Prepared in cooperation with the Washington Department of Fish and Wildlife

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Open-File Report 2014–1069

U.S. Department of the Interior
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Cover: Photographs of commercial fishing gear and a radio-tagged Chinook salmon (inset). (Photographs taken by Ann Stephenson, Washington Department of Fish and Wildlife.

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Conversion Factors

SI to Inch/Pound

Multiply	By	To obtain
	Length	
meter (m)	3.281	foot (ft)
kilometer (km)	0.6214	mile (mi)
	Volume	
liter (L)	0.2642	gallon (gal)

Datum

Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83).

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Executive Summary

Commercial salmon *Oncorhynchus* spp. fishers traditionally have used gill nets, and more recently tangle nets, to capture adult salmon in the lower Columbia River, Washington and Oregon, but these gear types are not selective and can result in unintentional injury or death to non-target species, which is a problem when wild or Endangered Species Act-listed salmon are present. Gill and tangle nets capture fish through physical retention. Gill nets have mesh sizes that are slightly larger than the diameter of the head of the target species so that a fish moving through the net becomes entangled behind its operculum. Tangle nets have mesh sizes that are smaller than the diameter of the head of the target species so that a fish becomes entangled by its teeth or jaw. The Washington Department of Fish and Wildlife (WDFW) has been evaluating Merwin traps, beach seines, and purse seines during the past decade to determine if these are viable alternative commercial fishing gear types that would reduce negative effects to non-target fish, including wild salmon. As opposed to gill and tangle nets, these alternative gear types capture fish without physical restraint. The nets encircle the area where a fish or school of fish is located and eliminate the ability of those fish to escape. Because fish are not physically restrained by the gear, it is believed that the likelihood of injury and death would be reduced, allowing the safe release of non-target fish.

In 2011 and 2012, WDFW conducted post-release mortality studies of steelhead (*Oncorhynchus mykiss*), Chinook salmon (*Oncorhynchus tshawytscha*), and coho salmon (*Oncorhynchus kisutch*) that were captured using beach or purse seines. These studies were comprised of two groups of fish tagged with passive integrated transponder tags (PIT tags): (1) treatment fish that were captured by one of the gear types 9–25 river kilometers (rkm) downstream of Bonneville Dam (rkm 234); and (2) control fish that were captured at the Adult Fish Facility near the Washington shore fish ladder at Bonneville Dam, and then transported and released 8 rkm downstream of the Bonneville Dam. Fish were confirmed to have survived if they moved upstream and were detected on PIT-tag antennas at or upstream of Bonneville Dam, were recovered at hatcheries or at the dam, or were captured by commercial or sport fishers. Post-release survival estimates were higher for steelhead (89–98 percent) than for Chinook salmon and coho salmon (50–90 percent; Washington Department of Fish and Wildlife, unpub. data, 2014). However, some Chinook salmon and coho salmon return to hatcheries, or spawn in the mainstem Columbia River and in tributaries downstream of Bonneville Dam. The proportion of Chinook salmon

and coho salmon in the treatment group that were destined for areas downstream of Bonneville Dam likely was higher than in the control group because the control fish were collected as they were attempting to pass the dam. If this assertion was true, mortality would have been overestimated in these studies, so WDFW developed a study plan to determine the post-release movements and intended location of Chinook salmon and coho salmon collected with beach and purse seines in the lower Columbia River.

A radiotelemetry study was done during 2013 to determine the intended locations of tule Chinook salmon, bright Chinook salmon, and coho salmon collected downstream of Bonneville Dam with alternative commercial fishing gear, and to quantify the proportion of fish that were destined for various areas in the Columbia River Basin. A secondary objective was to assess post-release survival of tagged fish that were captured in a beach or purse seine. Fish were collected by two fishers per gear type (four total fishers) and the target sample size was 100 fish per species for each of the four fishers (4 fishers × 3 species × 100 fish=1,200 total fish). Fish collection and tagging occurred during August–October 2013 (rkms 225–209), and 1,214 salmon were tagged with a PIT tag and radio transmitter. Catch varied by fisher and species, so some groups of fish did not meet the sample-size goal whereas other groups exceeded the goal. Species-specific group sizes by fisher ranged from 66 fish (fisher 3, tule Chinook salmon) to 153 fish (fisher 1, coho salmon) per group. A total of 333 tule Chinook salmon, 506 bright Chinook salmon, and 375 coho salmon were tagged and released. Tagged fish were monitored using fixed telemetry sites, mobile tracking, PIT-tag interrogation arrays, and tag recovery reports. Ninety-seven percent of the radio-tagged fish were detected by fixed sites or mobile tracking, 57 percent were detected by PIT-tag arrays, and 20 percent of the tags were recovered and reported after fish returned to a hatchery, were caught in a fishery, or were recovered in spawning surveys.

Movements of individual tagged fish were grouped into six general behavior categories and were summarized based on three possible outcomes, which included: (1) passing Bonneville Dam; (2) remaining between Bonneville Dam and Washougal, Washington (rkm 194); and (3) moving downstream of Washougal. For all species, the largest behavior category was comprised of fish that passed Bonneville Dam (44 percent of tule Chinook salmon, 62 percent of bright Chinook salmon, and 53 percent of coho salmon). Many fish (26 percent of tule Chinook salmon, 21 percent of bright Chinook salmon, and 14 percent of coho salmon) moved downstream after release and passed Washougal. The remaining fish showed one of three behavior patterns, but ultimately remained between Bonneville Dam and Washougal (29 percent of tule Chinook salmon, 15 percent of bright Chinook salmon, and 26 percent of coho salmon). Median travel times from the release site to Bonneville Dam were 31.9 hours (h) for tule Chinook salmon, 44.9 h for bright Chinook salmon, and 47.0 h for coho salmon. Median travel times from the release site to Cascade Locks, upstream of Bonneville Dam, were 70.3, 66. 5, and 58.2 h for tule Chinook salmon, bright Chinook salmon, and coho salmon, respectively. Median travel times from the release site to Washougal were 56.9 h for tule Chinook salmon, 58.0 h for bright Chinook salmon, and 64.0 h for coho salmon.

Tagged fish dispersed throughout the Columbia River Basin following release. Some fish remained in the mainstem Columbia River, moved upstream more than 300 rkm, and passed Wells Dam. Tag recovery reports showed that tagged fish returned to Dworkshak, Priest Rapids, Ringold, Spring Creek, and Bonneville hatcheries. Tagged fish also returned to numerous tributary rivers and streams including the Methow, Snake, Yakima, Deschutes, Washougal, Sandy, and Willamette Rivers, among others. Observed movements of tule Chinook salmon upstream of The Dalles Dam suggest that misidentification of some Chinook salmon occurred during this study. This is because it is believed that bright Chinook salmon are the only subspecies of fall Chinook salmon that are present upstream of The Dalles Dam.

Survival was assessed by examining the behavior of individual fish and determining the percentage of probable survivors. This conservative approach was used because we determined that, based on fish behaviors, the use of mark-recapture modeling to estimate survival for all study fish would not have produced reliable estimates. Probable survival rates for fish collected in beach seines were 93 percent for tule Chinook salmon, 87 percent for bright Chinook salmon, and 84 percent for coho salmon. Probable survival rates for fish collected in purse seines were 89 percent for tule Chinook salmon, 90 percent for bright Chinook salmon, and 80 percent for coho salmon. Fish that moved downstream, passed Washougal within 4 days of release, and were not detected after 4 days could not be reliably assigned as live or dead because this detection history could apply either to live fish moving downstream or to dead fish drifting in the river currents. Fish observed in this group were likely comprised of a mix of live and dead fish, so the probable survival rates we report are conservative.

Detection probabilities of fixed telemetry sites and PIT-tag arrays showed that some fish were not detected while moving through certain zones, which supports the hypothesis that true survival exceeded probable survival during the study. Telemetry sites upstream of the release site were pooled into a single detection zone to determine the probability of detecting tagged fish that moved upstream and passed Bonneville Dam. Detection probabilities in this zone were 99.3 percent for tule Chinook salmon and bright Chinook salmon, and 94.4 percent for coho salmon. PIT-tag detection probabilities at Bonneville Dam were 95.2 percent for tule Chinook salmon, 97.1 percent for bright Chinook salmon, and 95.9 percent for coho salmon. Telemetry detection sites at Washougal were pooled to determine detection probabilities for fish that moved downstream. Detection probabilities at Washougal were 97.7 percent for tule Chinook salmon, 99.1 percent for bright Chinook salmon, and 90.2 percent for coho salmon.

This study showed that one-third to one-half of the fish collected downstream of Bonneville Dam did not pass the dam. This finding indicates that the fish from the treatment and control groups for the 2011 and 2012 WDFW studies were not similar because fish collected at Bonneville Dam were likely comprised of a higher proportion of fish that moved to areas upstream of the dam. This would negatively bias survival estimates for fish collected in beach and purse seines downstream of Bonneville Dam. The study also showed that some PIT-tagged fish are not detected as they pass Bonneville Dam, so these findings could be used to correct estimates from 2011 and 2012. Although results from this study are insightful when considering the 2011 and 2012 findings, the results were collected during a single year, so variability could not be assessed. Therefore, the use of 2013 results to correct estimates obtained during 2011 and 2012 should be done with caution.

Telemetry studies of adult salmon have been done routinely in the Columbia River for many years, but these studies used fish that were collected at Bonneville Dam or at other upstream locations. This study provides new insights into the behavior and movements of salmon populations that are migrating in the Columbia River, downstream of Bonneville Dam, during late-summer and autumn.

Introduction

Commercial salmon fishers in the lower Columbia River have traditionally used gill nets to target hatchery fish, but this fishing gear is not selective and results in unintentional harvest of wild salmon and other non-target species. Alternative fishing gear has been developed in recent years to minimize the negative effects of commercial fishing. For example, tangle nets are similar to gill nets but have smaller mesh sizes designed to capture fish by their nose or jaw. Fish that are captured in tangle nets are less likely to sustain critical injuries and can often be released alive if they are removed from the nets within a reasonable time period and are carefully handled. Commercial fishing regulations limit soak times and overall length of the tangle nets to ensure that non-target fish are not detained for long time periods, and recovery boxes are required for holding fish prior to release (Washington Department of Fish and Wildlife, unpub. data, 2014). However, there are other alternative commercial gear types that could be used to capture fish in the lower Columbia River that may be less harmful than tangle nets.

In 2009, the Washington Department of Fish and Wildlife (WDFW) began evaluating three commercial fishing gear types as alternatives to gill and tangle nets. Merwin traps, beach seines, and purse seines were evaluated because these gear types may pose less risk of injury or death to wild salmon and other non-target species. These gear types capture fish by encircling them and eliminating the ability of fish to escape rather than physically restraining them, which is when injuries are most likely to occur. In 2011 and 2012, WDFW conducted studies to determine post-release survival rates of Chinook salmon (*Oncorhynchus tshawtscha*), coho salmon (*Oncorhynchus kisutch*), and steelhead (*Oncorhynchus mykiss*) captured using beach or purse seines. The studies were done during August–October each year, and individual fish were marked with a passive-integrated transponder tag (PIT tag). Survival was evaluated using Ricker’s two-release method, which requires treatment and control groups of fish (Burnham and others, 1987; Washington Department of Fish and Wildlife, unpub. data, 2014). Treatment fish were captured using beach and purse seines downstream of Bonneville Dam between rkms 209 and 225, PIT-tagged, and released near the capture site. Control fish were captured at the Adult Fish Facility near the Washington shore fish ladder at Bonneville Dam (rkm 233), PIT-tagged, transported downstream to rkm 226, and released. Tagged fish (treatment and control) were detected as they moved upstream and passed through PIT-tag interrogation arrays in fish ladders on dams, and when they were recovered in commercial fisheries or sport fisheries, or at hatcheries.

Estimates of survival rates from the WDFW studies showed that steelhead survival was higher than Chinook salmon and coho salmon (table 1). Cumulative survival of steelhead was estimated to range from 89 to 98 percent, whereas Chinook salmon and coho salmon survival was estimated to range from 50 to 90 percent depending on species and gear type (Washington Department of Fish and Wildlife, unpub. data, 2014; table 1). The fall Chinook salmon and coho salmon survival estimates may be biased, however, because of differences in the intended spawning locations of treatment and control fish. Fall Chinook salmon and coho salmon return to hatcheries, and spawn in the mainstem Columbia River and tributaries downstream of Bonneville Dam (Van der Naald and others, 2004), and, therefore, might not approach the dam where they could be detected by PIT-tag arrays. It is reasonable to assume that treatment fish captured downstream of Bonneville Dam were comprised of a mixture of fish destined for areas upstream and downstream of the dam. Control fish, however, were likely comprised of few fish destined for areas downstream of Bonneville Dam because they were collected in the adult fish ladder as they were attempting to pass the dam. If these differences in group composition existed, then treatment fish that remained downstream of Bonneville Dam would have artificially inflated the overall mortality estimates of the treatment group because they were not known to have “survived” based on detections at or upstream of the dam. Given these concerns, WDFW developed a study plan for 2013 to determine the proportion of treatment fish that did not pass Bonneville Dam.

A collaborative study between WDFW and the U.S. Geological Survey (USGS) was conducted during 2013. For this study, WDFW completed a third year of the two-release method (using PIT tags and methods similar to those used in 2011 and 2012) while USGS conducted a large-scale telemetry evaluation to describe movement patterns and proportions of intended location for fish in the treatment group. Telemetry was selected as a research tool to supplement the PIT-tag study because it can effectively monitor fish movements throughout the large study area and is not restricted to detecting fish solely at upstream PIT-tag arrays, such as the adult fish ladders at Bonneville Dam. Results from the telemetry evaluation then could be used to correct for treatment fish that were not destined to pass Bonneville Dam, providing the ability to obtain unbiased estimates of post-release survival for the alternative commercial fishing gear types.

The telemetry study focused on tule fall Chinook salmon, bright fall Chinook salmon, and coho salmon captured using beach and purse seines. An array of fixed monitoring sites (fixed sites) was established to monitor radio-tagged fish throughout the study area, and intensive mobile tracking efforts were used to supplement and to refine fish detections. The objectives were to: (1) describe movement patterns of radio-tagged Chinook salmon and coho salmon released into the mainstem Columbia River after being captured by a beach or purse seine; (2) quantify the proportions of radio-tagged Chinook salmon and coho salmon destined for areas upstream and downstream of Bonneville Dam; and (3) if possible, estimate survival rates of radio-tagged Chinook salmon and coho salmon captured by a beach or purse seine.

Methods

Study Area

The telemetry study focused on a 72-km reach of the Columbia River, but data on fish movements were obtained from a much larger area using various approaches. The primary study area was defined by the reaches in which fish were tagged, the locations of fixed sites, and the areas where mobile tracking occurred. The upstream boundary of the primary study area was Cascade Locks, Oregon (rkm 238), and the downstream boundary was the mouth of the Willamette River, Oregon (rkm 166) (fig. 1). Within these boundaries, fish were collected and tagged, and fish movements were monitored with fixed sites and mobile tracking. Additional fish movement data were collected in various ways. Contact information for WDFW was included on the labels of radio transmitters used during the study, so much information was received about fish movements when study fish were recovered at hatcheries or in fisheries outside of the primary study area. Fish also were PIT-tagged and could be detected on PIT-tag arrays throughout the Columbia River Basin. Finally, mobile tracking efforts were conducted for several days in the mainstem Columbia River and in tributaries outside of the primary study area toward the end of the study period. These data sources extended the spatial extent of the study area beyond the reach in which tagged fish were intensively monitored using radiotelemetry.

Sample Sizes

Several factors were considered to determine sample size targets for the study. The goal was to identify sample sizes required to represent groups of fish stratified by species type (tule Chinook salmon, bright Chinook salmon, coho salmon), gear type (beach seine, purse seine) and fisher (two fishers per gear type). This stratification yielded a total of 12 groups for the study. One of the objectives was to estimate post-release survival associated with capture by gear type, so the sample size analysis focused on factors affecting the precision of these estimates. The three primary factors that affect precision of survival estimates in telemetry studies are sample size, survival rate, and detection probability of the monitoring array. Several scenarios were developed that could be observed during the study period for a range of sample sizes (25, 50, 75, 100, 125, 150, 175, and 200 fish per group), survival rates (75, 90, 95, and 98 percent survival), and detection probabilities (85 and 95 percent), and the SampleSize software (Lady and others, 2003) was used to obtain precision estimates for each scenario (fig. 2). Large sample sizes in telemetry studies often are cost-prohibitive because transmitters are expensive, so we focused on identifying sample size targets that provided a balance between acceptable precision and transmitter expense. We plotted the precision estimates for each scenario and observed that increasing the sample size resulted in substantially improved precision for sample sizes ranging from 25 to 100 fish per group (fig. 2). This relation plateaued at about 100 fish per group for all scenarios. That is, increasing sample sizes greater than 100 fish per group resulted in incrementally smaller improvements in precision compared to increasing sample sizes less than 100 fish per group. Half confidence intervals for 100 fish per group ranged from about 3 to 10 percent across the scenarios we examined. We did not have a specified precision target to attain during this study, so these confidence intervals were deemed acceptable. Based on this analysis, we identified 100 fish per group as the minimum sample size target for the study. This resulted in an overall sample size of 1,200 fish for the study (12 groups of fish × 100 fish per group; table 2). Marked and unmarked fish were present in each group to ensure that results were applicable to all adult salmon that could be encountered by the fishers. Fish origin was not considered as a factor in data analyses because this was beyond the scope of the study.

Fish Collection and Tagging

Fish collection and tagging were a collaborative effort between contract fishers, WDFW, and the USGS. Two contract fishers captured fish using beach seines and two contract fishers captured fish using purse seines. The specifications of the seines and their deployment techniques were the same as those used during the 2011 and 2012 evaluations by Washington Department of Fish and Wildlife, (unpub. data, 2014). On each tagging date, the fishers conducted multiple sets, where a set represented the deployment and retrieval of the fishing gear. All collection efforts were conducted between rkms 225 and 209. Study fish collected in a given set were individually netted out of the seine, handled for tagging and morphometric data collection, and released near the point of capture. Study fish were evaluated, tagged, and released as soon as possible to minimize handling effects.

Following netting, fish were placed in a container (390 L) with river water, and WDFW staff visually made a species identification and assessed physical condition. Tule Chinook salmon generally were darker than bright Chinook salmon, but subspecies misidentification was possible in some cases. Fish also were assigned a capture condition value that ranged from 1 to 5 (1=vigorous, not bleeding; 2=vigorous, bleeding; 3=lethargic, not bleeding; 4=lethargic, bleeding; 5=no signs of life). Fish selected for radio-tagging were then transferred into an anesthetic bath (70 L) containing 25 mg/L Aqui-S® 20E (AquaTactics, Kirkland, Washington). After fish were lightly sedated (about 1 min), they were removed from the bath and a radio transmitter (Model MCFT-7F or MCFT-3EM, Lotek Wireless, Inc., Newmarket, Ontario) was gastrically inserted into the stomach using methods described by Keefer and others (2005). Following radio-tagging, fish were placed in a recovery container (390 L) with river water and WDFW staff measured fork length, conducted a visual examination to determine sex, and inserted a PIT-tag (Model HPT12, Biosonics, Inc., Boise, Idaho) in the peritoneal cavity. Fish were allowed to recover in the container for about 2–3 min, and immediately before release, WDFW staff assigned a release condition value using the same criteria for assessing capture condition (1=vigorous, not bleeding; 2=vigorous, bleeding; 3=lethargic, not bleeding; 4=lethargic, bleeding; 5=no signs of life). Tagged fish were released near the location where the set was completed.

Data Collection

Fish movement data were obtained from multiple sources. Study fish were tagged with a radio transmitter and a PIT-tag, enabling detection at fixed-telemetry sites, by mobile tracking, and at PIT-tag interrogation arrays located throughout the Columbia River Basin. Additionally, radio transmitters were labeled with WDFW contact information so that fish collected in hatcheries or captured in commercial or recreational fisheries could be reported. Significant efforts were made to communicate and coordinate with local hatcheries and fishers to encourage reporting of recovered fish.

An array of fixed sites was operated to monitor fish behavior and movement patterns (figs. 1 and 3). Sixteen fixed sites were located within the primary study area, 13 upstream and 3 downstream of the collection area. A single fixed site was located at Cascade Locks, Oregon (rkm 238), to confirm when fish passed Bonneville Dam, which is 4 rkm downstream of the site. Five fixed sites were located at Bonneville Dam (rkm 234) to monitor fish arrival and passage. Two of the five fixed sites monitored the dam forebay (using aerial antennas) and the three remaining fixed sites each monitored fish ladders (using underwater antennas) at powerhouse 1, the spillway, and powerhouse 2 (fig. 3). Two sites were located in the tailrace of Bonneville Dam (rkm 232) near the mouth of Tanner Creek. The Bonneville Hatchery is located on Tanner Creek. Therefore, the tailrace fixed sites served two purposes by detecting fish approaching Bonneville Dam and detecting fish that were returning to the hatchery. Three fixed sites were located around the Pierce Island/Ives Island complex (rkm 228; fig. 3). This area is heavily used by fall Chinook salmon and coho salmon that spawn in the mainstem Columbia River around the islands or in one of the five streams that enter the mainstem at this location (Van der Naald and others, 2004). Hamilton, Hardy, and Woodward Creeks enter the Columbia River on the Washington side of the river, and Moffett and McCord Creeks enter on the Oregon side of the river. One fixed site monitored the area near the mouth of Hamilton Creek, one site monitored the area near the mouth of Woodward Creek and the third site monitored the area near the mouths of Moffett and McCord Creeks. Two fixed sites were located at rkm 225 (one on each side of the river) to create a detection gate that was used to confirm when fish moved upstream of the release sites (fig. 3). These sites were located near Skamania Landing, Washington, and Dodson, Oregon, respectively (fig. 3). Three sites were located at Washougal, Washington, to confirm when fish moved downstream of the release sites. Two of the sites at Washougal were located at rkm 196, and the third site was located at rkm 194. The Oregon side of the river at Washougal is very shallow (<2 m), so both fixed sites at rkm 196 were located on the Washington shore. The fixed site at rkm 194 was located on Lady Island.

Mobile tracking was used to detect fish in areas where fixed sites were absent. Most mobile tracking was done using a boat, but some supplemental tracking also was done from a vehicle. Mobile tracking began on August 29, 2013, and was done daily through September 29, 2013. Mobile tracking was not done from October 1, 2013, to October 16, 2013, because of the U.S. government shutdown. After mobile tracking efforts resumed, tracking occurred five times per week during October 17–31, 2013. Five additional mobile tracking events occurred during November 1–21, 2013. Mobile tracking efforts during August–October primarily were from a boat and focused on the mainstem Columbia River between the Bonneville Dam tailrace and the mouth of the Willamette River. This area generally was divided into three reaches, and the tracking effort was focused on an individual reach during a given tracking day. The three reaches were (1) Bonneville Dam tailrace to Phoca Rock (rkms 232–212); (2) Phoca Rock to Washougal (rkms 212–194); and Washougal to the mouth of the Willamette River (rkms 194–166). Tracking in each reach typically occurred during successive days to ensure that each reach was surveyed within a 3-day period. When tagged fish were encountered, the following data were recorded—transmitter identification, date, time, telemetry receiver gain, and signal strength. A location then was logged into a global positioning system (Garmin® Model Dakota 10; Garmin International, Inc., Olathe, Kansas), and the latitude and longitude were recorded.

Detection records from PIT-tags were obtained from the Columbia Basin PIT Tag Information System (PTAGIS; *http://www.ptagis.org*). Interrogation sites for PIT tags have been installed at dams, in rivers and streams, and at hatcheries throughout the Columbia River Basin. Detection records from individual interrogation sites are compiled in PTAGIS as a centralized database that can be queried to obtain detection records of individual fish. The presence of the PIT-tag monitoring array throughout the Columbia River Basin allowed us to substantially increase the spatial extent of our study area beyond the boundaries of our telemetry fixed sites.

Contact information for the study was included on the labels of radio transmitters used during the study period so hatchery personnel, commercial and sport fishers, and the general public could contact us if they observed a tagged fish from our study. Like the PIT-tag detections, this approach allowed us to monitor fish movement patterns across a large spatial extent. Data from fixed sites, mobile tracking, PIT-tag interrogation sites, and transmitter recoveries were pooled for data analysis.

Behavior and Movement Patterns

Data records were analyzed to describe general behavior and movement patterns of tagged fish. Detection histories of individual tagged fish were examined and assigned to one of six behavior groups, based on their movements during the study. These behavior groups included fish that

- moved upstream of the release site and passed Bonneville Dam;
- moved upstream of the release site but did not pass Bonneville Dam;
- moved upstream of the release site and were detected at an upstream fixed site or by mobile tracking, then returned downstream but did not pass Washougal;
- moved upstream of the release site, then returned downstream and passed Washougal;
- moved downstream of the release site, but did not pass Washougal; and
- moved downstream and passed Washougal (fig. 4).

Movement patterns also were described by examining travel times between specific locations in the study area. Two travel times were calculated for fish that passed Bonneville Dam—(1) the elapsed time from release to first detection at Bonneville Dam; and (2) the elapsed time from release to last detection at Cascade Locks, Oregon. One travel time was calculated for fish that moved downstream and out of the study area, the elapsed time from release to the last detection at Washougal.

The 2011 and 2012 WDFW studies compared survival of treatment fish captured downstream of Bonneville Dam to survival of control fish captured at the Adult Fish Facility from the Washington shore ladder at Bonneville Dam. All radio-tagged fish in the study were collected downstream of Bonneville Dam, but some of these fish eventually entered the Washington fish ladder at Bonneville Dam. The movement patterns of radio-tagged fish that were detected inside the Washington ladder were compared to movement patterns of all fish that were radio-tagged downstream. We determined the percentage of each group that passed Bonneville Dam to determine if there were differences in the behavior of fish from each group. This provided a way to assess behavioral differences between groups of fish that were collected at the two sites in previous studies.

Intended Migratory Locations

Telemetry detection records, PIT-tag detection records, and tag recovery reports were examined and summarized to determine the last known location of each fish at the end of the study period, and this information was used to describe the intended migratory locations of tagged fish. For each fish, data records were sorted chronologically and the last records were examined to determine the last known location. This information then was pooled by species to create a distribution of last known locations that served to describe the intended migratory locations of study fish.

Survival of Captured Fish

Data were analyzed to determine short-term survival rates of tagged fish captured in beach or purse seines. For this study, “short-term” was defined as the 4-day period immediately after tagged fish were released. The 4-day period was selected to provide sufficient time to observe handling-related mortality (if present) while limiting the time period during which mortality could occur from factors that were unrelated to capture or tagging. Contemporary telemetry studies often use mark-recapture models (Melnychuk, 2009; Perry and others, 2010) to estimate survival of tagged individuals but that was not possible in this study for two reasons. First, many tagged fish moved downstream past Washougal shortly after release, and were not detected again (see section, “Results”). Live and dead fish could have this same type of detection history and could not be separated reliably using a mark-recapture model. Second, mobile tracking was not done for most of October as a result of the U.S. government shutdown. Mobile tracking was an important tool for detecting fish shortly after capture and release. With these data missing for much of October, we were unable to determine when many fish stopped moving, and a lack of movement is a strong indicator that the transmitter had been regurgitated, or that the fish had died. The combination of downstream movements by many tagged fish and lack of short-term fate resulted in uncertainties that would not support the application of a mark-recapture model to estimate survival of tagged fish during the study.

Although a mark-recapture model could not be used to estimate survival, the detection history for individual fish was examined to assess whether or not their behavior was suggestive of a fish that survived capture and release. Individual detection histories were examined and a fish was determined to have survived capture, tagging, and release if the detection history met at least one of the following criteria—(1) fish moved upstream and arrived at or passed Bonneville Dam; (2) fish was harvested in a commercial, recreational, or Tribal fishery; (3) fish returned to a hatchery; (4) fish entered a spawning tributary; or (5) fish was detected moving more than 4 days after release. Conversely, fish were classified as dead or potentially dead if their detection history met at least one of the following criteria—(1) fish was recovered dead within 4 days of release, (2) fish was not observed moving after the 4-day post-release period, or (3) fish was never detected. This approach allowed us to identify probable survivors during the study. The numbers of fish in each behavior group were compared between fishers of a given gear type using Fisher's exact test.

Detection Probabilities and Spit Transmitters

Telemetry and PIT-tag detection records were analyzed to determine detection probabilities in several zones. Tagged fish were released downstream of several fixed telemetry sites (rkm 225–238; fig. 1) used to describe upstream movement and passage at Bonneville Dam. The release site also was upstream of three fixed sites (rkm 194–196; fig. 1) used to describe downstream movements at Washougal. Detection probabilities were calculated for the upstream and downstream fixed sites to determine the probability of tagged fish moving outside of the primary study area without being detected. The 13 fixed sites located between rkms 225 and 238 were pooled to create the upstream detection zone, and the 3 fixed sites located between rkms 194 and 196 were pooled to create the downstream detection zone. Detection probabilities of the upstream telemetry detection zone (p_{ut}) were estimated as:

$$p_{ut} = n_{ut} / nu_{all} \qquad (1)$$

where

n_{ut} is the number of fish that were detected in the upstream telemetry detection zone, and
nu_{all} is the total number of tagged fish that passed Bonneville Dam.

Detection probabilities of the downstream telemetry detection zone (p_{dt}) were estimated as:

$$p_{dt} = n_{dt} / nd_{all} \qquad (2)$$

where

n_{dt} is the number of fish that were detected in the downstream telemetry detection zone, and
nd_{all} is the total number of tagged fish that moved downstream of Washougal.

Detection probabilities (p_{pit}) of the PIT-tag interrogation array at Bonneville Dam were estimated by examining detection histories of fish known to have moved upstream of the dam. Detection probabilities of the PIT-tag interrogation array were estimated as:

$$p_{pit} = n_{pit} / nu_{all} \quad (3)$$

where

n_{pit} is the number of fish detected on the PIT-tag interrogation array as they passed Bonneville Dam.

Detection records in the Bonneville Dam fish ladders were analyzed to estimate transmitter regurgitation (hereafter spit) rates during the study period. Fish that were detected on PIT-tag antennas but not on radiotelemetry antennas in the fish ladders were assumed to have spit their transmitter prior to passing Bonneville Dam. The spit rate (R_{spit}) for each species was calculated as:

$$R_{spit} = n_{spit} / n_{all} \quad (4)$$

where

n_{spit} is the number of fish that were determined to have spit their transmitter prior to passing Bonneville Dam

n_{all} is the total number of tagged fish that passed Bonneville Dam.

Results

Fish Collection and Tagging

Fish collection varied by species, gear type, and fisher, so the number of fish tagged per group was smaller than the sample size target for some groups of fish and larger for others (tables 2–5; fig. 5). A total of 1,214 fish were captured and radio-tagged for the study. The tagged population was comprised of 333 tule Chinook salmon (27 percent), 506 bright Chinook salmon (42 percent), and 375 coho salmon (31 percent). Sample sizes were less than the target of 100 fish per group for all tule Chinook salmon (table 3), exceeded the target for all bright Chinook salmon groups (table 4), and exceeded the target for two of the coho salmon groups (1 beach seine fisher and 1 purse seine fisher; table 5).

For tule Chinook salmon, 176 fish were tagged after being collected in a beach seine, and 157 fish were tagged following capture in a purse seine (table 3). Regardless of gear type, fishers captured more male than female tule Chinook salmon. The mean fork length of tule Chinook salmon was not significantly different between the two beach seine fishers (t=-0.02, df=155, p=0.98) or the two purse seine fishers (t=-0.12, df=234, p=0.91). For bright Chinook salmon, 238 and 268 fish were tagged from the beach seine and purse seine gear types, respectively (table 4). Three of four fishers (fishers 1, 2, 3; table 5) captured more male than female bright Chinook salmon. Bright Chinook salmon fork length was similar between fishers for each gear type (beach seine, t=1.11, df=266, p=0.27; purse seine, t=-1.62, df=174, p=0.11). A total of 210 and 165 coho salmon were captured and tagged using beach and purse seines, respectively (table 5). All fishers captured more male than female coho salmon. Beach seine fishers captured coho salmon that were similar in size (t=-1.69, df=163, p = 0.09) but fish size differed significantly between fish captured by the two purse seine fishers (t=2.28, df=208, p=0.02).

Monitoring Results

The monitoring approach used during the study successfully accounted for most of the tagged fish. A total of 1,214 salmon were tagged and 97 percent (1,174 fish) were detected on fixed sites or by mobile tracking. Detection proportions were highest for tule Chinook salmon (>99 percent; 332 of 333 fish), followed by bright Chinook salmon (98 percent; 497 of 506 fish), and were lowest for coho salmon (92 percent; 345 of 375 fish). Mobile tracking resulted in 988 detection events. Some fish were detected multiple times by mobile trackers. Overall, 35 percent (421 fish) of the fish were detected by mobile tracking, including 54 percent of tule Chinook salmon (179 fish), 35 percent of bright Chinook salmon (177 fish), and 17 percent of coho salmon (65 fish). A total of 693 fish (57 percent) were detected at PIT-tag interrogation sites throughout the Columbia River Basin. Forty-six percent of the tule Chinook salmon (154 fish), 63 percent of the bright Chinook salmon (318 fish), and 59 percent of the coho salmon (221 fish) were detected at PIT-tag interrogation sites. Tag recoveries were reported for 249 fish (20 percent), including 91 tule Chinook salmon (27 percent), 97 bright Chinook salmon (19 percent), and 61 coho salmon (16 percent).

Behavior and Movement Patterns

Tagged fish showed six general behavior patterns during the study period, as described in the section, “Methods.” To simplify presentation of results, behavior groups 2, 3, and 5 are pooled and referred to as fish that did not leave the study area during the monitoring period, and behavior groups 4 and 6 are pooled and referred to as fish that moved downstream and left the study area. The number of fish (and percentage) in each of the six behavior groups and the pooled results from the study are shown in table 6.

The largest percentage of tagged fish moved upstream and passed Bonneville Dam, but many fish also remained in the study area or moved downstream and passed Washougal. Forty-four percent of the tule Chinook salmon passed Bonneville Dam, 29 percent remained in the study area, and 26 percent moved downstream and out of the study area (table 6). Sixty-two percent of the bright Chinook salmon passed Bonneville Dam, 15 percent remained in the study area, and 21 percent moved downstream out of the study area (table 6). Fifty-three percent of the coho salmon passed Bonneville Dam, 26 percent remained in the study area, and 14 percent moved downstream and out of the study area (table 6). The number of marked and unmarked fish that comprised each of these groups is shown in appendix A. Median travel time from release to first detection at Bonneville Dam was fastest for tule Chinook salmon (31.9 h) and similar for bright Chinook salmon (44.9 h) and coho salmon (47.0 h) (table 7). Travel time from release to last detection at Cascade Locks was fastest for coho salmon (58.2 h), followed by bright Chinook salmon (66.5 h) and tule Chinook salmon (70.3 h) (table 7). Finally, median travel times from the release site to Washougal were 56.9, 58.0, and 64.0 h for tule Chinook salmon, bright Chinook salmon, and coho salmon, respectively. Most fish movements to each location occurred within 4 days of release for all species studied (fig. 6).

Tagged fish that entered the fish ladder on the Washington shore at Bonneville Dam passed the dam at a faster rate than the general population of all tagged fish that were released downstream. The percentages of tagged fish that passed Bonneville Dam after being detected in the Washington fish ladder were 87 percent for tule Chinook salmon, 89 percent for bright Chinook salmon, and 79 percent for coho salmon (table 8). Passage rates through Bonneville Dam for the entire tagged population were 44 percent for tule Chinook salmon, 62 percent for bright Chinook salmon, and 53 percent for coho salmon (table 8). Tagged fish that entered one of the fish ladders at Bonneville Dam rarely moved downstream and passed Washougal (1 percent for tule Chinook salmon, 6 percent for bright Chinook salmon, 2 percent for coho salmon; table 8).

Intended Migratory Locations

Salmon that were collected and tagged downstream of Bonneville Dam dispersed throughout the Columbia River Basin following release (tables 9–11). Tule Chinook salmon returned to 4 hatcheries and 15 tributaries during the study period (table 9). Several tule Chinook salmon moved upstream and passed Priest Rapids Dam (rkm 639.1), Rocky Reach Dam (rkm 762.3), or Wells Dam (rkm 830.1). Tule Chinook salmon that moved downstream entered the Washougal, Sandy, Willamette, Lewis, and Cowlitz Rivers (table 9). Bright Chinook salmon had similar dispersal patterns to tule Chinook salmon and returned to 4 hatcheries and 14 tributaries after being captured, tagged, and released (table 10). Some bright Chinook salmon moved upstream in the mainstem Columbia River and passed Wells Dam (table 10). Coho salmon returned to 2 hatcheries and 18 tributaries during the study (table 11). Some of the tagged coho salmon that moved upstream entered the Wenatchee, Yakima, and Snake Rivers, and fish that moved downstream entered the Washougal, Sandy, Clackamas and Lewis Rivers (table 11). The numbers reported in some of the mainstem areas are positively biased because it is likely that fish moved beyond some of these sites but were not subsequently detected on PIT-tag antennas or reported as tag recoveries.

Survival of Captured Fish

Probable survival estimates for Chinook salmon and coho salmon ranged from 80 to 93 percent. Tule Chinook salmon detection histories indicated that at least 93 percent of the fish captured in beach seines, and 89 percent of the fish captured in purse seines survived (table 12). These estimates were similar for bright Chinook salmon, as 87 percent of the beach seine fish and 90 percent of the purse seine fish showed post-release behavior suggestive of survival (table 12). Survival rates were lower for coho salmon than for Chinook salmon with 84 percent of the beach seine fish and 80 percent of the purse seine fish showing post-release behavior indicative of survival (table 12). The percentages of coho salmon and Chinook salmon that were not detected more than 4 days after release were similar, so the apparent survival differences between species are attributed primarily to the larger number of coho salmon that were not detected during the study (table 12). The number of fish that had fates that occurred prior to and after the 4-day period used for assessing survival are shown in appendixes B–D.

Statistical comparisons of fate groups showed that fisher effects were detectable for coho salmon but not Chinook salmon during the study. The proportion of tule Chinook salmon and bright Chinook salmon that were probable survivors were similar between fishers for both beach seine and purse seine gear types (table 12). However, coho salmon survival was significantly different between beach seine fishers (Fisher's exact test; $p = 0.018$), and purse seine fishers ($p=0.018$; table 13).

Detection Probabilities and Spit Transmitters

Detection probabilities of telemetry monitoring zones were high during the study period, but there were differences in detection between Chinook salmon and coho salmon. The probability of tagged fish being detected in the upstream detection zone, as fish approached and passed Bonneville Dam, was 99.3 percent for tule Chinook salmon and bright Chinook salmon (146 of 147 fish for tule Chinook salmon; 311 of 313 fish for bright Chinook salmon), and 94.4 percent for coho salmon (186 of 197 fish). Detection probabilities in the downstream detection zone were 97.7 percent for tule Chinook salmon (86 of 88 fish), 99.1 percent for bright Chinook salmon (106 of 107 fish), and 90.2 percent (46 of 51 fish) for coho salmon.

Detection probabilities of the PIT-tag interrogation array at Bonneville Dam ranged from 95.2 to 97.1 percent. Detection probabilities were 95.2 percent (140 of 147 fish) for tule Chinook salmon, 97.1 percent (304 of 313 fish) for bright Chinook salmon, and 95.9 percent (189 of 197 fish) for coho salmon.

None of the tule Chinook salmon or bright Chinook salmon that passed Bonneville Dam were observed to have spit their transmitter. We found that 13 coho salmon passed Bonneville Dam after apparently spitting their transmitter. The spit rate for tule Chinook salmon and bright Chinook salmon was 0 percent and the spit rate for coho salmon was 6.6 percent.

Discussion

Movements of radio-tagged fish indicated that a large number of Chinook salmon and coho salmon captured downstream of Bonneville Dam did not pass the dam. This is an important finding when considering results from the 2011 and 2012 studies conducted by WDFW. The two-release study design used by WDFW in 2011 and 2012 was based on an assumption that each release group was comprised of similar individuals. When this assumption is met, observed survival differences between groups can be attributed to the treatment factor, which in this case was capture in a beach or purse seine. The telemetry results from 2013 showed that a large percentage of fall Chinook salmon and coho salmon captured downstream of Bonneville Dam did not pass the dam. Fifty-five percent of the tule Chinook salmon, 36 percent of the bright Chinook salmon, and 40 percent of the coho salmon (tables 6 and 8) did not pass the dam during the study. Many of these fish were observed in hatcheries and spawning tributaries downstream of the dam (tables 9–11). Furthermore, comparisons between tagged fish that entered the fish ladder on the Washington shore at Bonneville Dam, and the general tagged population, indicated that the former group was more likely to pass the dam and was much less likely to pass Washougal than the latter group (table 8). These data support the WDFW hypothesis that fall Chinook salmon and coho salmon collected downstream of Bonneville Dam are comprised of a large segment of individuals that are not destined for areas upstream of the dam (Washington Department of Fish and Wildlife, unpub. data, 2014). These results also indicate that treatment and control groups of fish from the 2011 and 2012 WDFW studies were not comprised of similar individuals. Thus, survival differences between the two groups could not be attributed solely to capture in one of the alternative fishing gears that were tested.

Detection probabilities of PIT-tagged fish at the Bonneville Dam PIT-tag interrogation array were less than 100 percent, which could have minor implications on survival estimates obtained during the 2011 and 2012 studies. Species-specific detection probabilities of the PIT-tag antennas at Bonneville Dam ranged from 95 to 97 percent in our study, which supports observations from a previous study where detection efficiency was 96 percent (Burke and others, 2006). The two-release study design used in the 2011 and 2012 studies relied primarily on PIT-tag detections to estimate group-specific survival. The observed detection probabilities from 2013 show that some (<5 percent) PIT-tagged fish likely were not detected as they passed Bonneville Dam in 2011 and 2012. Missed detections of tagged fish at Bonneville Dam would result in overestimating mortality in a mark-recapture study. The results of this study should be useful for correcting survival estimates to account for bias associated with less-than-perfect PIT-tag detection probabilities. However, detection probabilities probably were similar between treatment and control fish, and relatively few fish would have been missed, so this finding might have minimal implications.

Tagged fish dispersed widely following capture and release, and an unexpected number of fish moved downstream of Washougal. Chinook salmon and coho salmon that passed Bonneville Dam dispersed upstream in the mainstem Columbia River and entered numerous tributaries and hatcheries (tables 9–11). Some tagged fish moved upstream more than 300 km and passed Wells Dam, whereas others entered the Snake, Yakima, and Deschutes Rivers, and other tributaries. These findings are similar to those of Jepsen and others (2010), who tagged nearly 6,000 fish at Bonneville Dam during 1998–2005. Although many of the fish in this study successfully passed Bonneville Dam and located hatcheries or tributaries for spawning, a relatively large number of fish moved downstream and passed Washougal. In this study, 26 percent of the tule Chinook salmon, 21 percent of the bright Chinook salmon, and 14 percent of the coho salmon moved downstream, out of the primary study area, after release. This result was unexpected. The telemetry array was developed with the assumption that many fish would pass Bonneville Dam whereas others would remain in the primary study area and likely would return to Bonneville Hatchery, or to tributaries near the Hamilton Island/Pierce Island complex (fig. 1). The locations of most of the fixed sites were based on this assumption. We recognized, however, that tributary overshoot has been documented for adult salmon (Keefer and others, 2008) in the Columbia River, so we deployed three fixed sites at Washougal (fig. 1), several kilometers downstream of the collection and tagging area. These sites allowed us to document downstream movements by tagged fish, but many of these movements occurred shortly after release (<24 h).

Some studies have shown that handling and tagging can affect adult salmon behavior in rivers, and this is important to consider given the number of fish that were observed moving downstream of Washougal during the study. Research has shown that some adult salmon stop migrating, or move downstream for a brief period following a handling or tagging event (Gray and Haynes, 1979; Burger and others 1985; Bernard and others, 1999). However, these fish resume normal behavior shortly thereafter. For example, Bernard and others (1999) found that 72 percent of the Chinook salmon during 1996 and 46 percent of the fish in 1997 moved downstream at least 3 km after being radio-tagged in the Kenai River, Alaska. This resulted in a migration delay of 4–5 days for most fish. However, Bernard and others (1999) reported that following this delay, tagged fish resumed normal migration behavior and moved upstream to spawning tributaries. They concluded that the handling-induced behavior resulted in biased travel time data but did not affect data on spawning distributions within the watershed (Bernard and others, 1999). In the Columbia River Basin, telemetry studies are used predominantly to assess migration and movement patterns of adult salmon because these methods produce reliable data on fish movement (Keefer and others, 2005, 2008; Jepsen and others, 2010). Given these observations, it is possible that some fish in the study showed non-typical behavior shortly after release, but the final distribution and fates of tagged fish were, at worst, minimally biased by handling or tagging.

Movement patterns of Chinook salmon upstream of Bonneville Dam suggest that some fish were not accurately identified during the tagging process. Tule fall Chinook salmon populations are generally located downstream of The Dalles Dam (Cindy LeFleur, Washington Department of Fish and Wildlife, oral commun., February 2014). However, 12 percent (40 fish; table 9) of the fish that were identified as tule Chinook salmon in this study moved to areas upstream of The Dalles Dam. Some of these fish were observed in areas as far upstream as the Snake River, the Yakima River, and at Wells, Rocky Reach, and Priest Rapids Dams. During collection, two subspecies of Chinook salmon were observed—tule Chinook salmon and bright Chinook salmon. Technicians made a visual assessment and assigned individual fish as either a tule Chinook salmon or a bright Chinook salmon. Tule Chinook salmon generally are darker than bright Chinook salmon after these fish return to freshwater. Therefore, the coloration of each fish was the primary indicator used during the visual assessment. The fate data for Chinook salmon show that this process likely resulted in misidentification (at the subspecies level) of at least some of the Chinook salmon.

The combination of higher-than-expected downstream movements, fast travel times, and lack of consistent monitoring capabilities downstream of Washougal precluded the use of a mark-recapture model to estimate survival of tagged fish during the study. Telemetry-based survival studies often are designed using results from a pilot study because mark-recapture models include a series of assumptions that must be met for survival estimates to be valid (Skalski and others, 1998). Our study did not have the advantage of using results from a pilot study, and although a substantial number of adult salmonid telemetry studies have been done in the Columbia River, most have used fish collected at Bonneville Dam or farther upstream (Keefer and others, 2005, 2008; Jepson and others, 2010). Potentially live fish could not be separated from potentially dead fish for the group that moved downstream of Washougal because the movement patterns would be similar for both groups. Given these observations, mark-recapture modeling would not have provided reliable survival estimates for results obtained during 2013. However, results from the study can be useful for designing future survival studies in the lower Columbia River.

The assessment of probable survival in this study suggests that fall Chinook salmon and coho salmon survival rates are high after capture in a beach or purse seine. Behavioral responses by tagged fish following release suggested that 93 percent of the tule Chinook salmon, 87 percent of the bright Chinook salmon, and 84 percent of the coho salmon survived capture in a beach or purse seine. These estimates are conservative because we were unable assess survival of fish that moved quickly downstream and passed Washougal. Many of these fish likely were alive, which means that the probable survival estimates from this study underestimated the true survival rates following capture. Furthermore, detection probabilities for telemetry and PIT-tag monitoring sites were less than 1.0, which means that some fish that were undetected could have been alive and moved past monitoring sites without being detected. In the 2011 and 2012 studies, WDFW estimated that steelhead survival after capture in a beach or purse seine ranged from 96 to 98 percent (Washington Department of Fish and Wildlife, unpub. data, 2014). Our data suggest that fall Chinook salmon and coho salmon survival during 2013 could be similar to steelhead survival in 2011 and 2012, if the potential limitations of the 2013 study are considered.

In summary, this study identified intended migratory locations for fall Chinook salmon and coho salmon captured in beach or purse seines downstream of Bonneville Dam. The proportion of tule Chinook salmon, bright Chinook salmon, and coho salmon that moved to areas located upstream and downstream of the dam were described. This study differed from many of the telemetry studies of adult salmon that have been conducted in the Columbia River because study fish were captured downstream of Bonneville Dam. Probable survival estimates from the study were conservative, but showed that survival rates were more than 84 percent. Results from this study provide new information that can be used to provide context for previous studies, help to better understand migration patterns in the system, and be useful for designing future mark-recapture survival studies downstream of Bonneville Dam.

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References Cited

Burke, B.J., Jepson, M.A., Frick, K.E., and Peery, C.A., 2006, Detection efficiency of a passive integrated transponder (PIT) tag interrogator for adult Chinook salmon at Bonneville Dam, 2005: Report by the National Marine Fisheries Service, Seattle, Washington, and University of Idaho, Moscow, for the U.S. Army Corps of Engineers, Portland, Oregon,18 p.

Bernard, D.R., Hasbrouck, J.J., and Fleishman, S.J., 1999, Handling-induced and downstream movement of adult Chinook salmon in rivers: Fisheries Research, v. 44, p. 37–46.

Burger, C.V., Wilmot, R.L., and Wangaard, D.B., 1985, Comparison of spawning areas and times for two runs of Chinook salmon (*Oncorhynchus tshawytscha*) in the Kenai River, Alaska: Canadian Journal of Fisheries and Aquatic Sciences, v. 42, p. 693–700.

Burnham, K.P., Anderson, D.R., White, G.R., and Brownie, C., 1987, Design and analysis methods for fish survival experiments based on release-recapture: Bethesda, Maryland, American Fisheries Society Monograph 5, 437 p.

Gray, R.H., and Haynes, J.M., 1979, Spawning migration of adult Chinook salmon (*Oncorhynchus tshawytscha*) carrying external and internal radio transmitters: Journal of the Fisheries Research Board of Canada, v. 36, p. 1060–1064.

Jepsen, M.A., Keefer, M.L., Naughton, G.P., Peery, C.A., and Burke, B.J., 2010, Population composition, migration timing, and harvest of Columbia River Chinook salmon in late summer and fall: North American Journal of Fisheries Management, v. 30, p. 72–88.

Keefer, M.L., Caudill, C.C., Peery, C.A., and Boggs, C.T., 2008, Non-direct homing behaviours by adult Chinook salmon in a large, multi-stock river system: Journal of Fish Biology, v. 72, p. 27–44.

Keefer, M. L., Peery, C.A., Daigle, W.R., Jepson, M.A., Lee, S.R., Boggs, C.T., Tolotti, K.R., and Burke, B.J., 2005, Escapement, harvest, and unknown loss of radio-tagged adult salmonids in the Columbia River-Snake River hydro-system: Canadian Journal of Fisheries and Aquatic Sciences, v. 62, p. 930–949.

Lady, J.M., Westhagen, P., and Skalski, J.R., 2003, SampleSize 1.1—Sample size calculations for fish and wildlife survival studies: Manual prepared for Bonneville Power Administration by University of Washington, Seattle, 18 p.

Melnychuk, M.C., 2009, Estimation of survival and detection probabilities for multiple tagged salmon stocks with nested migration routes, using a large-scale telemetry array: Marine and Freshwater Research, v. 60, p. 1231–1243.

Perry, R.W., Skalski, J.R., Brandes, P.L., Sandstrom, P.T., Klimley, A.P., Ammann, A., and MacFarlane, B., 2010, Estimating survival and migration route probabilities of juvenile Chinook salmon in the Sacramento-San Joaquin River delta: North American Journal of Fisheries Management, v. 30, p. 142–156.

Skalski, J.R., Smith, S.G., Iwamoto, R.N., Williams, J.G., and Hoffman, A., 1998, Use of passive-integrated transponder tags to estimate survival of migrant juvenile salmonids in the Snake and Columbia rivers: Canadian Journal of Fisheries and Aquatic Sciences, v. 55, p. 1484–1493.

Van der Naald, W., Duff, C., and Brooks, R., 2004, Evaluation of fall Chinook and chum salmon spawning below Bonneville Dam—Annual Report 2003–2004: Oregon Department of Fish and Wildlife, Project Number 1999-003-01, 63 p.

Zar, J.H. 1996, Biostatistical analysis: Upper Saddle River, New Jersey, Prentice Hall, 1,121 p.

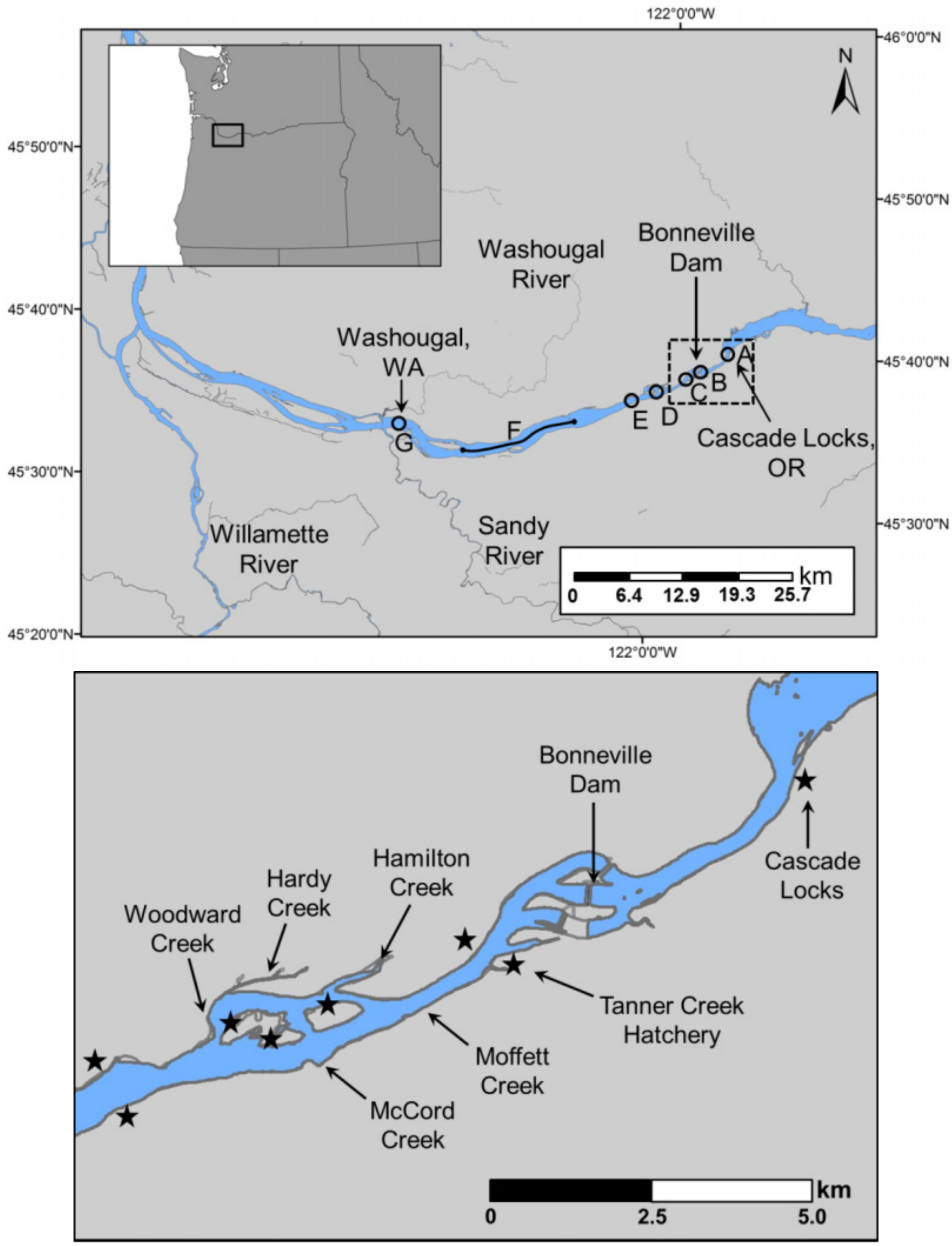

Figure 1. Maps of the study area (top) showing locations of fixed sites at Cascade Locks, Oregon: A, Bonneville Dam; B, Bonneville Dam tailrace; C, Hamilton Island/Pierce Island complex; D, Skamania, Washington; E and G, Washougal, Washington. The reach where collection, tagging, and release occurred (F) is also shown. Dashed box in top panel shows area contained in bottom map. Stars indicate locations of telemetry fixed sites.

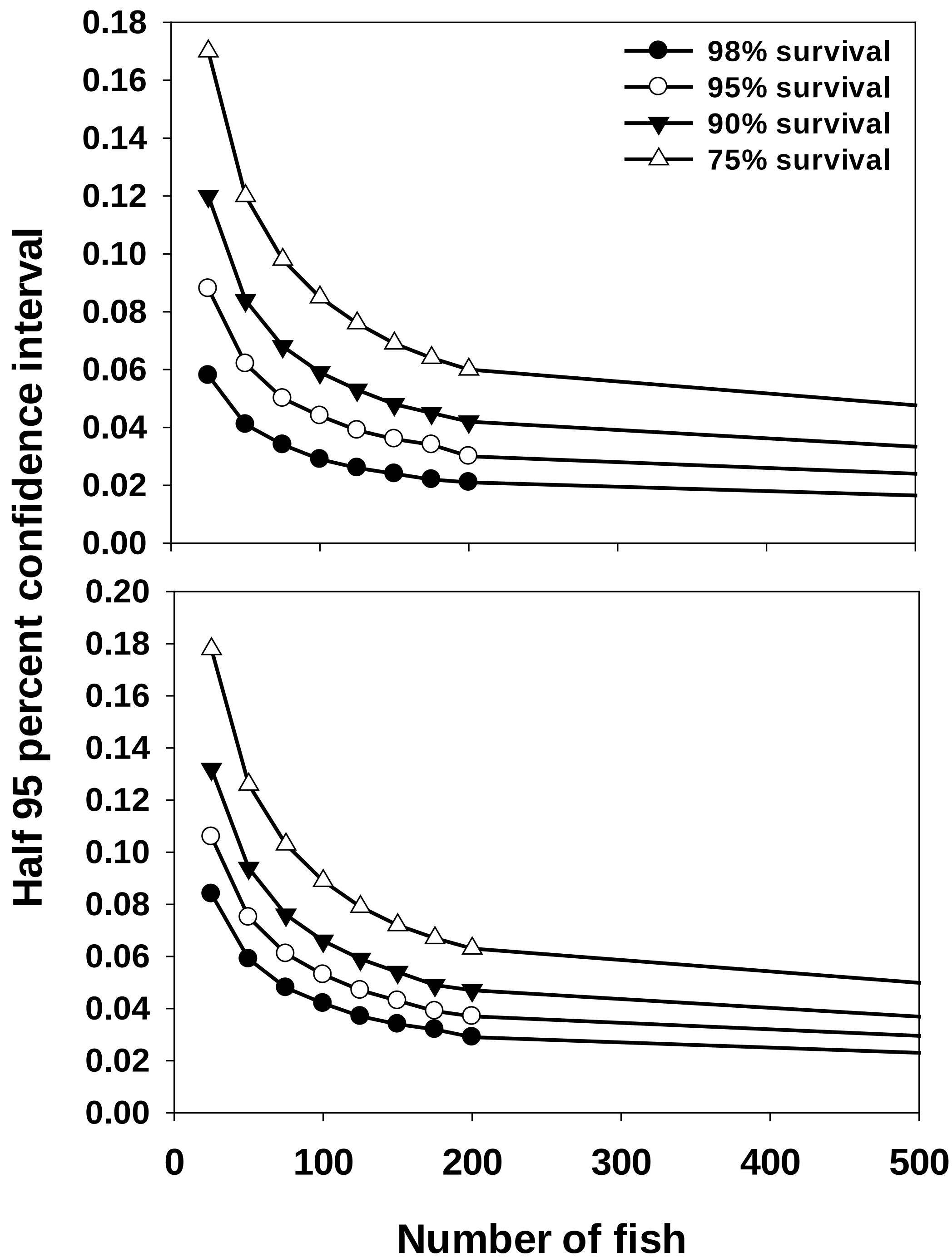

Figure 2. Graphs showing relation between the precision of survival estimates (half 95-percent confidence intervals) and sample size (number of fish). Scenarios include four survival rates (98, 95, 90, and 75 percent) and two detection probabilities (95 percent, top graph; 85 percent, bottom graph).

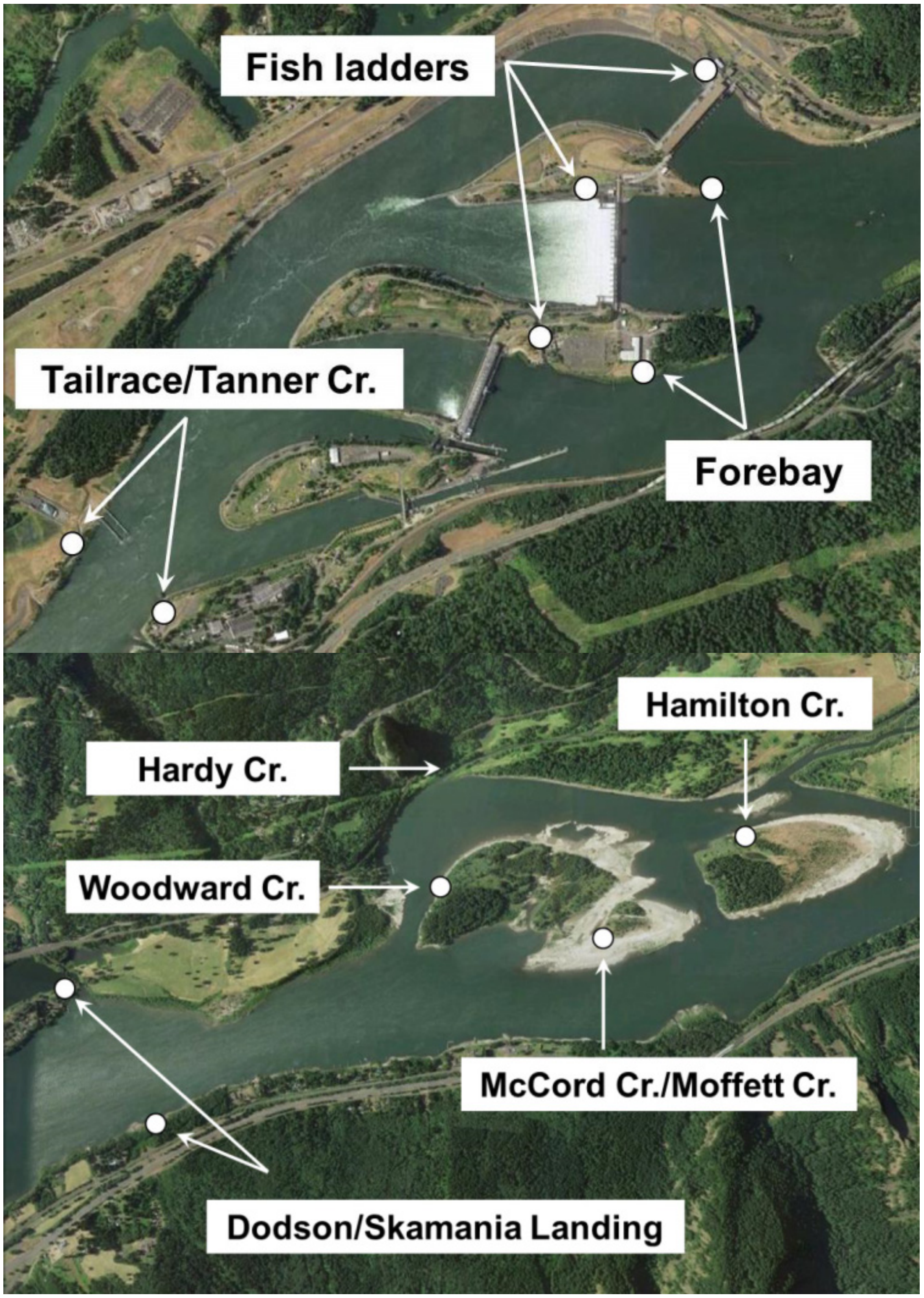

Figure 3. Aerial photographs showing locations of fixed telemetry sites on the Columbia River between Bonneville Dam and Skamania Landing, Washington, and Dodson, Oregon.

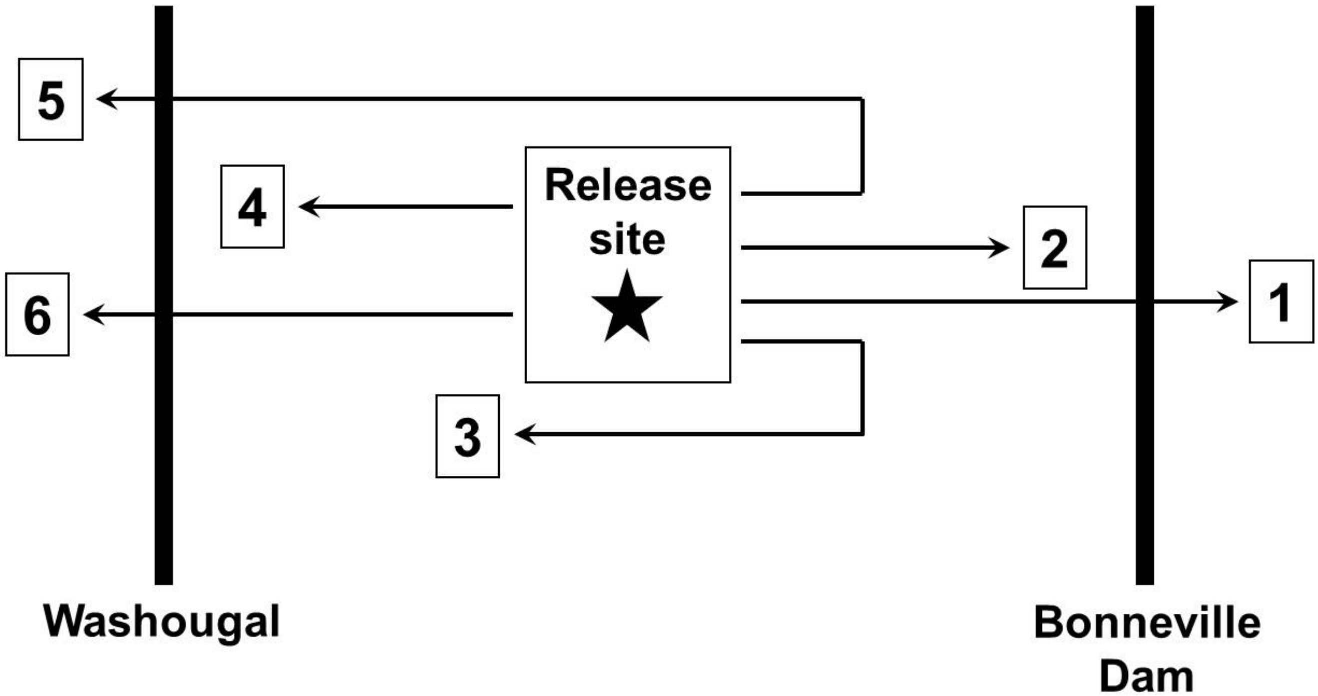

Figure 4. Schematic of six general behavior patterns that were observed during the study period. (1) Fish that moved upstream from the release site and passed Bonneville Dam; (2) fish that moved upstream from the release site but did not pass Bonneville Dam; (3) fish that moved upstream from the release site and were detected at an upstream fixed site or by mobile tracking, then returned downstream but did not pass Washougal, Washington; (4) fish that moved upstream from the release site, then returned downstream and passed Washougal, Washington; (5) fish that moved downstream from the release site, but did not pass Washougal, Washington; and (6) fish that moved downstream and passed Washougal, Washington.

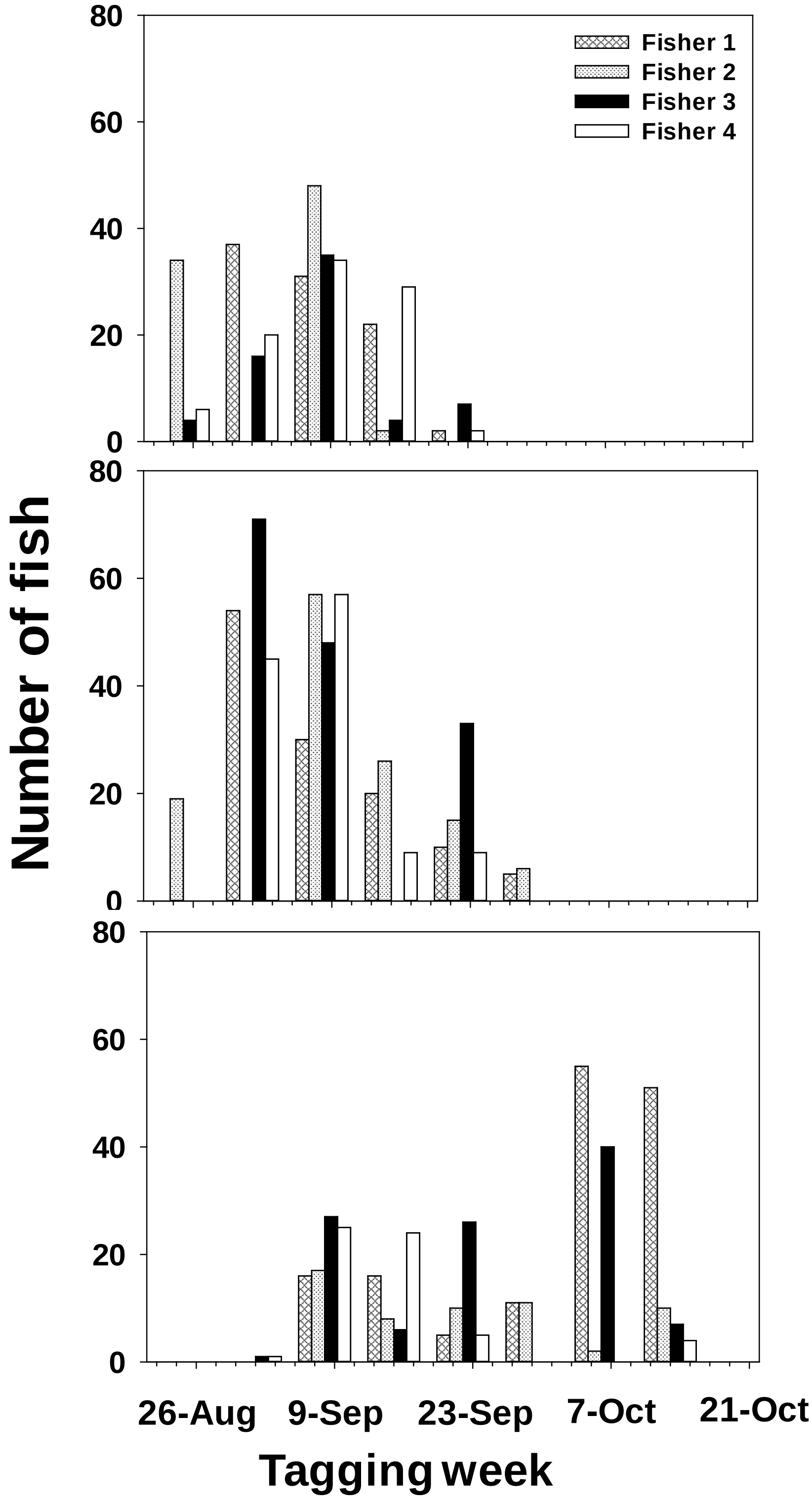

Figure 5. Graphs showing number of tule Chinook salmon (*Oncorhynchus tshawytscha*) (top), bright Chinook salmon (*Oncorhynchus tshawytscha*) (middle), and coho salmon (*Oncorhynchus kisutch*)(bottom) that were tagged and released on the lower Columbia River, Washington and Oregon, during August–October 2013.

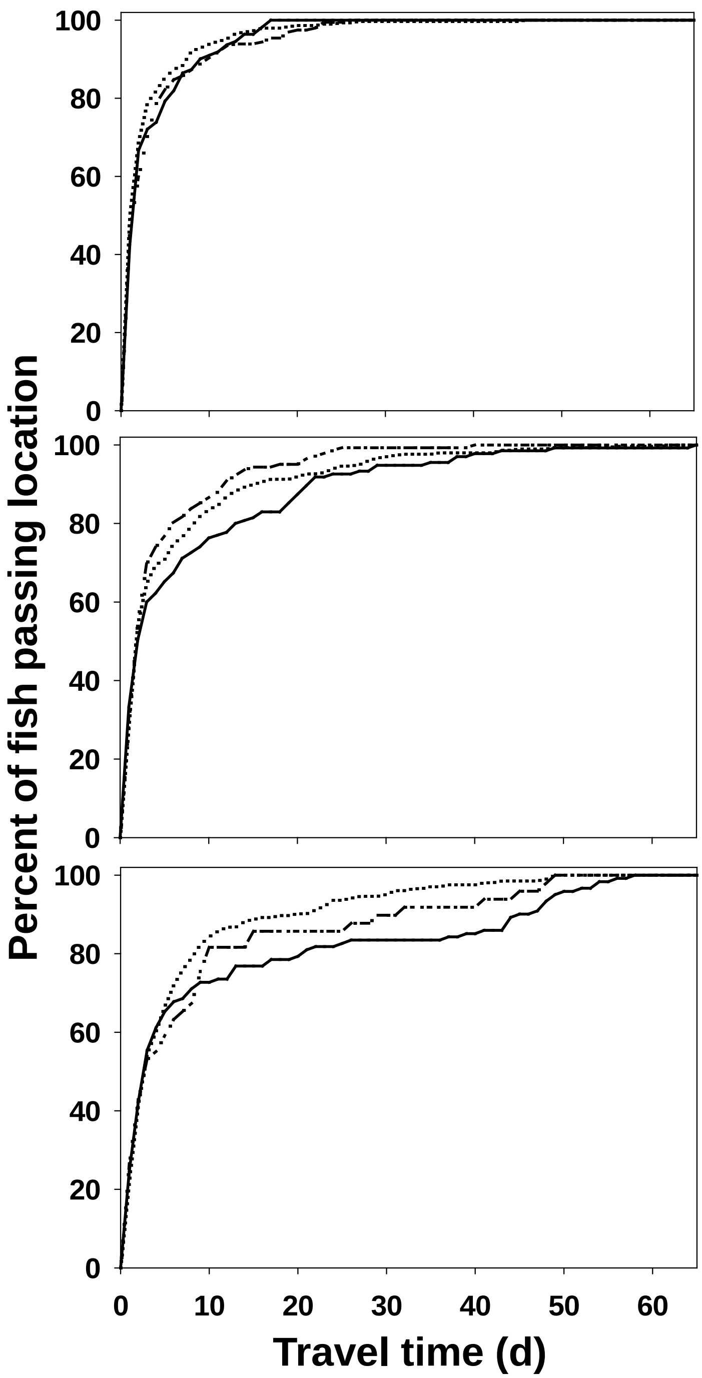

Figure 6. Graphs showing relation between travel time and the percentage of tule Chinook salmon(*Oncorhynchus tshawytscha*) (solid line), bright Chinook salmon (*Oncorhynchus tshawytscha*) (dotted line), and coho salmon (*Oncorhynchus kisutch)* (dashed line) that moved from the release site to Bonneville Dam (top), from the release site to Cascade Locks, Oregon (middle), and from the release site to Washougal, Washington (bottom).

Table 1. Cumulative survival estimates for steelhead (*Oncorhynchus mykiss*), tule Chinook salmon (*Oncorhynchus tshawytscha*), bright Chinook salmon (*Oncorhynchus tshawytscha*), and coho salmon (*Oncorhynchus kisutch)* that were captured using a beach or purse seine in the lower Columbia River, Washington and Oregon, 2011–12.

[Washington Department of Fish and Wildlife, unpub. data, 2014. Numbers in parentheses are 95-percent confidence intervals]

Species	Beach seine		Purse seine	
	2011	2012	2011	2012
Steelhead	0.92 (0.82–1.00)	0.89 (0.82–0.96)	0.98 (0.93–1.00)	0.98 (0.93–1.00)
Tule Chinook salmon	0.69 (0.43–0.97)	0.90 (0.73–1.00)	0.64 (0.40–0.90)	0.70 (0.53–0.89)
Bright Chinook salmon	0.56 (0.50–0.63)	0.75 (0.71–0.79)	0.78 (0.72–0.85)	0.74 (0.70–0.79)
Coho salmon	0.50 (0.34–0.69)	0.62 (0.46–0.81)	0.77 (0.62–0.94)	0.59 (0.45–0.78)

Table 2. Sample size goal and actual number of fish tagged (stratified by species, gear type, and fisher)during a radiotelemetry evaluation in the lower Columbia River, Washington and Oregon, 2013.

Species	Beach seine		Purse seine	
	Fisher 1	Fisher 2	Fisher 3	Fisher 4
Tule Chinook salmon	100/92	100/84	100/66	100/91
Bright Chinook salmon	100/120	100/118	100/150	100/118
Coho salmon	100/153	100/57	100/106	100/59

Table 3. Number (*n*), sex, and mean fork length for groups of tule Chinook salmon (*Oncorhynchus tshawytscha*) captured by commercial beach and purse seine fishers, radio-tagged and released in the lower Columbia River, Washington and Oregon, during 2013.

[Numbers in parentheses are one standard deviation from the mean]

Gear type	Fisher	*n*	Sex	Mean fork length (mm)
Beach seine	1	33	Female	768.0 (93.1)
	1	59	Male	781.6 (104.9)
	Sub-total=	92	Female and male	776.7 (100.5)
	2	22	Female	820.2 (89.8)
	2	62	Male	671.8 (51.0)
	Sub-total=	84	Female and male	802.8 (113.3)
	Total=	176	Female and male	789.2 (107.3)
Purse seine	3	27	Female	781.9 (78.2)
	3	39	Male	783.3 (115.1)
	Sub-total=	66	Female and male	782.7 (100.9)
	4	42	Female	793.5 (88.9)
	4	49	Male	774.1 (92.7)
	Sub-total=	91	Female and male	783.0 (90.9)
	Total=	157	Female and male	782.9 (94.9)

Table 4. Number (n), sex, and mean fork length of bright Chinook salmon (*Oncorhynchus tshawytscha*) captured by commercial fishers, radio-tagged and released in the lower Columbia River, Washington and Oregon, during 2013.

[Numbers in parentheses are one standard deviation from the mean. **Symbol:** =, equals]

Gear type	Fisher	***n***	Sex	Mean fork length (mm)
Beach seine	1	47	Female	795.7 (70.4)
	1	72	Male	755.8 (92.1)
	Sub-total=	119	Female and male	771.6 (86.2)
	2	53	Female	773.9 (87.9)
	2	64	Male	771.9 (88.9)
	Sub-total=	117	Female and male	772.9 (88.1)
	Total=	[1]236	Female and male	772.2 (86.9)
Purse seine	3	62	Female	754.3 (69.6)
	3	88	Male	717.3 (66.3)
	Sub-total=	150	Female and male	732.6 (69.9)
	4	60	Female	732.0 (77.6)
	4	58	Male	712.1 (86.7)
	Sub-total=	118	Female and male	722.2 (82.4)
	Total=	268	Female and male	727.9 (75.7)

[1]Sex and fork length data were not available for two bright Chinook salmon captured by fisher 2, so those data were not included in this table. A total of 238 bright Chinook salmon were tagged and released by fisher 2 during the study.

Table 5. Number (n), sex, and mean fork length of coho salmon (*Oncorhynchus kisutch*) captured by commercial fishers, radio-tagged and released in the lower Columbia River, Washington and Oregon, during 2013.

[Numbers in parentheses are one standard deviation from the mean]

Gear type	Fisher	***n***	Sex	Mean fork length (mm)
Beach seine	1	70	Female	707.4 (45.4)
	1	83	Male	689.8 (72.9)
	Sub-total=	153	Female and male	697.9 (62.3)
	2	17	Female	688.2 (55.5)
	2	40	Male	671.8 (51.0)
	Sub-total=	57	Female and male	676.7 (52.5)
	Total=	210	Female and male	692.1 (60.4)
Purse seine	3	45	Female	670.9 (42.6)
	3	61	Male	643.6 (58.1)
	Sub-total=	106	Female and male	655.2 (53.6)
	4	29	Female	671.4 (38.0)
	4	30	Male	667.0 (51.6)
	Sub-total=	59	Female and male	669.2 (45.1)
	Total=	165	Female and male	660.2 (51.0)

Table 6. Summary of six general behavior pattern groups and the number and percentage of radio-tagged tule Chinook salmon (*Oncorhynchus tshawytscha*), bright Chinook salmon (*Oncorhynchus tshawytscha*), and coho salmon (*Oncorhynchus kisutch*) observed in each behavior group.

[Bold text identifies the groups of fish that moved upstream and out of the study area, remained in the study area, or moved downstream and out of the study area]

Description of behavior	Tule Chinook salmon	Bright Chinook salmon	Coho salmon
Moved upstream of the release site and passed Bonneville Dam	147 (44 percent)	313 (62 percent)	197 (53 percent)
Moved upstream of the release site but did not pass Bonneville Dam	46 (14 percent)	20 (3 percent)	74 (20 percent)
Moved upstream of the release site, then returned downstream but did not pass Washougal	44 (13 percent)	49 (10 percent)	12 (3 percent)
Moved downstream of the release site but did not pass Washougal	7 (2 percent)	8 (2 percent)	11 (3 percent)
Total number of fish that did not leave the study area	97 (29 percent)	77 (15 percent)	97 (26 percent)
Moved upstream of the release site, then returned downstream and passed Washougal	26 (8 percent)	45 (9 percent)	9 (2 percent)
Moved downstream and passed Washougal	62 (18 percent)	62 (12 percent)	42 (12 percent)
Total number of fish that moved downstream out of the study area	88 (26 percent)	107 (21 percent)	51 (14 percent)
Not detected	1 (<1 percent)	9 (2 percent)	30 (7 percent)

Table 7. Summary of travel times (hours) for tagged fish from release to first detection at Bonneville Dam; last detection at Cascade Locks, Oregon; and last detection at Washougal, Washington.

[Numbers in parentheses are 1 standard deviation from the mean]

Species	Release to Bonneville Dam	Release to Cascade Locks	Release to Washougal
Tule Chinook salmon	31.9 (129.7)	70.3 (269.0)	56.9 (368.2)
Bright Chinook salmon	44.9 (106.0)	66.5 (221.7)	58.0 (203.4)
Coho salmon	47.0 (115.2)	58.2 (145.0)	64.0 (284.6)

Table 8. Comparison of general behavior patterns between groups of fish collected and tagged downstream of Bonneville Dam and groups of fish detected in the fish ladder on the Washington shore at Bonneville Dam during 2013.

		Destination		
Species	Group of fish	Upstream of Bonneville Dam	Bonneville Dam to Washougal	Downstream of Washougal
Tule Chinook salmon	All fish	44 percent	29 percent	26 percent
	Fish detected in the Washington fish ladder	87 percent	12 percent	1 percent
Bright Chinook salmon	All fish	62 percent	15 percent	21 percent
	Fish detected in the Washington fish ladder	89 percent	4 percent	6 percent
Coho salmon	All fish	53 percent	26 percent	14 percent
	Fish detected in the Washington fish ladder	79 percent	19 percent	2 percent

Table 9. Last known location (number and percentage) of radio-tagged tule Chinook salmon (*Oncorhynchus tshawytscha*) after release in the lower Columbia River, Washington and Oregon, during 2013.

[Locations are ordered spatially from upstream to downstream]

Tributary	Mainstem Columbia River	Hatchery
	Wells Dam: 1 (<1 percent)	
	Rocky Reach Dam: 2 (<1 percent)	
	Priest Rapids Dam: 3 (<1 percent)	Priest Rapids Hatchery: 3 (<1 percent)
	Hanford Reach: 1 (<1 percent)	Ringold Hatchery: 1 (<1 percent)
Yakima River: 2 (<1 percent)		
Snake River: 3 (1 percent)		
	McNary Dam: 10 (3 percent)	
Deschutes River: 4 (1 percent)	Zone 6: 11 (3 percent)	
	The Dalles Dam: 1 (<1 percent)	
Klickitat River: 3 (<1 percent)		
		Spring Creek Hatchery: 17 (5 percent)
Little White Salmon River: 4 (1 percent)		
Wind River: 1 (<1 percent)		
Herman Creek: 2 (<1 percent)		
	Cascade Locks: 51 (15 percent)	
	Bonneville Dam Forebay: 15 (4 percent)	
	Bonneville Dam: 4 (1 percent)	
Tanner Creek: 5 (1 percent)		Bonneville Hatchery: 30 (9 percent)
Oneonta Creek: 1 (<1 percent)		
Multnomah Creek: 3 (<1 percent)	Zone 5: 53 (16 percent)	
	Number of fish released = 333	
	Not detected = 1 (<1 percent)	
	Zone 4: 56 (17 percent)	
Washougal River: 9 (3 percent)		
Sandy River: 10 (3 percent)		
Willamette River: 2 (<1 percent)		
Lewis River: 5 (1 percent)	Zone 3: 6 (2 percent)	
Cowlitz River: 7 (2 percent)	Zone 2: 6 (2 percent)	

Table 10. Last known location (number and percentage) of radio-tagged bright Chinook salmon (*Oncorhynchus tshawytscha*) after release into the lower Columbia River, Washington and Oregon, during 2013.

[Locations are ordered spatially from upstream to downstream]

Tributary	Mainstem Columbia River	Hatchery
Methow River: 1 (<1 percent)		
	Wells Dam: 6 (1 percent)	
	Rocky Reach Dam: 5 (1 percent)	
	Rock Island Dam: 3 (<1 percent)	
	Priest Rapids Dam: 16 (3 percent)	Priest Rapids Hatchery: 34 (7 percent)
	Hanford Reach: 3 (<1 percent)	Ringold Hatchery: 7 (1 percent)
Snake River: 10 (2 percent)		
	McNary Dam: 50 (10 percent)	
Umatilla River: 3 (<1 percent)		
Deschutes River: 4 (<1 percent)	Zone 6: 12 (2 percent)	
	The Dalles Dam: 22 (4 percent)	
Klickitat River: 4 (<1 percent)		
White Salmon River: 1 (<1 percent)		
		Spring Creek Hatchery: 1 (<1 percent)
Little White Salmon River: 14 (3 percent)		
Herman Creek: 1 (<1 percent)		
	Cascade Locks: 86 (17 percent)	
	Bonneville Dam Forebay: 9 (2 percent)	
	Bonneville Dam: 3 (<1 percent)	
		Bonneville Hatchery: 18 (4 percent)
Moffett Creek: 2 (<1 percent)	Zone 5: 56 (11 percent)	
	Number of fish released = 506 Not detected = 9 (2 percent)	
	Zone 4: 106 (21 percent)	
Washougal River: 4 (<1 percent)		
Sandy River: 3 (<1 percent)		
Willamette River: 3 (<1 percent)		
Lewis River: 1 (<1 percent)	Zone 3: 5 (1 percent)	
Cowlitz River: 3 (<1 percent)	Zone 2: 1 (<1 percent)	

Table 11. Last known location (number and percentage) of radio-tagged coho salmon (*Oncorhynchus kisutch*) after release in the lower Columbia River, Washington and Oregon, during 2013.

[Locations are ordered spatially from upstream to downstream]

Tributary	Mainstem Columbia River	Hatchery
Wenatchee River: 1 (<1 percent)		
Yakima River: 1 (<1 percent)		
Snake River: 1 (<1 percent)		Dworshak Hatchery: 1 (<1 percent)
	McNary Dam: 5 (1 percent)	
Umatilla River: 2 (<1 percent)		
Deschutes River: 2 (1 percent)	Zone 6: 8 (2 percent)	
	The Dalles Dam: 6 (2 percent)	
Klickitat River: 14 (3 percent)		
Hood River: 1 (<1 percent)		
Little White Salmon River: 1 (<1 percent)		
Herman Creek: 1 (<1 percent)		
	Cascade Locks: 105 (28 percent)	
	Bonneville Dam Forebay: 33 (9 percent)	
	Bonneville Dam: 40 (10 percent)	
Tanner Creek: 4 (1 percent)		Bonneville Hatchery: 29 (8 percent)
Hamilton Creek: 2 (<1 percent)		
Moffett Creek: 1 (<1 percent)		
Oneonta Creek: 3 (1 percent)		
Multnomah Creek: 1 (<1 percent)	Zone 5: 29 (8 percent)	
	Number of fish released = 375 Not detected = 30 (8 percent)	
	Zone 4: 38 (10 percent)	
Washougal River: 3 (<1 percent)		
Sandy River: 5 (1 percent)		
Clackamas River: 1 (1 percent)		
Lewis River: 6 (2 percent)	Zone 3: 1 (<1 percent)	

Table 12. Summary of fate groups and percentage of fish that apparently survived capture, or may not have survived capture during 2013.

[All fish that passed Bonneville Dam were assigned to that fate group so all remaining fates are all comprised of fish that did not pass the dam]

Description	Beach seine	Purse seine
Tule Chinook salmon		
Arrived at, or passed Bonneville Dam	87 (49 percent)	71 (45 percent)
Harvested in fishery	13 (7 percent)	8 (5 percent)
Returned to hatchery	17 (10 percent)	13 (8 percent)
Entered a tributary	22 (13 percent)	17 (11 percent)
Observed moving >4 days after release	25 (14 percent)	30 (19 percent)
Total fish that survived capture	164 (93 percent)	139 (89 percent)
Not observed moving >4 days after release	11 (6 percent)	18 (11 percent)
Confirmed mortality	0	0
Not detected	1 (1 percent)	0
Total fish that may not have survived capture	12 (7 percent)	18 (11 percent)
Bright Chinook salmon		
Arrived at, or passed Bonneville Dam	142 (60 percent)	188 (70 percent)
Harvested in fishery	8 (3 percent)	8 (3 percent)
Returned to hatchery	8 (3 percent)	6 (2 percent)
Entered a tributary	7 (3 percent)	6 (2 percent)
Observed moving >4 days after release	41 (17 percent)	32 (12 percent)
Total fish that survived capture	206 (87 percent)	240 (90 percent)
Not observed moving >4 days after release	27 (11 percent)	23 (9 percent)
Confirmed mortality	1 (<1 percent)	0
Not detected	4 (2 percent)	5 (2 percent)
Total fish that may not have survived capture	32 (13 percent)	28 (10 percent)
Coho salmon		
Arrived at, or passed Bonneville Dam	130 (62 percent)	96 (58 percent)
Harvested in fishery	6 (2 percent)	2 (1 percent)
Returned to hatchery	18 (9 percent)	12 (7 percent)
Entered a tributary	16 (8 percent)	9 (5 percent)
Observed moving >4 days after release	8 (4 percent)	13 (8 percent)
Total fish that survived capture	177 (84 percent)	132 (80 percent)
Not observed moving >4 days after release	16 (8 percent)	19 (12 percent)
Confirmed mortality	0	0
Not detected	16 (8 percent)	14 (8 percent)
Total fish that may not have survived capture	33 (16 percent)	33 (20 percent)

Table 13. Number and percentage of tule Chinook salmon (*Oncorhynchus tshawytscha*), bright Chinook salmon (*Oncorhynchus tshawytscha*), and coho salmon (*Oncorhynchus kisutch*) observed in fate groups used to identify potential mortality related to capture by beach and purse seines during 2013.

[Bold typeface indicates groups that were statistically different from each other]

Description	Beach seine		Purse seine	
	Fisher 1	Fisher 2	Fisher 3	Fisher 4
Tule Chinook salmon				
Probable survivors	85 (92 percent)	79 (94 percent)	59 (89 percent)	80 (88 percent)
Potential mortality	7 (8 percent)	5 (6 percent)	7 (11 percent)	11 (12 percent)
Fisher's exact test result	*p*=0.769		*p*=0.806	
Bright Chinook salmon				
Probable survivors	105 (88 percent)	101 (85 percent)	131 (87 percent)	109 (92 percent)
Potential mortality	14 (12 percent)	18 (15 percent)	19 (13 percent)	9 (8 percent)
Fisher's exact test result	*p*=0.569		*p*=0.228	
Coho salmon				
Probable survivors	135 (88 percent)	42 (74 percent)	91 (86 percent)	41 (70 percent)
Unknown fate	18 (12 percent)	15 (26 percent)	15 (14 percent)	18 (30 percent)
Fisher's exact test result	***p*=0.018**		***p*=0.015**	

Appendix A. Number of Tule Chinook Salmon (*Oncorhynchus tshawytscha*), Bright Chinook Salmon (*Oncorhynchus tshawytscha*), and Coho Salmon (*Oncorhynchus kisutch*) that Passed Bonneville Dam, Remained Between Bonneville Dam and Washougal, Washington or Moved Downstream of Washougal, Washington During 2013

[Data are shown for all fish and for marked and unmarked fish separately]

Description	Upstream of Bonneville Dam	Between Bonneville Dam and Washougal	Downstream of Washougal
All tule Chinook salmon	147	97	88
Unmarked tule Chinook salmon	55	38	43
Marked tule Chinook salmon	92	59	45
All bright Chinook salmon	313	77	107
Unmarked bright Chinook salmon	196	49	69
Marked bright Chinook salmon	117	28	38
All coho salmon	197	97	51
Unmarked coho salmon	46	34	30
Marked coho salmon	151	63	21

Appendix B. Summary of Fate Groups for Tule Chinook Salmon (*Oncorhynchus tshawytscha*) and the Percentage of Fish that Apparently Survived Capture, or May Not Have Survived Capture During 2013

[Fates are based on inferences from telemetry detection histories. Table contains the same information that is shown in table 12 of this report but also shows the number of fish that had fates assigned prior to or after the 4-day post-tagging period that was used for assessing probable survival]

	Beach seine			Purse seine		
		Elapsed time from release to fate			Elapsed time from release to fate	
Description	Overall	< 4 d	> 4 d	Overall	< 4 d	>4 d
Arrived at, or passed Bonneville Dam	87 (49 percent)	15	72	71 (45 percent)	24	47
Harvested in fishery	13 (7 percent)	3	10	8 (5 percent)	3	5
Returned to hatchery	17 (10 percent)	3	14	13 (8 percent)	1	12
Entered a tributary	22 (13 percent)	1	21	17 (11 percent)	1	16
Observed moving >4 d after release	25 (14 percent)	0	25	30 (19 percent)	0	30
Total fish that survived capture	**164 (93 percent)**	**22**	**142**	**139 (89 percent)**	**29**	**110**
Not observed moving >4 d after release	11 (6 percent)	11	0	18 (11 percent)	18	0
Confirmed mortality	0	0	0	0	0	0
Not detected	1 (1 percent)	1	0	0	0	0
Total fish that may not have survived capture	**12 (7 percent)**	**12**	**0**	**18 (11 percent)**	**18**	**0**

Appendix C. Summary of Fate Groups for Bright Chinook Salmon (*Oncorhynchus tshawytscha*) and the Percentage of Fish that Apparently Survived Capture, or May Not Have Survived Capture During 2013

[Fates are based on inferences from telemetry detection histories. Table contains the same information that is shown in table 12 of this report but also shows the number of fish that had fates assigned prior to or after the 4-day post-tagging period that was used for assessing probable survival]

	Beach seine			Purse seine		
		Elapsed time from release to fate			Elapsed time from release to fate	
Description	Overall	< 4 d	> 4 d	Overall	< 4 d	> 4 d
Arrived at, or passed Bonneville Dam	142 (60 percent)	32	110	188 (70 percent)	40	148
Harvested in fishery	8 (3 percent)	2	6	8 (3 percent)	1	7
Returned to hatchery	8 (3 percent)	0	8	6 (2 percent)	0	6
Entered a tributary	7 (3 percent)	1	6	6 (2 percent)	0	6
Observed moving >4 d after release	41 (17 percent)	0	41	32 (12 percent)	0	32
Total fish that survived capture	**206 (87 percent)**	**35**	**171**	**240 (90 percent)**	**41**	**199**
Not observed moving >4 d after release	27 (11 percent)	27	0	23 (9 percent)	23	0
Confirmed mortality	1 (<1 percent)	1	0	0	0	0
Not detected	4 (2 percent)	4	0	5 (2 percent)	5	0
Total fish that may not have survived capture	**32 (13 percent)**	**32**	**0**	**28 (10 percent)**	**28**	**0**

Appendix D. Summary of Fate Groups for Coho Salmon (*Oncorhynchus kisutch)* and the Percentage of Fish that Apparently Survived Capture, or May Not Have Survived Capture During 2013

[Fates are based on inferences from telemetry detection histories. Table contains the same information that is shown in table 12 of this report, but also shows the number of fish that had fates assigned prior to or after the 4-day post-tagging period that was used for assessing probable survival. **Abbreviation and Symbols:** d, days; >, greater than; <, less than]

Description	Beach seine			Purse seine		
	Overall	Elapsed time from release to fate		Overall	Elapsed time from release to fate	
		< 4 d	> 4 d		< 4 d	> 4 d
Arrived at, or passed Bonneville Dam	130 (62 percent)	78	52	96 (58 percent)	49	47
Harvested in fishery	6 (2 percent)	3	2	2 (1 percent)	2	0
Returned to hatchery	18 (9 percent)	2	16	12 (7 percent)	2	10
Entered a tributary	16 (8 percent)	4	12	9 (5 percent)	0	9
Observed moving >4 d after release	8 (4 percent)	0	8	13 (8 percent)	0	13
Total fish that survived capture	**177 (84 percent)**	**87**	**90**	**132 (80 percent)**	**53**	**79**
Not observed moving >4 d after release	16 (8 percent)	17	0	19 (12 percent)	19	0
Confirmed mortality	0	0	0	0	0	0
Not detected	16 (8 percent)	16	0	14 (8 percent)	14	0
Total fish that may not have survived capture	**33 (16 percent)**	**33**	**0**	**33 (20 percent)**	**33**	**0**

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