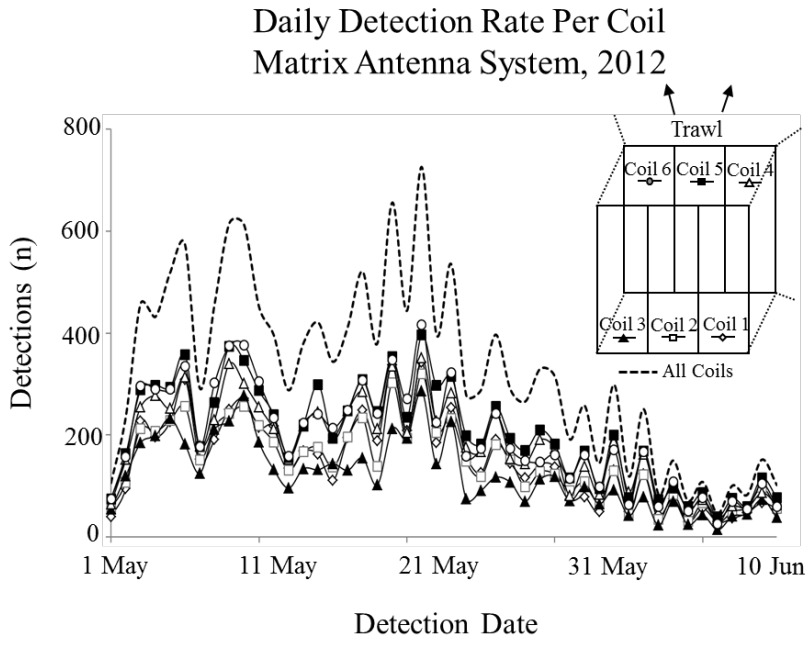
Antenna (dimensions)	Total tags read (N)	Total tags available (N)	Overall antenna efficiency (%)
Cylindrical (0.9-m diameter)	784	1,176	66.6
Matrix (0.7- × 2.8-m perimeter)	955	1,512	63.2

Although there was a significant gain in volitional fish passage using the larger fish passage opening of the matrix antenna system (53% more fish detections on the matrix system than the older system during simultaneous testing in 2008, Magie et al. 2010), the read efficiency of test tags was 3.4% lower than the read efficiency of test tags obtained using the smaller cylindrical antenna system (66.6 to 63.2%). We believe that this slight drop in read efficiency was caused by an increased rate of tag collisions, which was a by-product of the extended read range of SST tags and the larger matrix style antenna (Figure B2). Tag collision occurs when two or more tags are energized in the detection field and transmit their codes simultaneously, resulting in neither tag being correctly decoded. Although the older cylindrical antenna had a slightly higher read efficiency with the test tape, the smaller exit to the trawl in the older antenna delayed fish and allowed them more time to escape forward.

To test how tag-code collisions affect antenna performance, we conducted laboratory tests with the matrix antenna attempting to reduce the size of the z-axis detection field (front to rear) without compromising field strength (expressed as side-to-side read range, Magie et al. 2011). We were able to do this successfully, but the set-up was not practical for field operations. Tag collision still can occur with the trawl system due to periodic high densities of PIT-tagged fish passing the antenna, and for this reason we configured the antenna system with front and rear antenna arrays.

A two-component antenna system provides a second chance to decode tagged fish on the rear component in case they were missed by coils on the front component. This decreases the probability of completely missing a fish as fish movements are dynamic not static, like with our test tags. We remain confident that few fish pass undetected through the matrix antenna system.

As with previous antennas, we also evaluated matrix antenna performance daily by comparing the total number of fish detected to the number detected on each individual coil, all front coils, and all rear coils (Appendix Figure B3). A significantly lower proportion of fish detected on an individual coil than on other coils indicated a problem with that coil. Normally, more detection records and more unique fish detections occurred on the front component (coils 4, 5, and 6) than on the rear component (coils 1, 2, and 3). Some fish approach the front component and come close enough to be detected, but then move upstream only to approach this component again and eventually pass through. Other fish approach the front component and are detected, but then move upstream and escape the trawl so that they are never detected on the rear array.



Appendix Figure B3. Daily detections of juvenile salmonids by matrix antenna coils during the two-shift sample period, 2012. Coils 1, 2, and 3 formed the rear component (exit) while coils 4, 5, and 6 formed the front component (entrance) attached to the trawl.

Appendix C: Vessel Design for Mobile Separation-by-Code System

Appendix Figure C. Cost summary from the COE Marine Design Center's estimated cost and construction details for an adequately engineered support platform to replace the NOAA Fisheries vessel *RV* Electric Barge. That vessel was modified in 2010-2011 to support development of a mobile PIT-tag separation by code (MSbyC) system for sampling juvenile operation in the estuary. Initial testing of the MSbyC system behind our trawl successfully demonstrated the concept but the vessel modifications created structural and safety issues. Additional details and associated drawings for the replacement vessel were provided in co-operation with the US Army COE Marine Design Center and NOAA Fisheries Small Boat Program. The entire report is available upon request (see "New Electric Barge COE Engineering .zip").

Appendix Table C.

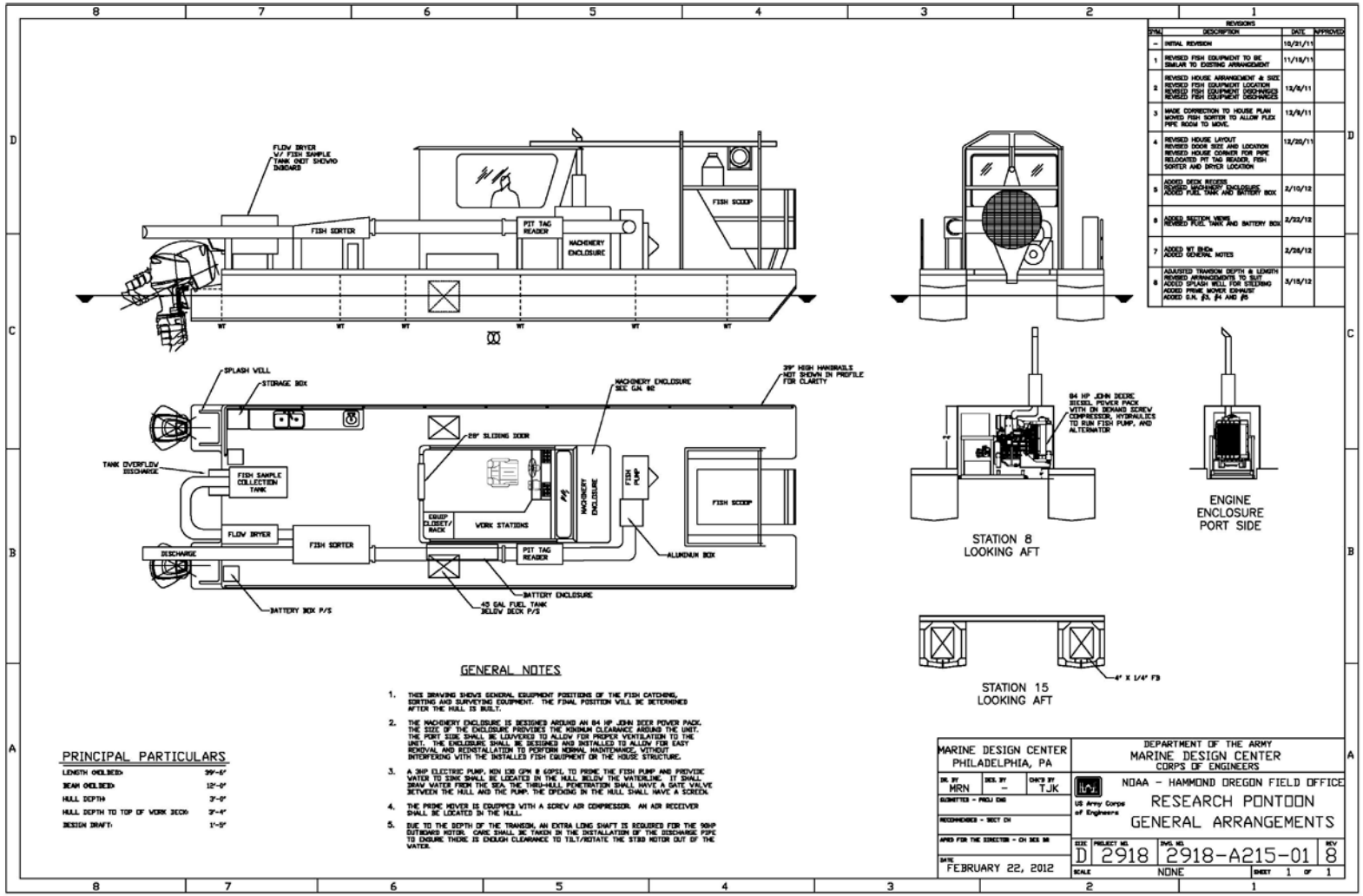
NOAA RESEARCH PONTOON - CONSTRUCTION COST ESTIMATE				page:	
MARINE DESIGN CENTER					
100 Penn Square East, Room 630 South		MDC PROJ:	2918	DATE:	3/15/12
Philadelphia, PA 19107		BY: TJK		REV.:	-

ITEM	WEB	DESCRIPTION	ESTIMATED ALUMINUM/STRUCTURAL CONSTRUCTION COST
1	307	Shell Plating	$50,055
2	309	Transverse Structure	$16,069
3	311	Longitudinal Structure	$3,271
4	315	Deckhouse Structure	$14,852
		SUB-TOTAL	$84,247

ITEM	WEB	DESCRIPTION	ESTIMATED OUTFITTING & SYSTEMS COST
5	300-700	Equipment/Outfitting	$124,347
		SUB-TOTAL	$124,347

Total cost construction estimate‡	$208,594

‡ Additional costs associated with PIT tag diversion electronics setup and installation of navigation equipment and outboard motors



Appendix Figure C. Engineering drawing for pontoon barge suitable for deployment of separation by code (MSbyC) PIT-tag diversion system in Columbia River estuary.