**STATE OF WASHINGTON** **April 2014**

# Lower Columbia River Alternative Commercial Fishing Gear Mortality Study: 2011 and 2012

by Josua Holowatz, Mara Zimmerman, Ann Stephenson, Dan Rawding, Kristen Ryding, and Eric Kinne

*Washington Department of FISH AND WILDLIFE*
*Fish Program*
*Science Division*

FPT 14-03

# Lower Columbia River Alternative Commercial Fishing Gear Mortality Study: 2011 and 2012


**Washington Department of Fish and Wildlife**

Josua Holowatz
Region 5 Fish Management
2108 Grand Boulevard, Vancouver, Washington, 98661

Mara Zimmerman
Fish Science Division
2108 Grand Boulevard, Vancouver, Washington, 98661

Ann Stephenson
Region 5 Fish Management
2108 Grand Boulevard, Vancouver, Washington, 98661

Dan Rawding
Fish Science Division
2108 Grand Boulevard, Vancouver, Washington, 98661

Kristen Ryding
Fish Science Division
600 Capitol Way North, Olympia, Washington 98501

Eric Kinne
Region 5 Fish Management
2108 Grand Boulevard, Vancouver, Washington, 98661



**April 2014**

## Acknowledgements

The authors would like to express their appreciation to the following individuals: Washington Department of Fish and Wildlife (WDFW) data management staff Michelle Groesbeck, Bob Woodard and Ben Warren for PIT tag coordination and Steven Vanderploeg for creating the maps in the document; WDFW alternative gear field staff who worked tirelessly to collect excellent data; the four contracted commercial fishers who operated the treatment gear; Ben Truscott and the WDFW Supplementation Research Team for design and installation of the Bonneville Hatchery PIT tag array; Greg Davis with the Oregon Department of Fish and Wildlife (ODFW) and other Bonneville Hatchery staff for access to the Bonneville hatchery ladder and installation of the Passive Integrated Transponder (PIT) tag array; Casey L. Risley with the U.S. Fish and Wildlife Service (USFWS) and the Little White Salmon National Fish Hatchery staff that assisted with collection of the 2012 supplemental tule fall Chinook control group. We would also like to extend our appreciation to the following agencies for their support of this project: Columbia River Inter-Tribal Fisheries Commission, U.S. Army Corps of Engineers, Oregon Department of Fish and Wildlife, University of Idaho, NOAA Fisheries, the Fish Passage Operations and Maintenance (FPOM) Team and the *U.S. v. Oregon* Technical Advisory Committee (TAC). Administrative support from former WDFW Region 5 Fish Program manager Pat Frazier is also greatly appreciated. Finally, we would like to thank Congressman Norm Dicks for securing Mitchell Act and Pacific Coast Salmon Recovery Funds for this research.

**Table of Contents**

## List of Tables

## List of Figures

## List of Appendices

## Executive Summary

This study was designed to estimate the survival associated with the release of fish from commercial fishing gear fished in the Columbia River below Bonneville Dam in the months of August, September, and October. This report includes results from the first two years, 2011 and 2012, of a three year study.

Steelhead, coho salmon, and fall Chinook salmon, both tules and brights, were the focal species for this study. Survival was estimated using the Ricker two-release method which estimates survival of each treatment group based on recapture probabilities of treatment fish relative to control fish. Treatment fish were captured in beach and purse seines, tagged with passive integrated transponders (PIT) and released between river miles 129 and 144. Control fish were captured at the Bonneville Adult Fish Facility (AFF), PIT tagged, and released into the Columbia River near Skamania Landing (river mile 139). Survival was estimated as a cumulative measure and broken into short-term and long-term. Cumulative survival was from release to the final detection point, short-term survival was from the release point to Bonneville Dam, and long-term survival was from Bonneville Dam to a final detection point. Re-detections were based on array observations, fish trap or spawning ground recaptures, and fishery mortalities as reported in the PIT Tag Integration System (PTAGIS) database.

For steelhead, cumulative survival for these two years ranged from 89% to 92% for the beach seine and 97% to 98% for the purse seine releases. Long-term survival ranged from 92% to 94% for the beach seine and 98% to 99% for the purse seine releases.

For bright fall Chinook salmon, cumulative survival ranged from 56% to 75% for the beach seine and 74% to 78% for the purse seine releases. Long-term survival ranged from 82% to 88% for the beach seine and 88% to 94% for the purse seine releases.

For tule fall Chinook salmon, cumulative survival ranged from 69% to 90% for the beach seine and 64% to 70% for the purse seine releases. Long-term survival ranged from 90% to 92% for the beach seine and 67% to 76% for the purse seine releases.

For coho salmon, cumulative survival ranged from 50% to 62% for the beach seine and 59% to 77% for the purse seine releases. Long-term survival ranged from 86% to 93% for the beach seine and 77% to 91% for the purse seine releases.

The survival estimates produced from this study for these two years may underestimate the survival following release from commercial fishing gear if fish in the treatment groups were a mix of fish destined for spawning localities above Bonneville Dam and those intending to spawn in the lower river below Bonneville Dam. This explanation warrants further study. Pending results from the third year of the study in 2013, the estimates between Bonneville Dam and the final detection point may be considered a maximum survival estimate (or minimum mortality) associated with the commercial fishing gear handled in 2011 and 2012.

## Introduction

The Columbia River has hosted a rich tradition of subsistence fishing going back thousands of years and commercial fishing going back hundreds of years. Native American societies harvested salmon from the Columbia using nets and seines constructed of plant materials. In 1852, P.J. McGowen bought salmon from the Chinook Indians who used seines (Smith 1979). Ample opportunity and abundant salmon populations enabled a variety of techniques to be developed. Fixed traps and pound nets were used in Baker Bay and other locations in the estuary and by 1879 there were 156 in operation. Horse and beach seines were set off of Desdemona Sands and Sand Island in the lower Columbia River. Purse seines and gillnets were employed in open water. In 1892 there were 38 seines and 1,314 gillnets in operation all the way upstream to Celilo Falls, approximately 323 kilometers or 201 miles from the mouth (Donaldson and Cramer 1971). At the peak of their use, seines harvested only about 15% of the catch (Smith 1979). Contrary to popular belief, fish wheels were not used in the lower Columbia River, defined as the area from the mouth of the Columbia River, river mile (rm) and river kilometer (rkm) zero, to the present site of Bonneville Dam at rm 145/rkm 233. These mechanized fish catchers were relegated further upstream to the fast, narrow reaches, which were not tidally influenced, of the Cascades and The Dalles (Craig and Hacker, 175). Fish wheels caught between five and seven percent of the total commercial harvest of Columbia River salmon (Donaldson and Cramer 1971). There were 76 fish wheels located between The Dalles and the falls of the Cascades in the year 1900.

The numbers and composition of the Columbia River commercial catch has changed over the past century as has the methods used to record landings. The commercial catch of Chinook salmon from the Columbia River peaked in 1883 with over 47,799,000 pounds of fish caught in one year (Beiningen 1976, Lichatowich 1995). The catch declined and averaged around 25 million pounds annually over the next 30 years. From the early 1920s to the present era annual catch has continued to decline. Between 1892 and 1920, the Columbia River commercial harvest underwent some qualitative changes in catch composition. In 1892, 95% of the salmon harvest consisted of spring and summer run Chinook salmon. By 1912, the spring and summer run fish had dropped to 75% of the catch as more fall Chinook salmon were harvested. By 1920, fall Chinook salmon made up half of the commercial landings, the fish that were brought to shore. While landings during this period appear to remain stable, the underlying statistics show a major shift in the harvest of fish from different life history types, from spring and summer Chinook salmon to fall Chinook salmon (Lichatowich and Mobrand 1995). Some of the inconsistency in commercial landings' data during the late $19^{th}$ and early $20^{th}$ century may have been due to inconsistent methods of fish ticket and landing reporting. For example, landings from 1892 to 1922 were estimated from the cases of canned salmon while the numbers from 1923 to 1940 were counted from actual landings (Mullen 1981).

The state of Oregon banned purse seines in 1922. Horse and hand seines were banned in Washington in 1934 and later in Oregon in 1948 but under court injunction. Beach seines were operated in Oregon until 1950.

Gillnets have dominated commercial fisheries in recent years. They are relatively inexpensive, flexible, and efficient and can be operated by one person. Gillnets entangle fish by the gills, making it generally a lethal method of capture for the target species. Gillnets are managed by mesh size to target specific species. Large mesh gillnets can be deployed to harvest large species such as sturgeon, while reducing the handling of smaller species. Small mesh "tangle" nets, used in conjunction with minimal soak times, short multi-strand nets and recovery boxes form the basis of the non-tribal mark-selective spring Chinook salmon fishery on the lower Columbia River today. For decades, commercial fisheries have been managed selectively by modifying the time, area and mesh size with respect to differences in physical morphology or migration behavior of different species or stocks. Besides the introduction of "tangle" nets there have been few modifications to gillnets to improve the post-release survival rates of fish caught in these nets.

During the 1990s and early 2000s, nine Evolutionary Significant Units (ESUs) of salmonids in the Snake and Columbia rivers were listed and federally protected under the Endangered Species Act (ESA). Included in these listings are stocks of Chinook salmon *Oncorhynchus tshawytsch*, coho salmon *Oncorhynchus kisutch* and steelhead *Oncorhynchus mykiss*, some of which are found during the fall commercial fishing periods. The need to minimize harvest - impacts on these ESA-listed stocks and the initiation of Hatchery Reform measures by the state of Washington, (WDFW 2009) have increased the need for selective harvest of ESA-listed salmonids by all user groups in the lower Columbia River. A major component of hatchery reform is the reduction of the proportion of hatchery origin spawners (pHOS) on the spawning grounds. Mark-selective fishing contributes to this goal by removing hatchery fish before they can reach the spawning ground while releasing wild fish to return to the spawning grounds. The external marking of hatchery fish, typically in the form of a clipped adipose fin, allows some hatchery and wild fish to be distinguished in the catch.

The mass marking of salmonids is a management tool which allows for the selective harvest of hatchery origin fish while allowing the release of non-adipose clipped, natural origin fish. In the late 1990s, most hatchery coho salmon in the Columbia River were mass marked. Chinook salmon have also been transitioning to a mass marked program Additional hatchery fish, which are double index tagged (DIT), are recognizable by a coded wire tag but not a clipped adipose fin. DIT groups are necessary for estimating the total mark-selective fisheries impacts on unmarked fish (Selective Fisheries Evaluation Committee 2009). The implementation of mark-selective harvest of hatchery-produced salmon on a commercial scale is thought to be the most promising method for achieving the objective of reducing pHOS, while providing high quality and high value salmon for the marketplace to benefit rural communities while minimizing impacts on ESA-listed natural stocks.

The lower Columbia River alternative commercial fishing gear mortality study is a multi-year effort by the Washington Department of Fish and Wildlife (WDFW) and cooperating commercial fishers. Initiated in the summer of 2009 with trials of three different fishing gear types, this study evaluates the release mortalities associated with the use of two of those alternative commercial fishing gear in the lower Columbia River. The objective of this study is to evaluate the post release survival rates of coho, Chinook, and steelhead captured and released from beach and purse seines. Both tule and bright fall Chinook were included in the study. Freshwater migration of tule fall Chinook occurs over a shorter time frame than bright fall Chinook, making them potentially more susceptible to mortality associated with commercial fishing gear. Results from this study will be used to develop fishing regimes that can achieve the management goals for commercial fisheries while maintaining healthy wild salmon and steelhead populations in the lower Columbia River.

## Methods

*Study Site*

The alternative commercial fishing gear mortality study in 2011 and 2012 took place between Rooster Rock, river kilometer rkm 209/rm 130 and Bonneville Dam, rkm 233/rm 145 (Figure 1). Test gear was operated in the treatment reach upstream from Rooster Rock, rkm 209, to rkm 233 over a 66-day period from August 24 to October 28, 2011 and for a 65 day period from August 20 to October 23, 2012. Four fishers were contracted to fish for a total of 30 days each year, using one of the two types of gear, two purse seines and two beach seines. They operated under a variety of conditions such as different tidal stages, light levels, and weather conditions. In both years, a control group of fish was collected at the Adult Fish Facility (AFF) located at the Washington Shore fish ladder at Bonneville Dam and released at Skamania Landing, just above the treatment reach. In 2012, a supplemental control group of tule fall Chinook salmon were also collected at the Little White Salmon National Fish Hatchery (NFH) and released at Camas, WA, below the treatment reach.

Research boats were marked with conspicuous signs that clearly indicated the gear was part of a research project. Law enforcement was also notified of the fishing dates and areas.

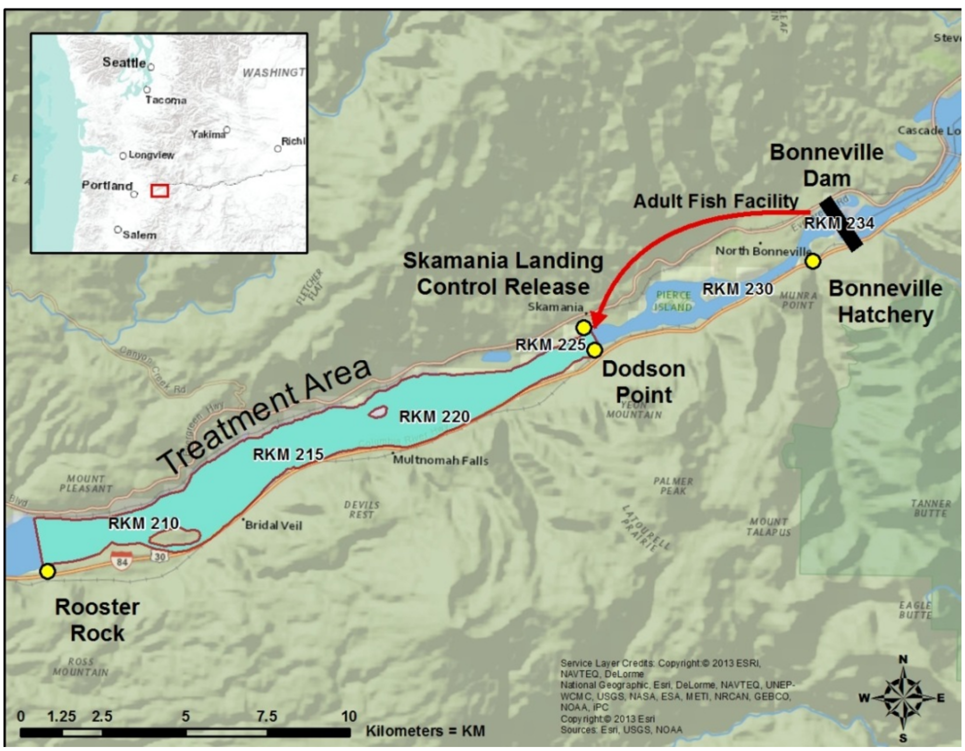



FIGURE 1.─Map of alternative commercial fishing gear mortality study area. Treatment fish were released from beach and purse seines in the treatment area. Control fish were captured at the Adult Fish Facility at Bonneville Dam and released at Skamania Landing.

*Study Design*

The study design was based on Ricker's two-release method (Burnham et al. 1987). This method estimates survival of the treatment fish by comparing the recaptures of a treatment group to a control group of fish. The treatment fish were those captured and released from the commercial fishing gear. The control fish were captured at the Bonneville Dam AFF in both 2011 and 2012. In 2012, an additional group of tule fall Chinook from the Little White Salmon NFH was used as both treatment and control fish. Chinook collected at Little White Salmon NFH were trucked downstream and released at Camas, WA (rm 119/rkm 192). Fish from this release intercepted in the commercial gear were intended to be the treatment fish and those by- passing the commercial gear, the control fish.

Survival was measured as a cumulative survival from the gear to the final detection point and as short-term and long-term survival. Short-term survival was estimated from the gear to Bonneville Dam (rm 146). Long-term survival was estimated from Bonneville Dam to the final detection point. McNary Dam (rm 292) was selected as the final detection point for steelhead, bright fall Chinook, and coho salmon. Little White Salmon NFH (rm 162) and Spring Creek National Fish Hatchery (NFH) (rm 167) were jointly selected as the final detection points for tule fall Chinook salmon.

*Modified Purse Seine (Treatment)*

Purse seines consisted of a lead line, cork line, auxiliary lines, purse line, and purse rings and mesh webbing. The purse seine was used to encircle fish and prevent their escape under the bottom of the net by means of the purse line so that it forms a closed bag. Although purse seines may be deployed from either boats or from the beach, fishers in this study deployed the gear from boats only.

The purse seine net had a minimum length of 150 fathoms (~274 m) and a maximum length of 250 fathoms (~457 m). Minimum net size was based on the results of a pilot alternative gear study in the lower Columbia River in 2009 where a 120 fathom (~219 m) seine was judged to be too short to provide adequate catch rates. Maximum length of 250 fathoms (~458 m) was proposed because the professional judgment of the fishers and biologists suggested that longer seines might be too unwieldy in the lower Columbia River where strong current conditions and river traffic are common. The depth of the net was determined based on the actual area to be fished, but was likely to be 12 m or deeper. The mesh was highly visible knotted cord to help retain the fish inside the seine with a mesh size of 3 ½" (8.9 cm) bar measure and a bunt mesh size of 1" (2.5 cm). The mesh size in the bunt, the bag of the net, was smaller than the remainder of the net because the smaller mesh size coupled with a highly visible cord is thought to result in less entanglement of fish, thereby reducing potential injury to the fish.

The purse seines were deployed using a purse seiner and a motorized skiff leading the bunt end of the seine. The seiner deployed the net and held it in a "C" shape against the upstream salmonid migration for a time that was left up to the discretion of the fisher. The purse seine lead line maintained a vertical attitude of the seine in relation to the river bottom. The purse seine was considered closed when the skiff and the seiner met and closed the cork line. At this point, the skiff held the seiner's position while the seiner pursed the seine using a hydraulic capstan and power block. The actual method of pursing, either full or half, was left up to the discretion of the operator. Once the seine has been pursed, the seine was hauled aboard using a power block while the crew stacked the seine net on the seiner. The last ten fathoms of the seine were hauled very slowly to allow the fish to become acclimated to confinement. The fish were ultimately brailed individually using a rubberized net to dip the fish out of the pursed seine and into a tote on board the seiner for tagging. The rubberized net had a rigid hoop and handle and bag of rubber web. The hoop was triangular in shape (28 inches from bottom of hoop to handle, 21 inches across the bottom) and the bag was 19 inches deep. Mesh of the bag was 1.25 and 2.5 inches on the bottom and sides, respectively. Tagging totes were half full of river water circulated with 16 gallons of water per minute using a trash pump or wash down pump. The number of fish in the tote never exceeded two salmonids. The fishing areas were cleared of obstructions prior to the fishing season by the fisher to maximize the effectiveness of these gears.

Fishing time was recorded from the time that the purse seine was closed to the time the last cork was pulled from the water. In 2011, a total of 239 purse seine sets were completed with a median fishing time of 35 minutes (minimum 14 minutes, maximum 170 minutes). In 2012, a total of 212 purse seine sets were completed with a median fishing time of 44 minutes (minimum 23 minutes, maximum 203 minutes).

*Beach Seine (Treatment)*

The beach seines had a minimum length of 100 fathoms (~183 m) based on results of the pilot study in 2009 where the 120 fathom net provided reasonable catch rates when flow was conducive to successful deployment and retrieval. The beach seine used in 2009 was 120 fathoms (~220 m) in length and ~12 m deep, and was made up of 3½ inch bar measure black nylon mesh. A maximum length of 250 fathoms (~458 m) was proposed because professional judgment and results of the 2009 and 2010 studies indicated that seines longer than that might be too unwieldy in this reach of the lower Columbia River due to strong current conditions. The mesh was highly visible with a mesh size of 3 ½" (8.9 cm) bar measurement. As with the purse seine, the visibility of the mesh due to the small mesh size and large cord resulted in less entanglement of fish in the gear. The beach seine was deployed using a small motorized skiff with one end anchored to the bank. The skiff deployed the net downstream in a "J" shape against the upstream migrating salmon for a time left up to the discretion of the fisher. The seine was set parallel to the beach and the direction of the current to reduce the resistance on the seine from the current.

The seine was considered closed when the skiff returned to shore downstream of the anchored end. The crew then set the seine back onto the beach using motorized assistance, taking care to keep the lead line on the bottom so that fish did not escape. The fish were captured by hand. A rubberized net was used to transfer fish out of the seine and into a tagging tote. Tagging totes were held in the water to ensure that water temperatures remained comparable to river water. The number of fish in the tote never exceeded two salmonids. The fishing areas were cleared of obstructions prior to the fishing season by the fisher to maximize the effectiveness of the gear.

Fishing time was recorded from the time that the beach seine was closed to the time the last cork was pulled from the water. In 2011, a total of 254 beach seine sets were completed with a median fishing time of 20 minutes (minimum 2 minutes, maximum 104 minutes). In 2012, a total of 282 beach seine sets were completed with a median fishing time of 22 minutes (minimum 7 minutes, maximum 86 minutes).

*Bonneville Adult Fish Facility (Control)*

Fish collected at the Bonneville Dam AFF were used as a control group in 2011 and 2012. All fish handling protocols were in compliance with established AFF guidelines established by the Fish Passage Operation and Maintenance Coordination Team in the Fish Passage Plan for Bonneville Dam (USACE 2011). Fish from the control group were transported downstream and released at Skamania Landing, rm 140/rkm 225 (FIGURE 1).

*Fish Handling, Data Collection, and Tagging*

Each fisher was paired with two WDFW observers. One observer handled the fish and took biological data while the other observer recorded the data into a data logger and tagged the fish. The objective was for the crew to rotate between both treatment gears and the control group to minimize bias and to mitigate for personal tagging and fish handling efficiency.

At the end of each purse seine set, each fish was individually brailed out of the gear using a rubberized net and transferred into a plumbed holding container (4’ X 2’ X 3’ deep). At the end of each beach seine set, fish were captured by hand and transferred in a rubberized net to a non-plumbed cattle tote (oblong shape, 4’ long, 2’ wide, 2’ tall). All fish handling was done bare handed to prevent de-sliming and de-scaling. To maximize sample size and minimize bias, all live steelhead, fall Chinook salmon, and coho salmon were included in the study under the assumption that they should have similar survival responses. Any fish that was dead or moribund after a completed fishing effort was retained for enumeration, inspection and determination of cause of death. All other fish were released by hand immediately after sampling and tagging.

The following data were collected from each fish: species, stock, sex, fork length, gear type (purse, beach), capture status (free swimming, entangled in the gear), and capture condition or lividity (Whisler 2003). Time spent in the gear was recorded as the time the set started (net closed), time the fish was removed from net and tagged, and the time the tagged fish was released. Fall Chinook tules were distinguished from fall Chinook brights based on physical characteristics, such as a dark brown appearance, which make them distinguishable in the field (Horner and Bjornn 1979). Capture condition was scored on a scale of 1 to 5 using the following criteria - 1 (vigorous, not bleeding), 2 (vigorous, bleeding), 3 (lethargic, not bleeding), 4 (lethargic, bleeding), and 5 (no signs of life). This scoring system was consistent with the condition categories used in other studies that have investigated survival of fish released from commercial fishing gear (Vander Haegen et al. 2004).

All Chinook salmon, coho salmon and steelhead were scanned for existing PIT tags using established PIT sampling protocols (Rawding et al. In Prep.). Fish with existing PIT tags were recorded as previously tagged and released. By-catch was also enumerated by species, life stage, relative size, and capture condition. All data were recorded into a digital hand held data logger (Psion Workabout Pro, Strategic Mobility Group; Schaumburg, IL).

All treatment and control group fish not previously tagged were tagged in the peritoneal cavity with a 12.5 mm 134.2 kHz full duplex PIT tag (Biomark, Boise, ID). Tags were implanted using a MK-25 Rapid Implant Gun (Biomark, Boise, ID) (Figure 2). The PIT tags were injected into the peritoneal cavity because of the possibility that these fish could be harvested and consumed after release. This is the only FDA-accepted tagging location for food fish (Biomark, undated).

The control group was similarly sampled and assumed to be representative of the available population. As discussed earlier, the intended control group was captured at the AFF located in the Washington Shore adult fish ladder at Bonneville Dam. Fish collected for the control group were PIT tagged, transported by truck and released at Skamania Landing boat ramp, the nearest access point to the fishing area. Severely injured fish, those showing extreme lethargy, fresh seal bites, etc., were noted and tagged consistent with the study protocols. Only moribund fish were excluded from both the treatment and control groups. There were no other criteria used in the field to exclude fish from the mortality test. An additional analysis of the data included moribund fish as immediate mortalities in the survival estimate. Results of this analysis are included in Appendix A-H.

*Tag Recovery*

All PIT tag release and recovery information was obtained through the PIT Tag Information System, PTAGIS. Tags were recovered as observations at existing arrays, recaptures at weirs and fish traps, and mortalities in fisheries. Short-term recapture probabilities were determined from a combination of observations from the arrays at Bonneville Dam, Bonneville Hatchery and recaptures at the Bonneville Dam Adult Fish Facility. PIT tag detection capabilities at Bonneville Hatchery were made possible by the installation of a calibrated PIT tag array in the fish ladder at Bonneville Hatchery in 2011 and 2012. Long-term recapture probabilities were determined from observations at the McNary Dam arrays (steelhead, bright fall Chinook, coho) and Little White Salmon NFH and Spring Creek NFH (tule fall Chinook). An additional analysis of long-term recapture probabilities included all detections above Bonneville Dam. Results of this analysis are included in Appendix A-H.

Hand held PIT tag detectors (Biomark 601 and FS2001F ISO, Biomark, Inc., Boise, ID) were used to sample salmonids caught in the sport fishery during creel sampling below Bonneville Dam, in the non-tribal commercial fisheries, and during carcass surveys in the study area. Main stem tribal fisheries above Bonneville Dam were also sampled for PIT tags.


FIGURE 2.—MK-25 Rapid Implant Gun (Biomark, Boise, ID).

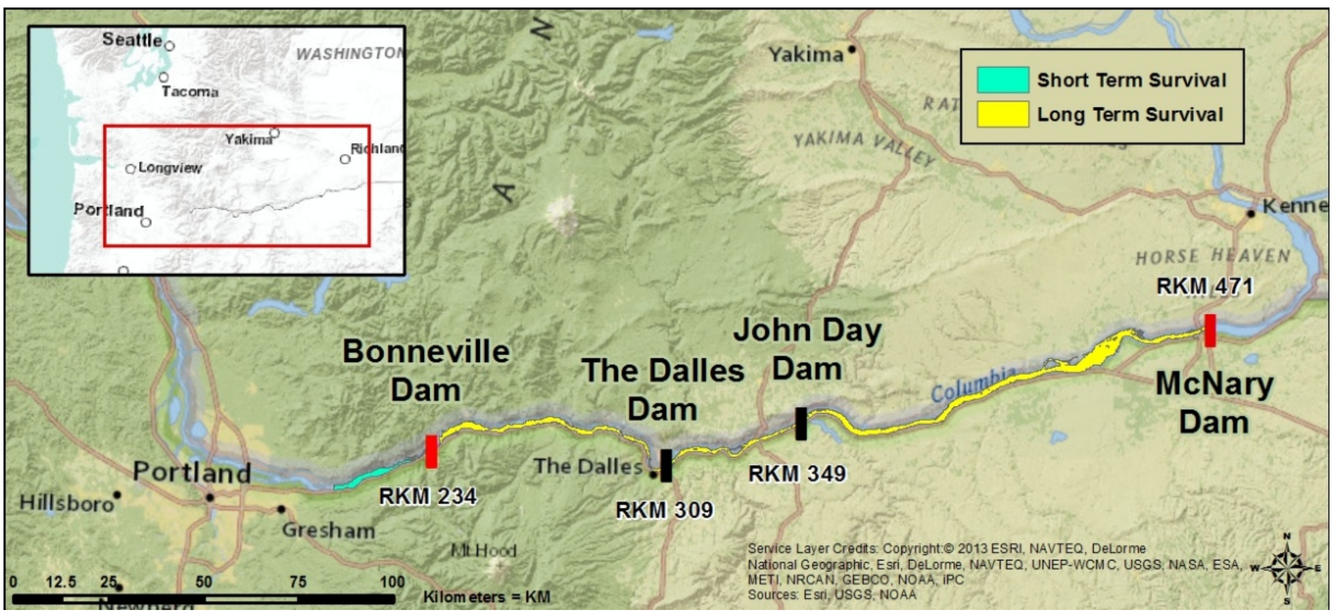



FIGURE 3.—Map of Alternative Gear Mortality Study Area.

*Power Analysis*

A power analysis was conducted to determine the sample sizes needed to estimate post-release survival following release from the commercial gear. The objective was to detect a post-release mortality (mortality = 1-$S_T$, where $S_T$ is survival following release from commercial gear) of at least 5% with 80% probability and a Type 1 error rate of 5%. The power analysis was conducted assuming that recapture probability of the control fish (θ) was 100% and 90%. The hypothesis test was Ho: $S_T \geq 1$ versus the alternative that the purse and beach seine mortality is significantly less than one, i.e., Ha: $S_T < 1$. Table 1 provides the power and precision (PSE, percent standard error) associated with sample sizes of 500, 750, and 1000 fish in a treatment group. Based on this analysis, a target of 1000 for each group of fish was selected for both the treatment and control groups.

TABLE 1.─Power and precision (PSE) expected to detect a post-release mortality of 5% with 80% probability and a Type 1 error rate of 5%. Power and precision were calculated for samples sizes of 500, 750, and 1000 fish and for recapture probabilities (θ) of 1.0 and 0.9.

| | $\theta = 1.0; S_T = 0.95; \alpha = 0.05$ | | $\theta = 0.9; S_T = 0.95; \alpha = 0.05$ | |
|---|---|---|---|---|
| Sample Size N | Power | PSE (1- $S_T$ ) | Power | PSE (1- $S_T$ ) |
| 500 | 1.00 | 19 % | 0.75 | 45% |
| 750 | 1.00 | 16% | 0.88 | 37% |
| 1000 | 1.00 | 14% | 0.95 | 32% |

*Description of Release Groups*

Fork lengths among the control and treatment groups were compared using an analysis of variance (Zar 1999). If the overall model was statistically significant ($\alpha \leq 0.05$), a Tukey Honest Significant Difference (HSD) pairwise comparison test was conducted among the individual groups. ANOVA and Tukey HSD analysis was performed using the “aov” and “Tukey HSD” functions in the R platform (version 2.15.1).

The ratio of female to males was compared among the treatment groups using a Chi-square analysis (Zar 1999). If the overall model was statistically significant ($\alpha \leq 0.05$), pairwise chi-square tests were performed among the individual groups .This analysis was performed using the “chisq.test” function in the R platform (version 2.15.1).

The condition of fish was compared among the treatment groups using a chi-square analysis. Although condition was scored one through five, condition scores were pooled into two groups – good (1-2) and poor (3-5) to increase sample size in each group for analysis (there were very few fish scored as 3-5 upon release). If the overall model was statistically significant ($\alpha \leq 0.05$), pairwise chi-square tests were performed among the individual groups.

*Description of Upstream Migration Rates*

Migration upstream was summarized as the first, median, and last arrival date at fixed locations with PIT arrays upstream of the release point. For steelhead, bright fall Chinook, and coho these fixed locations were Bonneville and McNary dams. For tule fall Chinook, these fixed arrays were Bonneville Dam and Little White Salmon NFH/Spring Creek NFH (combined) because few tule fall Chinook migrate all the way to McNary dam.

The detection efficiencies of these locations were calculated for each species by determining the number of tagged fish detected above the array (detections included observations at arrays, recoveries at weirs/hatchery racks, or fishery mortalities) and then calculating the percent of these tags that were also detected at the location in question. Detection efficiency at Little White Salmon NFH and Spring Creek NFH could not be determined because this is the terminal recovery area for these fish with no additional upstream detections.

Travel time between release and detection between the fixed locations (gear to Bonneville, Bonneville to McNary or Bonneville to Little White Salmon NFH/Spring Creek NFH) was calculated for individual fish. Travel time was summarized as a median, mean, and standard deviation for control and treatment groups. Differences between groups were examined using a Kolmogorov-Smirnov test (Zar 1999). An $\alpha \leq 0.05$ was used for statistical significance. Analysis was performed using the "ks.test" function in the R platform (version 2.15.1).

*Covariates of Recapture Probabilities*

Variables with potential to contribute to recapture probabilities were examined with a multiple logistic regression. Covariates included in this analysis included date of capture/release, fork length, sex, water temperature at release, and release condition. Re-detection (yes, no) of tagged fish associated with these variables was the response variable. Water temperature was obtained from Bonneville Dam scroll temperature (ACOE 2011, 2012). The logistic regression was conducted separately for fish from the control group and each of the treatment groups. An $\alpha \leq 0.05$ was used for statistical significance. Analysis was performed using the "glm" function (family = binomial) in the R platform (version 2.15.1).

*Estimate of Survival*

Survival probabilities are calculated from relative recovery probabilities of treatment fish and control fish:

$$S_T = \frac{r_T / n_T}{r_C / n_C},$$

where $S_T$ = the survival probability of fish caught in selective gears;

$n_C$ = number of control fish tagged and released;

$r_C$ = number of control fish recovered out of $n_c$ fish tagged;

$n_T$ = number of treatment fish caught in selective gears, tagged and released;

$r_T$ = number of treatment fish recovered out of $n_T$ fish tagged.

Recapture and survival parameters were estimated using a Bayesian approach to Ricker's two-release method (Lee et al. 2006). This method calculates each parameter (recapture probability and survival) and its distribution based on the distribution of posterior probabilities from the Bayesian analysis. The posterior probability that a parameter is a given value is the prior probability of that value multiplied by the likelihood of that value given the data collected. Uniform priors, which are uninformative, were selected for this analysis. The likelihood of a value given the data was calculated using a binomial distribution. The Bayes' estimates were based on Monte Carlo samples drawn from the posterior distribution of model parameters. A Gibbs sampler (Casella and George 1992) was used to run 10,000 iterations after a burn-in sample of 2,000 iterations. The MCMC chains were visually inspected for convergence. Sample draws were thinned to one in five in order to minimize autocorrelation. Survival was estimated based on the median and the 95% credible intervals of the posterior distribution. The posterior distribution plot was visually inspected for shape and modality.

The survival estimator and associated variance estimation are based on the assumptions:

1. Fate of each fish is independent.
2. Both control and fish caught in selective gears have the same handling survival, survival from release to detection, and upriver recovery probability.
3. All fish within a treatment have equal probabilities of survival and recovery.

## Steelhead Results

*Description of Release Groups*

In 2011, a total of 1,019 steelhead were captured and released from both the treatment and control groups between August 24th and October 28th (Table 2). All steelhead were tagged prior to release, except 25 steelhead that were previously tagged. Of the tagged steelhead, eight fish (0.8%) were not included in the analysis. In 2012, a total of 1,267 steelhead were captured and released in the study area between August 20th and October 23rd. All steelhead were tagged prior to release except 29 previously tagged steelhead. Of the tagged steelhead, 10 fish (0.7%) were not included in the analysis. Reasons for excluding individuals from the analysis included incomplete tag codes, individuals equal or less than 510 mm fork length which are not likely to be anadromous, and individuals that were included in more than one release group such as those captured and tagged in a purse seine, then recaptured and treated as a "previous capture" in the beach seine.

The average length of steelhead included in the study was 712.8 ±105.4 mm fork length (FL mean ±1 SD) in 2011 and did not differ among control and treatment groups ($F_{2,1023} = 2.1$, $p = 0.13$, TABLE 2). In 2012, the average FL of steelhead included in the study was 743.1 ±108.9 mm FL and did not differ among control and treatment groups ($F_{2,1282} = 0.14$, $p = 0.87$).

Female steelhead represented 53.5% of the total sample in 2011 and 54.9 % of the total sample in 2012 (TABLE 2). In 2011, the proportion of females differed among control and treatment groups ($\chi^2 = 11.1$, $df = 2$, $p = 0.003$). Specifically, the proportion of females in the beach seine group was lower than the control ($\chi^2 = 4.2$, $df = 1$, $p = 0.04$) and purse seine groups ($\chi^2 = 10.5$, $df = 1$, $p = 0.001$) but did not differ from each other ($\chi^2 = 2.3$, $df = 1$, $p = 0.13$). In 2012, the proportion of females differed among control and treatment groups ($\chi^2 = 9.7$, $df = 2$, $p = 0.008$). Specifically, the proportion of females was higher in the control group than either the beach seine ($\chi^2 = 8.9$, $df = 1$, $p = 0.003$) or purse seine ($\chi^2 = 4.1$, $df = 1$, $p = 0.04$) treatment groups but did not differ between treatment groups ($\chi^2 = 1.04$, $df = 1$, $p = 0.3$).

Most steelhead, 94.3% in 2011 and 95.5% in 2012, were in good condition (condition score 1) at time of release (TABLE 2). In 2011, steelhead released in a condition described as lethargic or no sign of life upon release (condition score 3-5) differed among control and treatment groups ($\chi^2 = 50.5$, df = 2, $p < 0.001$). Release condition of steelhead in the control group was better than those in the beach seine ($\chi^2 = 51.9$, df = 1, $p < 0.001$) and purse seine treatment groups ($\chi^2 = 21.4$, df = 1, $p < 0.001$). Release condition did not differ between treatment groups ($\chi^2 = 0.09$, df = 1, $p = 0.8$). In 2012, steelhead released in a condition described as lethargic or no sign of life upon release (condition score 3-5) also differed among treatment and control groups ($\chi^2 = 29.1$, df = 2, $p < 0.001$). Release condition of steelhead in the control group was better than those in the beach seine ($\chi^2 = 29.1$, df = 1, $p < 0.001$) and purse seine treatment groups ($\chi^2 = 22.8$, df = 1, $p < 0.001$). Release condition did not differ between the two treatment groups ($\chi^2 = 0.5$, df = 1, $p = 0.4$).

TABLE 2.─Count, length, sex ratio, and condition of steelhead released from commercial fishing gear and the AFF control group in the Columbia River below Bonneville Dam. Length data are average (1 standard deviation). Condition scores were 1 (vigorous, not bleeding), 2 (vigorous, bleeding), 3 (lethargic, not bleeding), 4 (lethargic, bleeding), and 5 (no signs of life).

| | | | | | Release Condition | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Study Year | Capture Gear | Tags | Fork Length (mm) | Percent Female | 1 | 2 | 3 | 4 | 5 | UNK |
| 2011 | Control | 466 | 703.2 (101.0) | 53.8% | 403 | 0 | 2 | 0 | 0 | 61 |
| | BSeine | 234 | 725.8 (107.7) | 45.3% | 154 | 1 | 27 | 0 | 0 | 52 |
| | PSeine | 319 | 714.4 (111.4) | 59.6% | 216 | 0 | 16 | 0 | 1 | 86 |
| | Total | 1019 | 711.9 (106.2) | 53.5% | 773 | 1 | 45 | 0 | 1 | 199 |
| 2012 | Control | 415 | 740.2 (101.0) | 60.7% | 415 | 0 | 0 | 0 | 0 | 0 |
| | BSeine | 385 | 744.5 (114.3) | 50.0% | 357 | 0 | 28 | 0 | 0 | 0 |
| | PSeine | 467 | 744.6 (111.1) | 53.7% | 438 | 2 | 27 | 0 | 0 | 0 |
| | Total | 1,267 | 743.1 (108.8) | 54.9% | 1210 | 2 | 55 | 0 | 0 | 0 |

*Description of Upstream Migration Rates*

Short-term survival of steelhead was estimated based on tag detections from arrays at the Bonneville Dam fish ladders, the Bonneville Dam Adult Fish Facility (AFF), and the Bonneville Fish Hatchery. The combination of these arrays will hereafter be referred to as “Bonneville”. Long-term survival was estimated based on tag detections at the McNary Dam arrays, hereafter “McNary”. Detection efficiency for steelhead at Bonneville (98.8% in 2011 and 99.2% in 2012) was estimated based on the number of tags observed above Bonneville which were also observed at Bonneville. Detection efficiency for steelhead at McNary (97.4% in 2011 and 97.5% in 2012) was estimated based on the number of tags observed above McNary also observed at McNary. Observations included array detections, recoveries, and mortalities recorded in the PTAGIS database.

In 2011, the median arrival date for steelhead from treatment and control groups was September 22$^{nd}$ at Bonneville and October 4$^{th}$ at McNary (TABLE 3). The median travel time between the release gear and Bonneville was 1.5 days. Control fish travelled more quickly to Bonneville than fish in either treatment group (control vs. beach seine $D$ = 0.59, $p$ < 0.001; control vs. purse seine $D$ = 0.83, $p$ < 0.001), although the difference was just 1-2 days (FIGURE 4). Travel time between the gear and Bonneville was, on average, one day slower for purse seine fish than fish released from the beach seine ($D$ = 0.43, $p$ < 0.001). Median travel time between Bonneville and McNary was 9.1 days. Travel time of control and beach seine fish did not differ between Bonneville and McNary ($D$ = 0.10, $p$ = 0.3). Travel time between Bonneville and

McNary for fish released from the purse seine fish was 1 to 1.5 days slower than that of either beach seine (*D* = 0.15, *p* = 0.03) or control fish (*D* = 0.15, *p* = 0.004).

In 2012, median arrival date for steelhead from treatment and control groups was September 22nd at Bonneville and October 5th at McNary (TABLE 3). The median travel time between the release gear and Bonneville was 1.0 day. Control fish travelled more quickly to Bonneville than fish in either treatment group (control vs. beach seine $D = 0.53$, $p < 0.001$; control vs. purse seine $D = 0.74$, $p < 0.001$), although the difference was just one to two days (FIGURE 5). Travel time between the gear and Bonneville was, on average, 0.5 days slower for purse seine fish than fish released from the beach seine ($D = 0.21$, $p < 0.001$). Median travel time between Bonneville and McNary was 8.0 days. Control fish travelled more quickly between Bonneville and McNary than treatment fish (control vs. beach seine $D = 0.43$, $p < 0.001$, control vs. purse seine $D = 0.45$, $p < 0.001$), although the difference was just 2.0 to 2.5 days. Travel time between Bonneville and McNary for fish released from the purse seine was on average 0.5 days slower than fish released from the beach seine ($D = 0.43$, $p < 0.001$).

TABLE 3.—Detection of all PIT tagged steelhead at Bonneville and McNary dams. Steelhead were tagged and released below Bonneville Dam between river miles 129 to 139.

| Study Year | Detection Site | River Mile | Number of Tags | Median Detection | First Detection | Last Detection |
|---|---|---|---|---|---|---|
| 2011 | Bonneville | 146 | 952 | 9/22/11 | 8/24/11 | 11/1/11 |
| | McNary | 292 | 708 | 10/04/11 | 8/30/11 | 4/17/12 |
| 2012 | Bonneville | 146 | 1220 | 9/22/12 | 8/22/12 | 11/26/12 |
| | McNary | 292 | 944 | 10/5/12 | 8/30/12 | 3/16/13 |

FIGURE 4.─2011 travel time of PIT tagged adult steelhead between release from commercial fishing gear in the lower Columbia River to Bonneville and from Bonneville to McNary. Travel time is shown for control (*a*,*d*), beach seine (*b*,*e*), and purse seine (*c*,*f*) treatments.

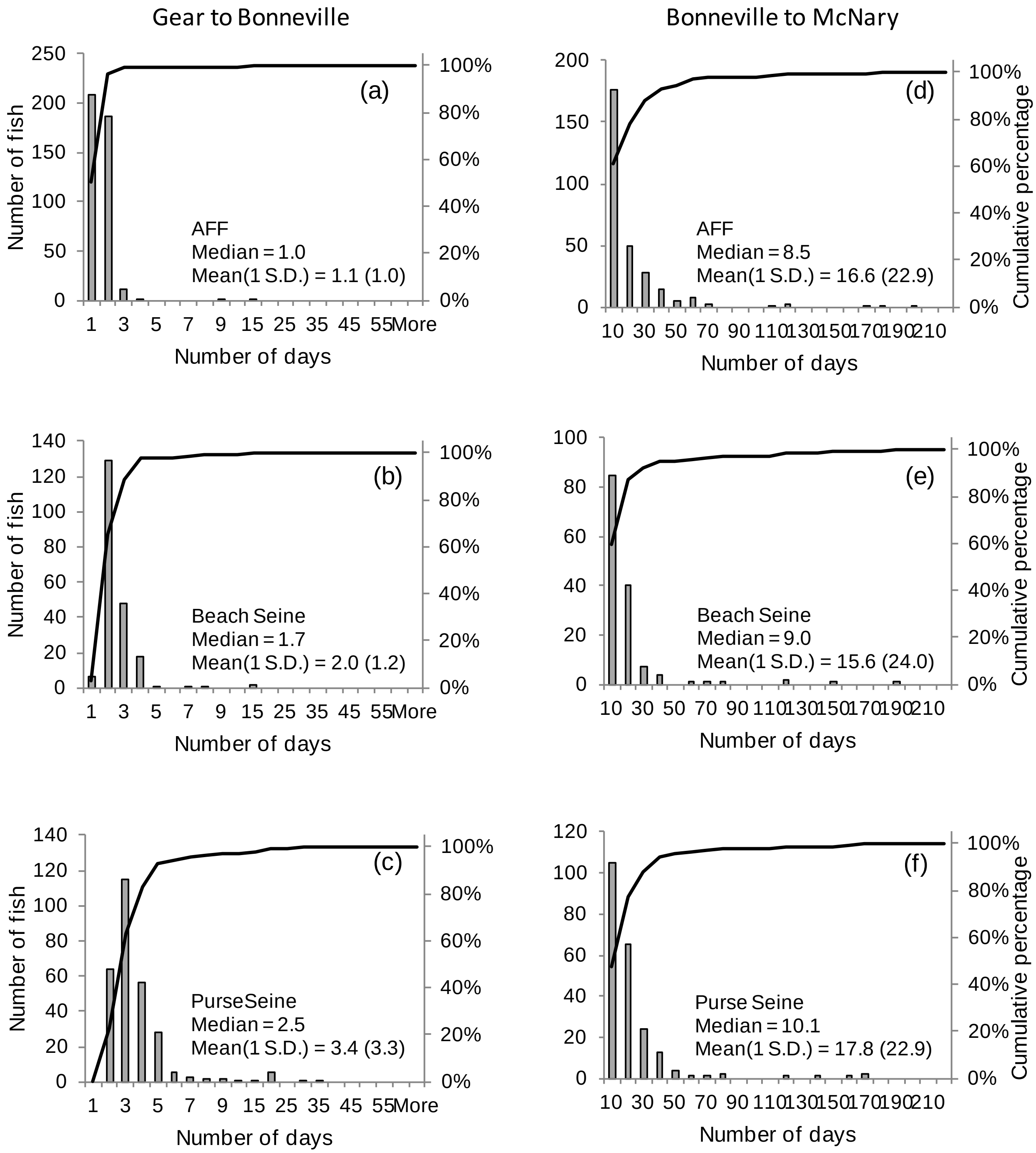
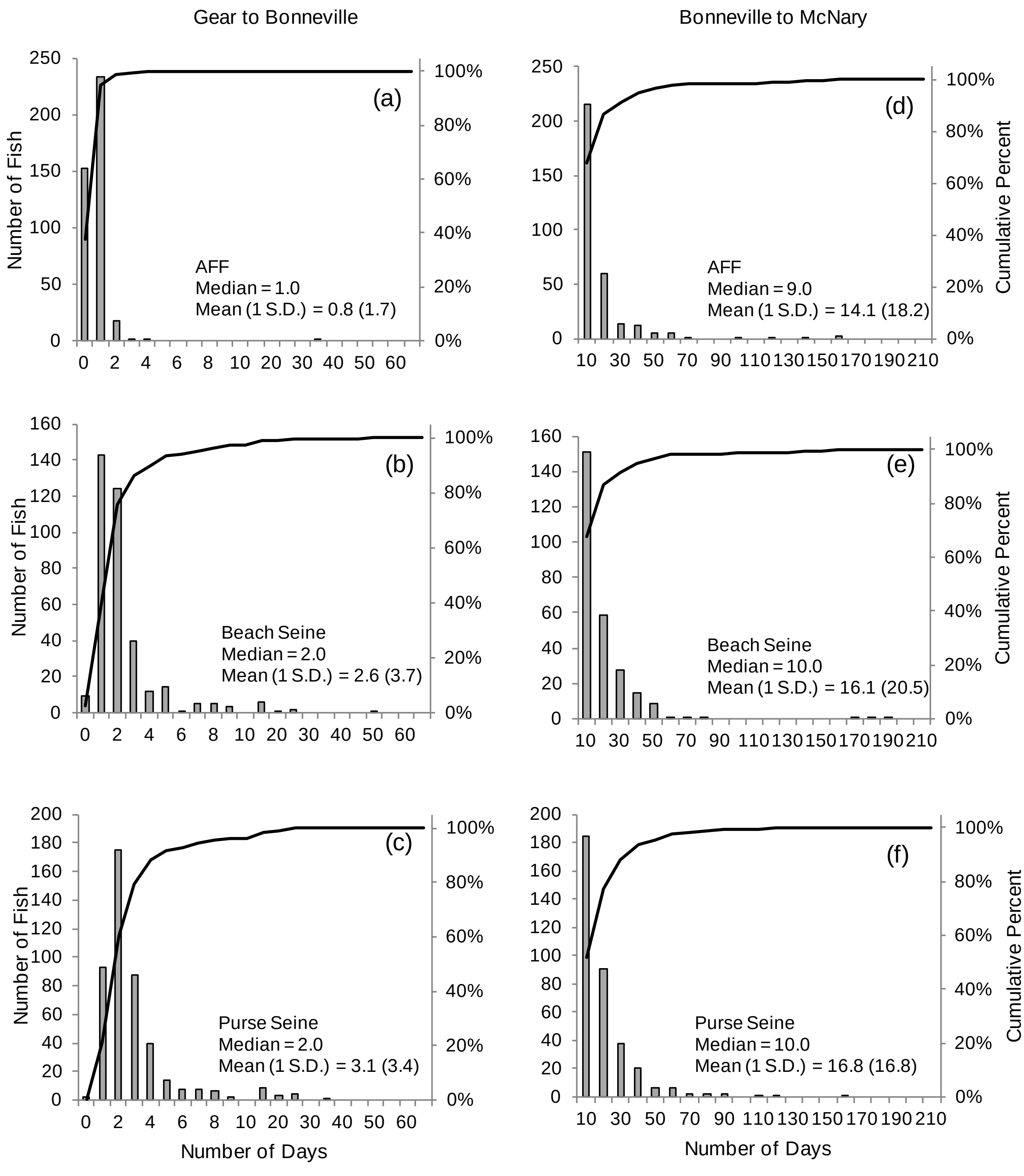


FIGURE 5.─2012 travel time of PIT tagged adult steelhead between release from gear to Bonneville and from Bonneville to McNary. Travel time is shown for control (*a*,*d*), beach seine (*b*,*e*), and purse seine (*c*,*f*) treatments.



*Covariates of Recapture Probabilities*

Very few of the covariates were correlated with steelhead recapture probabilities. In 2011, steelhead recapture probability at Bonneville (beach seine group only) was higher for fish released at larger rather than smaller sizes. Recapture probability for steelhead at McNary was higher for fish released at smaller than larger sizes (TABLE 4).

In 2012, male steelhead had a higher recapture probability at McNary dam than female steelhead (TABLE 4).

TABLE 4.─Logistic regression parameters predicting steelhead recapture probabilities at Bonneville (BON) and McNary (MCN) dams in 2011 and 2012. Statistically significant variables ($p < 0.05$) are indicated with the direction of the correlation (+, -). Non-significant contributions are blank.

| Study Year | Recapture Location | Predictor | AFF | Beach Seine | Purse Seine |
|---|---|---|---|---|---|
| 2011 | BON | Intercept | | | |
| | | Date | | | |
| | | Fork Length | | + | |
| | | Sex | | | |
| | | Release Temperature | | | |
| | | Release Condition | | | |
| | MCN | Intercept | | | |
| | | Date | | | |
| | | Fork Length | | | – |
| | | Sex | | | |
| | | Release Temperature | | | |
| | | Release Condition | | | |
| 2012 | BON | Intercept | | | |
| | | Date | | | |
| | | Fork Length | | | |
| | | Sex | | | |
| | | Release Temperature | | | |
| | | Release Condition | | | |
| | MCN | Intercept | | | |
| | | Date | | | |
| | | Fork Length | | | |
| | | Sex | | – | |
| | | Release Temperature | | | |
| | | Release Condition | | | |

*Survival Estimates*

The survival estimates in this section include steelhead at least 51 cm fork length encountered in the study. Survival estimates of steelhead that include immediate mortalities and all recoveries above Bonneville Dam are provided in Appendix A (2011) and Appendix B (2012).

In 2011, cumulative survival, from the gear to McNary, was estimated to be 0.92 (0.82 – 1.00 95% C.I) for steelhead released from the beach seine and 0.98 (0.93 – 1.00 95% C.I.) for steelhead released from the purse seine (TABLE 5). Short-term survival of steelhead released from the beach seine was estimated to be 0.96 (0.90 – 1.00 95% C.I.) and survival of steelhead released from the purse seine was estimated to be 0.98 (0.94 – 1.00 95% C.I.). Long-term survival of steelhead was estimated to be 0.93 (0.85 – 1.00 95% C.I.) for those released from the beach seine and 0.98 (0.94 – 1.00 95% C.I.) for those released from the purse seine.

In 2012, cumulative survival, from the gear to McNary, was estimated to be 0.89 (0.82 – 0.96 95% C.I.) for steelhead released from the beach seine and 0.97 (0.93 – 1.00 95% C.I.) for steelhead released from the purse seine (TABLE 6). Short-term survival of steelhead released from the beach seine was estimated to be 0.96 (0.94 – 0.99 95% C.I.) and survival of steelhead released from the purse seine was estimated to be 0.98 (0.94 – 1.00 95% C.I.). Long-term survival of steelhead was estimated to be 0.92 (0.85 – 0.98 95% C.I.) for those released from the beach seine and 0.98 (0.94 – 1.00 95% C.I.) for those released from the purse seine.

TABLE 5.—Steelhead recapture probabilities and survival of treatment fish in 2011. Estimates include immediate mortalities in the fishing gear. Recapture probabilities and survival are the median point estimates (and 95% credible intervals, C.I.) from the posterior distribution.

CUMULATIVE: GEAR TO MCNARY

| Treatment | No. Tagged | No. Recaptured | Recapture Prob. | Survival |
|---|---|---|---|---|
| Control (AFF) | 466 | 289 | 0.65 | --- |
| Bseine | 233 | 142 | 0.60 | 0.92 (0.82 – 1.00) |
| Pseine | 316 | 219 | 0.64 | 0.98 (0.93 – 1.00) |

SHORT-TERM: GEAR TO BONNEVILLE

| Treatment | No. Tagged | No. Recaptured | Recapture Prob. | Survival |
|---|---|---|---|---|
| Control (AFF) | 466 | 417 | 0.89 | --- |
| Bseine | 233 | 203 | 0.86 | 0.96 (0.90 – 1.00) |
| Pseine | 316 | 283 | 0.88 | 0.98 (0.94 – 1.00) |

LONG-TERM: BONNEVILLE DAM TO MCNARY

| Treatment | No. Over BON | No. Recaptured | Recapture Prob. | Survival |
|---|---|---|---|---|
| Control (AFF) | 411 | 289 | 0.74 | --- |
| Bseine | 203 | 142 | 0.69 | 0.94 (0.85 – 1.00) |
| Pseine | 283 | 219 | 0.73 | 0.99 (0.94 – 1.00) |

TABLE 6.─Steelhead recapture probabilities and survival of treatment fish in 2012. Estimates include immediate mortalities in the fishing gear. Recapture probabilities and survival are the median point estimates (and 95% credible intervals, C.I.) from the posterior distribution

| CUMULATIVE: GEAR TO MCNARY | | | | |
|---|---|---|---|---|
| **Treatment** | **No. Tagged** | **No. Recaptured** | **Recapture Prob.** | **Survival** |
| Control (AFF) | 415 | 317 | 0.78 | --- |
| Bseine | 385 | 267 | 0.69 | 0.89 (0.82 – 0.96) |
| Pseine | 467 | 360 | 0.77 | 0.98 (0.93 – 1.00) |
| SHORT-TERM: GEAR TO BONNEVILLE | | | | |
| **Treatment** | **No. Tagged** | **No. Recaptured** | **Recapture Prob.** | **Survival** |
| Control (AFF) | 415 | 406 | 0.98 | --- |
| Bseine | 385 | 366 | 0.95 | 0.97 (0.94 – 0.99) |
| Pseine | 467 | 448 | 0.96 | 0.98 (0.94 – 1.00) |
| LONG-TERM: BONNEVILLE DAM TO MCNARY | | | | |
| **Treatment** | **No. Over BON** | **No. Recaptured** | **Recapture Prob.** | **Survival** |
| Control (AFF) | 406 | 317 | 0.80 | --- |
| Bseine | 364 | 267 | 0.73 | 0.92 (0.85 – 0.98) |
| Pseine | 448 | 360 | 0.80 | 0.98 (0.94 – 1.00) |

## Bright Fall Chinook Results

*Description of Release Groups*

In 2011, a total of 3,623 bright fall Chinook salmon were released in both the treatment and control groups between August 24th and October 28th (TABLE 7). All Chinook were tagged prior to release, except the 68 Chinook that had been previously tagged. Of the tagged Chinook, three fish (0.08%) were not included in the analysis. In 2012, a total of 6,359 bright fall Chinook salmon were captured and released in the study area between August 27th and October 23rd. All Chinook were tagged prior to release except the 78 previously tagged. All bright fall Chinook tagged in 2012 were used in the analysis. Reasons for excluding individuals from the analysis included incomplete tag codes and individuals that were included in more than one release group such as those captured and tagged in a purse seine, then recaptured and treated as a "previous capture" in the beach seine.

The average length of bright fall Chinook salmon included in the study was 671.8±163.4 mm FL (mean ±1 SD) in 2011 and differed among control and treatment groups ($F_{2,3617} = 11.38$, $p < 0.001$, TABLE 7). A pairwise comparison test (Tukey HSD) indicated that the beach seine and purse seine fish were an average of 2.5 cm longer than the control fish ($p < 0.001$). In 2012, the average length of bright fall Chinook salmon included in the study was 640.0±153.6 mm FL ($F_{2,6476} = 34.1$, $p < 0.001$). A pairwise comparisons indicated that the beach seine fish were an average of 3 cm longer than the control fish ($p < 0.001$) and that the purse seine fish were on average 3 cm shorter than the beach seine ($p < 0.001$).

Females represented 59.6% of the total adult fish in 2011 and 49.9 % of the total adult fish in 2012 (TABLE 7). In 2011, the proportion of females differed among control and treatment groups ($\chi^2 = 76.4$, $df = 2$, $p < 0.001$). Specifically, the proportion of females was lower in the control group than the beach seine ($\chi^2 = 7.2$, $df = 1$, $p = 0.007$) or purse seine ($\chi^2 = 74.2$, $df = 1$, $p < 0.001$) treatment groups and higher in the purse seine than the beach seine group ($\chi^2 = 20.3$, $df = 1$, $p < 0.001$). In 2012, the proportion of females differed among control and treatment groups ($\chi^2 = 34.9$, $df = 2$, $p < 0.001$). Specifically, the proportion of females was lower in the control group than the beach seine ($\chi^2 = 33.2$, $df = 1$, $p < 0.001$) or purse seine ($\chi^2 = 18.8$, $df = 1$, $p < 0.001$) treatment groups but did not differ between the treatment groups ($\chi^2 = 1.7$, $df = 1$, $p = 0.18$).

Most bright fall Chinook salmon, 91.4% in 2011 and 94.9% in 2012, were in good condition (condition score 1) at time of release (TABLE 7). In 2011, Chinook released in a condition described as lethargic or no sign of life upon release (condition score 3-5) differed among control and treatment groups ($\chi^2 = 159.5$, df = 2, $p < 0.001$). Release condition of Chinook in the control group was better than those in the beach seine ($\chi^2 = 178.0$, df = 1, $p < 0.001$) and purse seine treatment groups ($\chi^2 = 117.6$, df = 1, $p < 0.001$) and release condition of fish in the purse seine treatment group was better than those in the beach seine treatment group ($\chi^2 = 10.7$, df = 1, $p = 0.001$). In 2012, Chinook released in a condition described as lethargic or no sign of life upon release (condition score 3-5) differed among control and treatment groups ($\chi^2 = 108.1$, df = 2, $p <$

0.001). Release condition of which in the control group was better than those in the beach seine ($\chi^2$ = 104.5, df = 1, $p$ < 0.001) and purse seine treatment groups ($\chi^2$ = 104.9, df = 1, $p$ < 0.001). Release condition did not differ between treatment groups ($\chi^2$ = 0, df = 1, $p$ = 0.97).

TABLE 7.─Count, length, sex ratio, and condition of bright fall Chinook salmon released from commercial fishing gear in the Columbia River below Bonneville Dam. Length data are average (1 standard deviation). Condition scores were 1 (vigorous, not bleeding), 2 (vigorous, bleeding), 3 (lethargic, not bleeding), 4 (lethargic, bleeding), and 5 (no signs of life).

| Study Year | Capture Gear | Tags | Fork Length (mm) | Percent Female | Release Condition 1 | 2 | 3 | 4 | 5 | UNK |
|---|---|---|---|---|---|---|---|---|---|---|
| 2011 | Control | 1235 | 689.4 (146.8) | 52.2% | 1076 | 3 | 0 | 0 | 0 | 152 |
| | BSeine | 745 | 661.9 (175.5) | 58.5% | 481 | 2 | 84 | 5 | 3 | 173 |
| | PSeine | 1643 | 663.9 (167.9) | 68.1% | 1191 | 20 | 135 | 6 | 0 | 291 |
| | Total | 3623 | 671.8 (163.4) | 59.6% | 2748 | 25 | 219 | 11 | 3 | 616 |
| 2012 | Control | 1641 | 623.3 (138.6) | 43.6% | 1638 | 1 | 2 | 0 | 0 | 0 |
| | BSeine | 2623 | 657.9 (156.5) | 52.7% | 2447 | 5 | 169 | 2 | 0 | 0 |
| | PSeine | 2173 | 631.1 (158.7) | 50.7% | 2025 | 5 | 134 | 4 | 5 | 0 |
| | Total | 6437 | 640.0 (153.6) | 49.9% | 6110 | 11 | 305 | 6 | 5 | 0 |

*Description of Upstream Migration Rates*

Short-term survival of bright fall Chinook was estimated based on tag detections from arrays at Bonneville.  Long-term survival was estimated based on tag detections at McNary. Detection efficiency for bright fall Chinook at Bonneville (98.8% in 2011 and 99.2% in 2012) was estimated based on the number of tags observed above Bonneville which were also observed at Bonneville. Detection efficiency for bright fall Chinook at McNary (93.1% in 2011 and 94.7% in 2012) was estimated based on the number of tags observed above McNary also observed at McNary. Observations used in these calculations included array detections, recoveries, and mortalities recorded in the PTAGIS database.

In 2011, the median arrival date for bright fall Chinook was September 22nd at Bonneville and September 29th at McNary (TABLE 8). The median travel time between the release gear and Bonneville was 1.7 days. Control fish travelled more quickly to Bonneville than fish in either treatment group (control vs. beach seine $D$ = 0.59, $p$ < 0.001; control vs. purse seine $D$ = 0.65, $p$ < 0.001), although the difference was just one to two days (FIGURE 6). Travel time between the gear and Bonneville was, on average, 0.7 days slower for purse seine fish than fish released from the beach seine ($D$ = 0.22, $p$ < 0.001). Median travel time between Bonneville and McNary was 6.1 days. Control fish travelled an average of 1.5 days more quickly between Bonneville and

McNary than beach seine (*D* = 0.24, $p < 0.001$) or purse seine treatment groups (*D* = 0.25, $p < 0.001$). Travel time between Bonneville and McNary did not differ between the treatment groups (*D* = 0.04, $p = 0.9$).

In 2012, median arrival date for bright fall Chinook was September 17th at Bonneville and September 23rd at McNary (TABLE 8). The median travel time between the release gear and Bonneville was 2.0 days. Control fish travelled more quickly to Bonneville than fish in either treatment group (control vs. beach seine *D* = 0.46, $p < 0.001$; control vs. purse seine *D* = 0.71, $p < 0.001$), although the difference was just one to two days (FIGURE 7). Travel time between the gear and Bonneville was, on average, 0.9 days slower for purse seine fish than fish released from the beach seine (*D* = 0.25, $p < 0.001$). Median travel time between Bonneville and McNary was 6.0 days. Control fish travelled more quickly between Bonneville and McNary than treatment fish (control vs. beach seine *D* = 0.10, $p < 0.001$, control vs. purse seine *D* = 0.23, $p < 0.001$), although the difference was just 0.4 to 0.9 days. Travel time between Bonneville and McNary for fish released from the purse seine was on average 0.5 days slower than fish released from the beach seine (*D* = 0.13, $p < 0.001$).

TABLE 8.—Detection of PIT tagged bright fall Chinook at Bonneville and McNary dams. Chinook were tagged and released from below Bonneville Dam between river miles 129 to 139.

| Study Year | Detection Site | River Mile | Number of Tags | Median Detection | First Detection | Last Detection |
|---|---|---|---|---|---|---|
| 2011 | Bonneville | 146 | 2,816 | 9/22/2011 | 9/9/2011 | 10/19/2011 |
| | McNary | 292 | 1,536 | 9/29/2011 | 9/9/2011 | 1/28/2012 |
| 2012 | Bonneville | 146 | 5,477 | 9/17/2012 | 8/22/2012 | 11/26/2012 |
| | McNary | 292 | 3,229 | 9/23/2012 | 8/30/2012 | 3/16/2013 |

FIGURE 6.—2011 travel time of PIT tagged bright fall Chinook between release from commercial fishing gear in the lower Columbia River to Bonneville Dam and to McNary Dam. Travel time is shown for control (*a*,*d*), beach seine (*b*,*e*), and purse seine (*c*,*f*) treatments.

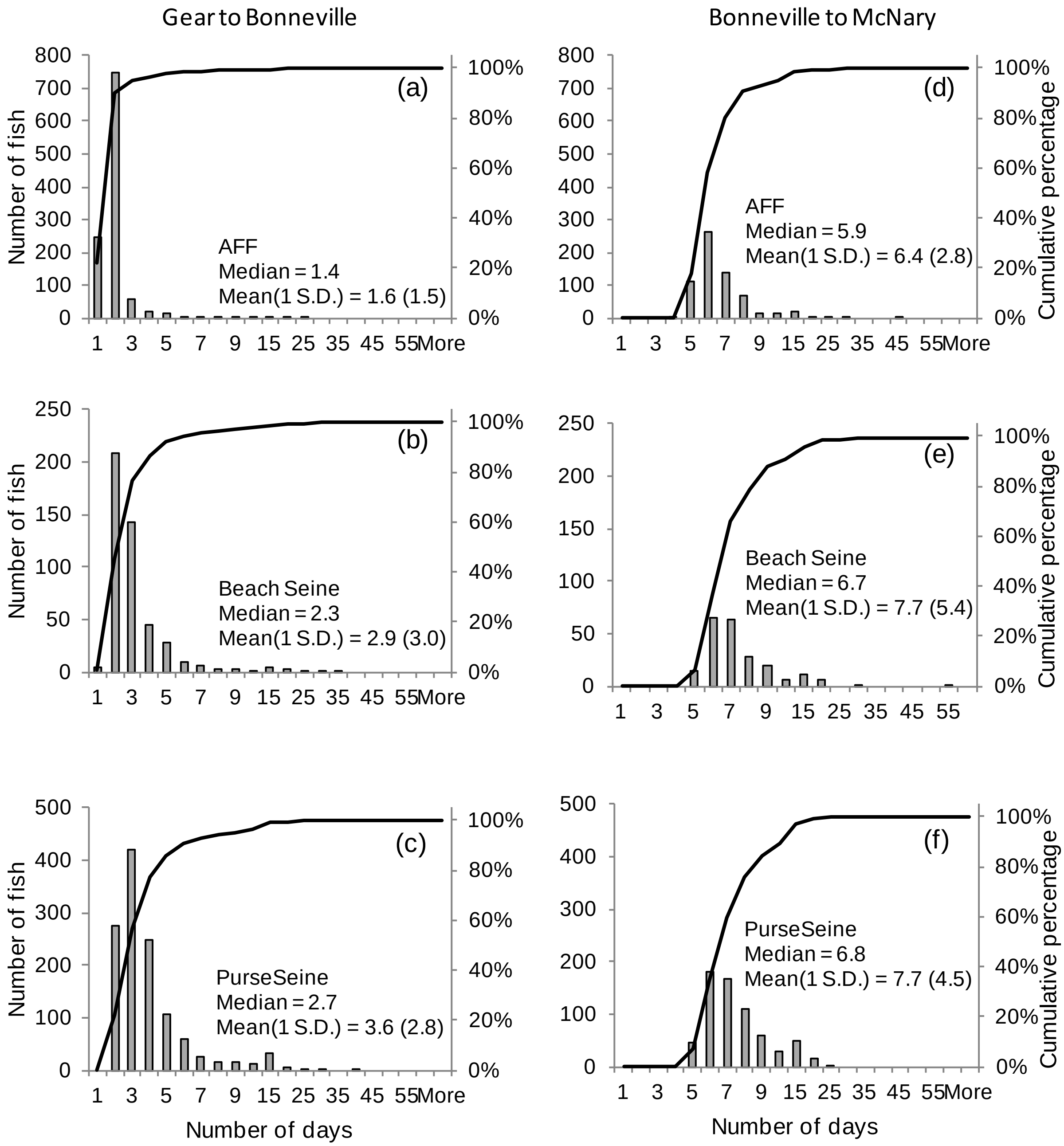
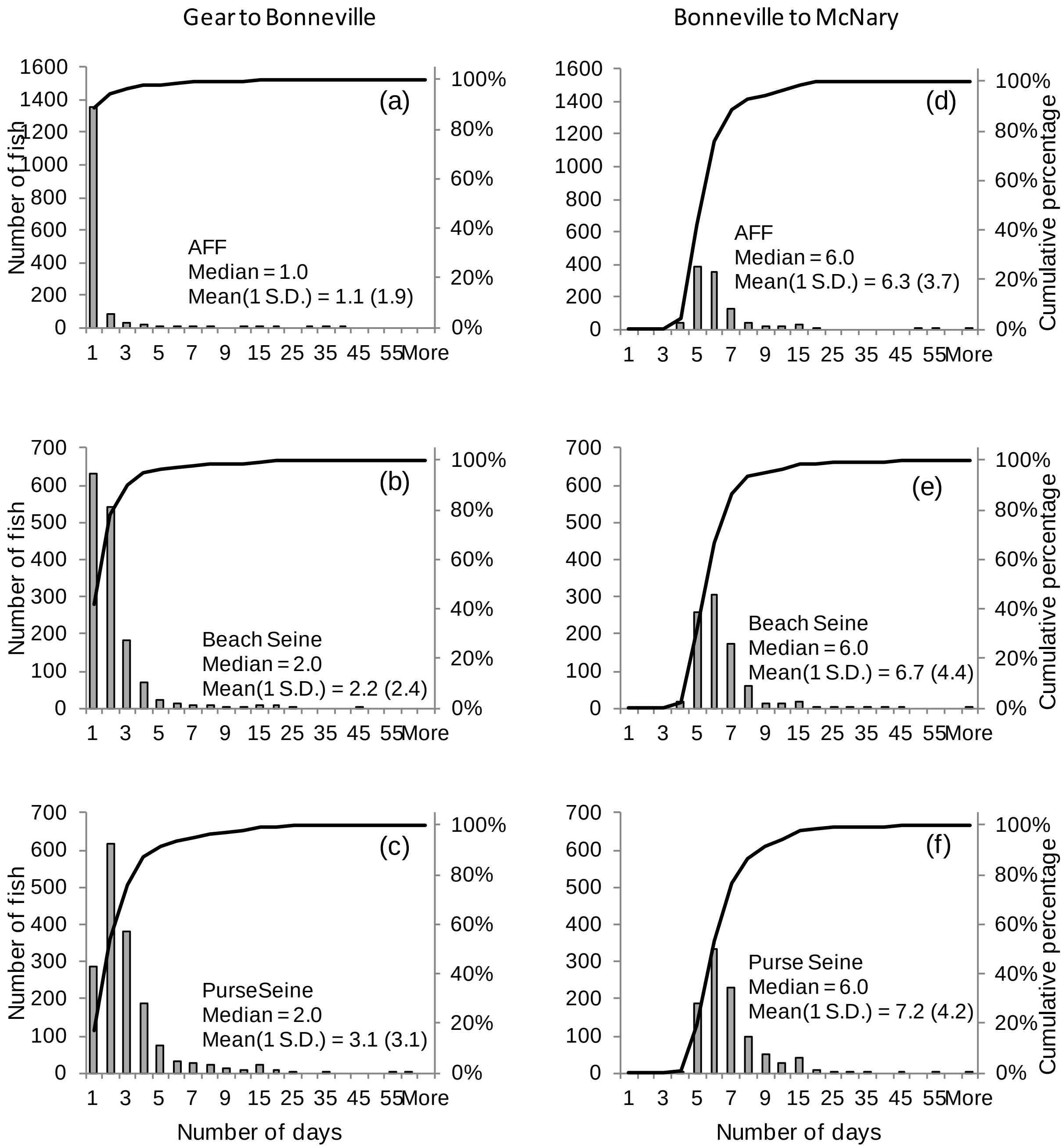


FIGURE 7.─2012 travel time of PIT tagged bright fall Chinook between release from commercial fishing gear in the lower Columbia River to Bonneville Dam and to McNary Dam. Travel time is shown for control (*a*,*d*), beach seine (*b*,*e*), and purse seine (*c*,*f*) treatments.



*Covariates of Recapture Probabilities*

In 2011, bright fall Chinook recapture probability McNary was higher for small than large fish, regardless of control or treatment group (TABLE 9, $p < 0.02$). Recapture probability at Bonneville decreased for fish released later than earlier from the beach and purse seines and for larger fish released from the beach seine. Recapture probability at McNary increased for fish released at warmer temperatures.

In 2012, recapture probabilities at both Bonneville and McNary decreased with fish length in all control and treatment groups (TABLE 9). Recapture probability at Bonneville also decreased for fish captured later in the study period, beach and purse seine groups only, released under warmer water temperature (beach seine group only), and released in poor condition (purse seine group only).

TABLE 9.—Logistic regression parameters predicting bright fall Chinook recapture probabilities at Bonneville (BON) and McNary (MCN) dams in 2011 and 2012. Statistically significant variables ($p < 0.05$) is indicated with the direction of the correlation (+, -). Non-significant contributions are blank.

| Study Year | Recapture Location | Predictor | AFF | Beach Seine | Purse Seine |
|---|---|---|---|---|---|
| 2011 | BON | Date | | – | – |
| | | Fork Length | | – | |
| | | Sex | | | |
| | | Release Temperature | | | |
| | | Release Condition | | | |
| | MCN | Date | | | |
| | | Fork Length | – | – | – |
| | | Sex | | | |
| | | Release Temperature | | + | |
| | | Release Condition | | | |
| 2012 | BON | Date | | – | – |
| | | Fork Length | | – | – |
| | | Sex | | | |
| | | Release Temperature | | – | |
| | | Release Condition | | | – |
| | MCN | Date | | – | |
| | | Fork Length | – | – | – |
| | | Sex | | | |
| | | Release Temperature | | – | |
| | | Release Condition | | | |

*Survival Estimates*

The survival estimates in this section include all bright fall Chinook encountered in the study. Survival estimates of adults only (≥ 57 cm FL) that include immediate mortalities and all recoveries above Bonneville Dam are provided in Appendix C (2011) and Appendix D (2012).

In 2011, cumulative survival (from release to McNary) was estimated to be 0.56 (0.50 – 0.63 95% C.I.) for bright fall Chinook released from the beach seine and 0.78 (0.72 – 0.85 95% C.I.) for Chinook released from the purse seine (TABLE 10). Survival from the gear to Bonneville was estimated to be 0.68 (0.64 – 0.72 95% C.I.) for fish released from the beach seine and 0.82 (0.79 – 0.84 95% C.I.) for fish released from the purse seine. Survival between Bonneville and McNary was estimated to be 0.82 (0.73 – 0.91 95% C.I.) for fish released from the beach seine and 0.94 (0.88 – 0.99 95% C.I.) for fish released from the purse seine.

In 2012, cumulative survival (from release to McNary) was estimated to be 0.75 (0.71 – 0.79 95% C.I.) for Chinook released from the beach seine and 0.74 (0.70 – 0.79 95% C.I.) for Chinook released from the purse seine (TABLE 11). Survival from the gear to Bonneville was comparable to survival between Bonneville and McNary. Survival from the gear to Bonneville was estimated to be 0.88 (0.87 – 0.90 95% C.I.) for fish released from the beach seine and 0.85 (0.83 – 0.87 95% C.I.) for fish released from the purse seine. Survival between Bonneville and McNary was estimated to be 0.88 (0.84 – 0.93 95% C.I.) for fish released from the beach seine and 0.88 (0.84 – 0.93 95% C.I.) for fish released from the purse seine.

TABLE 10.—Bright fall Chinook recapture probabilities and survival of treatment fish in 2011. Recapture probabilities and survival are the median point estimates (and 95% credible intervals, C.I.) from the posterior distribution.

CUMULATIVE: GEAR TO MCNARY

| Treatment | No. Tagged | No. Recaptured | Recapture Prob. | Survival |
|---|---|---|---|---|
| Control (AFF) | 1231 | 651 | 0.53 | --- |
| BSeine | 748 | 223 | 0.30 | 0.56 (0.50 – 0.63) |
| PSeine | 1643 | 679 | 0.41 | 0.78 (0.72 – 0.85) |

SHORT-TERM: GEAR TO BONNEVILLE

| Treatment | No. Tagged | No. Recaptured | Recapture Prob. | Survival |
|---|---|---|---|---|
| Control (AFF) | 1231 | 1126 | 0.91 | --- |
| Bseine | 748 | 465 | 0.62 | 0.68 (0.64 – 0.72) |
| Pseine | 1643 | 1226 | 0.75 | 0.82 (0.79 – 0.84) |

LONG-TERM: BONNEVILLE DAM TO MCNARY

| Treatment | No. Over BON | No. Recaptured | Recapture Prob. | Survival |
|---|---|---|---|---|
| Control (AFF) | 1108 | 651 | 0.59 | --- |
| Bseine | 463 | 223 | 0.48 | 0.82 (0.73 – 0.91) |
| Pseine | 1224 | 679 | 0.55 | 0.94 (0.88 – 0.99) |

TABLE 11.─Bright fall Chinook recapture probabilities and survival of treatment fish in 2012. Recapture probabilities and survival are the median point estimates (and 95% credible intervals, C.I.) from the posterior distribution.

CUMULATIVE: GEAR TO MCNARY

| Treatment | No. Tagged | No. Recaptured | Recapture Prob. | Survival |
|---|---|---|---|---|
| Control (AFF) | 1641 | 1018 | 0.62 | --- |
| BSeine | 2623 | 1218 | 0.46 | 0.75 (0.71 – 0.79) |
| PSeine | 2173 | 993 | 0.46 | 0.74 (0.70 – 0.79) |

SHORT-TERM: GEAR TO BONNEVILLE

| Treatment | No. Tagged | No. Recaptured | Recapture Prob. | Survival |
|---|---|---|---|---|
| Control (AFF) | 1641 | 1548 | 0.94 | --- |
| Bseine | 2623 | 2193 | 0.83 | 0.88 (0.87 – 0.90) |
| Pseine | 2173 | 1736 | 0.80 | 0.85 (0.83 – 0.87) |

LONG-TERM: BONNEVILLE DAM TO MCNARY

| Treatment | No. Over BON | No. Recaptured | Recapture Prob. | Survival |
|---|---|---|---|---|
| Control (AFF) | 1536 | 1018 | 0.66 | --- |
| Bseine | 2091 | 1218 | 0.58 | 0.88 (0.84 – 0.93) |
| Pseine | 1694 | 993 | 0.59 | 0.88 (0.84 – 0.93) |

## Tule Fall Chinook Results

*Description of Release Groups*

In 2011, a total of 631 tule fall Chinook salmon were released in both the treatment and control groups between August 24th and October 19th (TABLE 12). All Chinook were tagged prior to release, except the eight Chinook that had been previously tagged. In 2012, a total of 870 tule fall Chinook salmon were captured and released in the study area between August 27th and October 16th. All fish were tagged prior to release except the one previously tagged fish. All tule fall Chinook tagged in 2011 and 2012 were used in the analysis.

An additional 508 tule fall Chinook from the Little White Salmon NFH were released into the study area on September 20th and 21st, 2012. Of these fish, three tule fall Chinook were recaptured and released in beach seine and three tule fall Chinook were recaptured and released from the purse seine. These fish were not used for analysis due to low capture rates in the treatment gear.

The average length of tule fall Chinook salmon included in the study was 803.9±93.4 mm fork length (FL) (mean ±1 SD) in 2011 and differed among control and treatment groups ($F_{2,628} = 6.4$, $p = 0.002$, TABLE 12). In 2011, pairwise comparisons indicated that the beach seine and purse seine fish were an average of 4 cm longer than the control fish ($p < 0.001$). In 2012, the average length of tule fall Chinook salmon included in the study was 818.8±94.5 mm FL and differed among control and treatment groups ($F_{2,869} = 18.6$, $p < 0.001$). Pairwise comparisons indicated that the beach seine fish were an average of 7.5 cm longer than the control fish ($p < 0.001$) and that the purse seine fish were on average 4 cm longer than the control fish ($p = 0.01$) and an average of 3 cm shorter than the beach seine ($p < 0.001$).

Females represented 42.2% of the total adult fish in 2011 and 43.7 % of the total adult fish in 2012 (TABLE 12). The proportion of females did not differ among treatment and control groups in 2011 ($\chi^2 = 5.3$, df = 2, $p = 0.07$) or 2012 ($\chi^2 = 5.4$, df = 2, $p = 0.07$).

Most tule fall Chinook salmon, 86.7% in 2011 and 94.1% in 2012, were in good condition (condition score 1) at time of release (TABLE 12). In 2011, Chinook released in a condition described as lethargic or no sign of life upon release (condition score 3-5) differed among control and treatment groups ($\chi^2 = 11.5$, df = 2, $p = 0.003$). Chinook released in the control group were in better condition than those released in the beach seine ($\chi^2 = 10.2$, df = 1, $p = 0.001$) and purse seine treatment groups ($\chi^2 = 9.3$, df = 1, $p = 0.002$). Chinook release condition did not differ between treatment groups ($\chi^2 = 0.1$, df = 1, $p = 0.7$). In 2012, Chinook released in a condition described as lethargic or no sign of life upon release (condition score 3-5) differed among control and treatment groups ($\chi^2 = 14.9$, df = 2, $p < 0.001$). Chinook released in the purse seine treatment group were in better condition than those in the beach seine treatment group ($\chi^2 = 12.7$, df = 1, $p < 0.001$). Release condition of control fish did not differ from either the beach seine ($\chi^2 = 3.5$, df = 1, $p = 0.06$) or the purse seine treatment groups ($\chi^2 = 0.5$, df = 1, $p = 0.5$).

TABLE 12.─Count, length, sex ratio, and condition of tule fall Chinook released from commercial fishing gear in the Columbia River below Bonneville Dam. Length data are average (1 standard deviation). Condition scores were 1 (vigorous, not bleeding), 2 (vigorous, bleeding), 3 (lethargic, not bleeding), 4 (lethargic, bleeding), and 5 (no signs of life).

| | | | | | Release Condition | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Study Year | Capture Gear | Tags | Fork Length (mm) | Percent Female | 1 | 2 | 3 | 4 | 5 | UNK |
| 2011 | Control | 80 | 776.9 (90.5) | 48.7% | 65 | 0 | 0 | 0 | 0 | 15 |
| | BSeine | 143 | 817.7 (94.8) | 34.5% | 79 | 1 | 16 | 0 | 0 | 47 |
| | PSeine | 408 | 817.1 (94.9) | 43.3% | 246 | 1 | 42 | 0 | 0 | 119 |
| | Total | 631 | 803.9 (93.4) | 42.2% | 390 | 2 | 58 | 0 | 0 | 181 |
| 2012 | Control | 52 | 762.3 (99.2) | 55.1% | 52 | 0 | 0 | 0 | 0 | 0 |
| | BSeine | 459 | 837.3 (100.9) | 39.0% | 419 | 2 | 38 | 0 | 0 | 0 |
| | PSeine | 359 | 803.8 (108.2) | 40.7% | 348 | 1 | 9 | 0 | 1 | 0 |
| | Total | 870 | 818.8 (94.5) | 43.7% | 819 | 3 | 47 | 0 | 1 | 0 |

*Description of Upstream Migration Rates*

Short-term survival of tule fall Chinook was estimated based on tag detections from arrays at Bonneville. Long-term survival was estimated based on tag detections at the combination of Spring Creek NFH (mouth of White Salmon River) and Little White Salmon NFH (Drano Lake at the mouth of the Little White Salmon River), which will hereafter be referred to as "Little White Salmon NFH" for brevity. Detection efficiency for tule fall Chinook at Bonneville (98.5% in 2011 and 96.1% in 2012) was estimated based on the number of tags observed above Bonneville which were also observed at Bonneville. Detection efficiency at Spring Creek NFH and Little White Salmon NFH could not be measured because this was the terminal recovery area for these fish with no additional upstream observations.

In 2011, the median arrival date for tule fall Chinook from treatment and control groups was September 15th at Bonneville and September 21rd at the Little White Salmon NFH (TABLE 13). The median travel time between the release gear and Bonneville was 2.5 days. Control fish travelled more quickly to Bonneville than fish in either treatment group (control vs. beach seine $D = 0.57$, $p < 0.001$; control vs. purse seine $D = 0.74$, $p < 0.001$), although the difference was just one to two days (FIGURE 6). Travel time between the gear and Bonneville was, on average, 0.7 days slower for purse seine fish than fish released from the beach seine ($D = 0.25$, $p = 0.04$). Median travel time between Bonneville and Little White Salmon NFH was 4.6 days. Travel time between Bonneville and Little White Salmon NFH did not differ among control and treatment groups (D = 0.19, $p = 0.92$).

In 2012, the median arrival date for tule fall Chinook from treatment and control groups was September 8th at Bonneville and September 23rd at the Little White Salmon NFH (TABLE 13). The median travel time between the release gear and Bonneville was 1.6 days. Control fish travelled more quickly to Bonneville than fish in either treatment group (control vs. beach seine $D = 0.40$, $p < 0.001$; control vs. purse seine $D = 0.61$, $p < 0.001$), although the difference was just one to two days (FIGURE 9). Travel time between the gear and Bonneville was, on average, 0.9 days slower for purse seine fish than fish released from the beach seine ($D = 0.21$, $p < 0.001$). Median travel time between Bonneville and Little White Salmon NFH was 5.0 days and did not differ between control and treatment fish (FIGURE 9, $p > 0.14$).

TABLE 13.— Detection of PIT tagged tule fall Chinook at Bonneville Dam and Little White Salmon NFH/Spring Creek NFH. Chinook were tagged and released from below Bonneville Dam between river miles 129 and 139.

| Study Year | Detection Site | River Mile | Number of Tags | Median Detection | First Detection | Last Detection |
|---|---|---|---|---|---|---|
| 2011 | Bonneville | 146 | 418 | 09/15/2011 | 08/27/2011 | 10/30/2011 |
| | Little White Salmon NFH | 162 | 119 | 09/21/2011 | 09/05/2011 | 11/09/2011 |
| 2012 | Bonneville | 146 | 939 | 09/08/2012 | 08/28/2012 | 11/01/2012 |
| | Little White Salmon NFH | 162 | 292 | 09/23/2012 | 08/31/2012 | 10/22/2012 |

FIGURE 8.—2011 travel time of PIT tagged of tule fall Chinook between release from commercial fishing gear in the lower Columbia River to Bonneville Dam and to Spring Creek NFH and Little White Salmon NFH. Travel time is shown for control (*a*,*d*), beach seine (*b*,*e*), and purse seine (*c*,*f*) treatments.

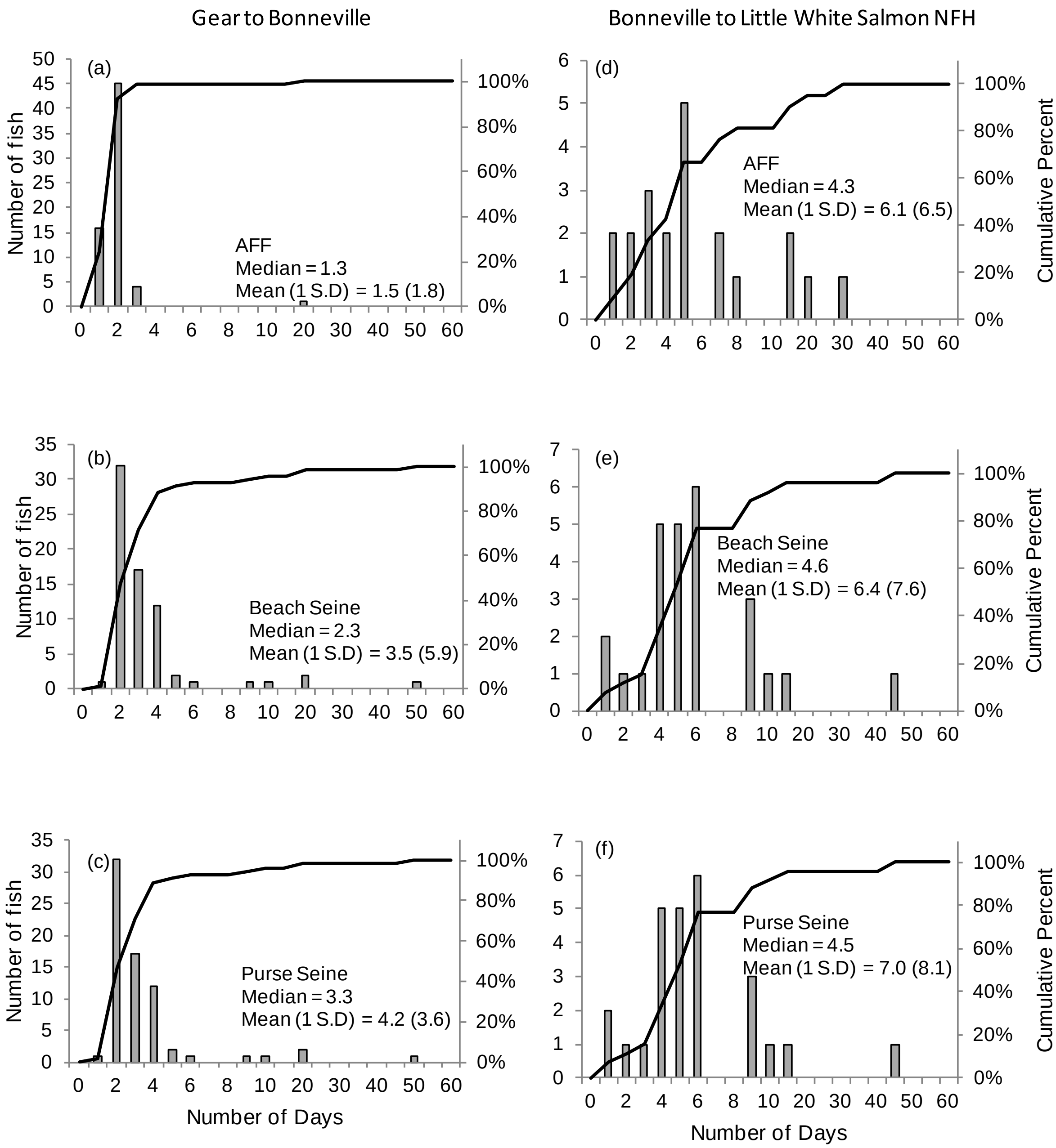
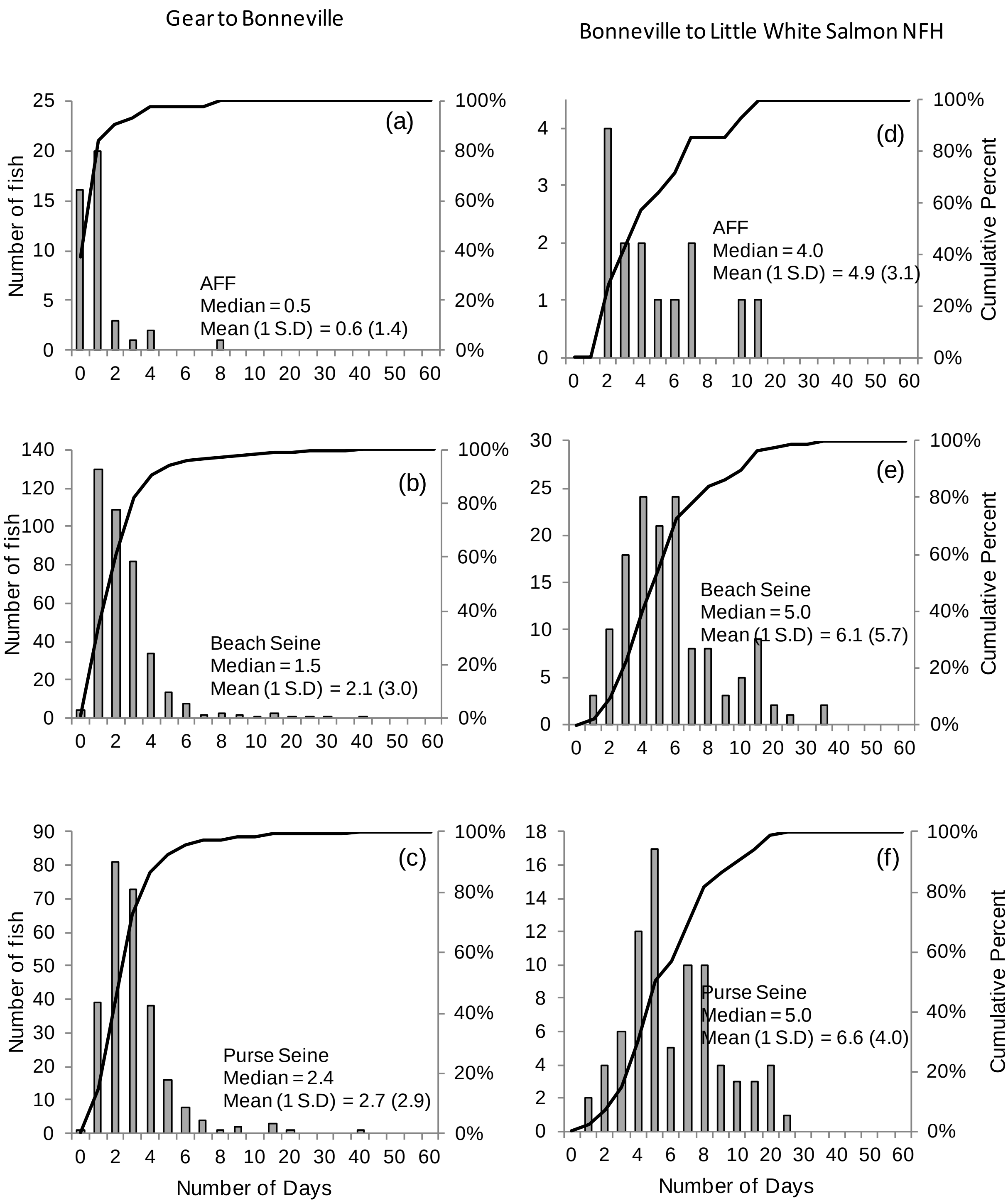


FIGURE 9.─2012 travel time of PIT tagged of tule fall Chinook between release from commercial fishing gear in the Lower Columbia River to Bonneville Dam and to Little White Salmon and Spring Creek National Fish Hatcheries in 2012. Travel time is shown for control (*a*,*d*), beach seine (*b*,*e*), and purse seine (*c*,*f*) treatments.



*Covariates of Recapture Probabilities*

In 2011, tule fall Chinook recapture probability at Bonneville was higher for beach and purse seine fish released earlier in the season than those released later (TABLE 14). None of the variables examined were correlated with recapture probability at Little White Salmon NFH.

In 2012, tule fall Chinook recapture probability at Bonneville was higher for fish captured earlier in the season than those captured later in the beach seine and purse seine groups only. Recapture probability at the Little White Salmon NFH (purse seine group only) was also higher for fish captured earlier in the study period compared to fish captured later.

TABLE 14.─Logistic regression parameters predicting tule fall Chinook recapture probabilities at Bonneville (BON) and Little White Salmon NFH hatchery (LWL) in 2011 and 2012. Statistically significant variables ($p < 0.05$) is indicated with the direction of the correlation (+,-). Non-significant contributions are blank.

| Study Year | Recapture Location | Predictor | AFF | Beach Seine | Purse Seine |
|---|---|---|---|---|---|
| 2011 | BON | Date | | − | − |
| | | Fork Length | | | |
| | | Sex | | | |
| | | Release Temperature | | | |
| | | Release Condition | | | |
| | LWL | Date | | | |
| | | Fork Length | | | |
| | | Sex | | | |
| | | Release Temperature | | | |
| | | Release Condition | | | |
| 2012 | BON | Date | | − | − |
| | | Fork Length | | | |
| | | Release Temperature | | | |
| | | Release Condition | | | |
| | LWL | Date | | | − |
| | | Fork Length | | | |
| | | Release Temperature | | | |
| | | Release Condition | | | |

*Survival Estimates*

The survival estimates in this section include all tule fall Chinook encountered in the study. Survival estimates of adults only (≥ 57 cm FL) that includes immediate mortalities and all recoveries above Bonneville Dam are provided in Appendix E (2011) and Appendix F (2012).

In 2011, cumulative survival from release to Little White Salmon NFH was estimated to be 0.69 (0.43 – 0.97 95% C.I.) for tule fall Chinook released from the beach seine and 0.64 (0.43 – 0.90 95% C.I.) for tule fall Chinook released from the purse seine (TABLE 15). Survival between the gear and Bonneville was estimated to be 0.60 (0.49 – 0.72 95% C.I.) for fish released from the beach seine and 0.83 (0.74 – 0.94 95% C.I.) for fish released from the purse seine. Survival between Bonneville and Little White Salmon NFH was estimated to be 0.89 (0.69 – 1.00 95% C.I.) for fish released from the beach seine and 0.68 (0.50 – 0.90 95% C.I.) for fish released from the purse seine.

In 2012, cumulative survival from release to Little White Salmon NFH was estimated to be 0.90 (0.73 – 1.00 95% C.I.) for tule fall Chinook released from the beach seine and 0.70 (0.53 – 0.89 95% C.I.) for tule fall Chinook released from the purse seine (TABLE 16). Survival between the gear and Bonneville was estimated to be 0.94 (0.86 – 1.00 95% C.I.) for fish released from the beach seine and 0.88 (0.79 – 0.96 95% C.I.) for fish released from the purse seine. Survival between Bonneville and Little White Salmon NFH was estimated to be 0.92 (0.76 – 1.00 95% C.I.) for fish released from the beach seine and 0.76 (0.58 – 0.94 95% C.I.) for fish released from the purse seine.

TABLE 15.—Tule fall Chinook recapture probabilities and survival of treatment fish in 2011. Recapture probabilities and survival are the median point estimates (and 95% credible intervals, C.I.) from the posterior distribution.

CUMULATIVE: GEAR TO SPRING CREEK/LITTLE WHITE SALMON NFH

| Treatment | No. Tagged | No. Recaptured | Recapture Prob. | Survival |
|---|---|---|---|---|
| Control (AFF) | 80 | 22 | 0.27 | --- |
| BSeine | 143 | 27 | 0.19 | 0.69 (0.43–0.97) |
| PSeine | 408 | 70 | 0.17 | 0.64 (0.4 –0.90) |

SHORT-TERM: GEAR TO SPRING CREEK/LITTLE WHITE SALMON NFH

| Treatment | No. Tagged | No. Recaptured | Recapture Prob. | Survival |
|---|---|---|---|---|
| Control (AFF) | 80 | 68 | 0.84 | --- |
| Bseine | 143 | 72 | 0.50 | 0.60 (0.49–0.72) |
| Pseine | 408 | 282 | 0.69 | 0.83 (0.74–0.94) |

LONG-TERM: BONNEVILLE DAM TO SPRING CREEK/LITTLE WHITE SALMON NFH

| Treatment | No. Over BON | No. Recaptured | Recapture Prob. | Survival |
|---|---|---|---|---|
| Control (AFF) | 67 | 22 | 0.37 | --- |
| Bseine | 70 | 27 | 0.33 | 0.90 (0.69–1.0) |
| Pseine | 280 | 70 | 0.25 | 0.67 (0.50–0.90) |

TABLE 16.—Tule fall Chinook recapture probabilities and survival of treatment fish in 2012. Recapture probabilities and survival are the median point estimates (and 95% credible intervals, C.I.) from the posterior distribution.

CUMULATIVE: GEAR TO SPRING CREEK/LITTLE WHITE SALMON NFH

| Treatment | No. Tagged | No. Recaptured | Recapture Prob. | Survival |
| --- | --- | --- | --- | --- |
| Control (AFF) | 52 | 14 | 0.34 | --- |
| BSeine | 459 | 144 | 0.31 | 0.90 (0.73 – 1.00) |
| PSeine | 359 | 84 | 0.24 | 0.70 (0.53 – 0.89) |

SHORT-TERM: GEAR TO SPRING CREEK/LITTLE WHITE SALMON NFH

| Treatment | No. Tagged | No. Recaptured | Recapture Prob. | Survival |
| --- | --- | --- | --- | --- |
| Control (AFF) | 52 | 44 | 0.8518 | --- |
| Bseine | 459 | 396 | 0.8024 | 0.94 (0.86 – 1.00) |
| Pseine | 359 | 268 | 0.7455 | 0.88 (0.79 – 0.96) |

LONG-TERM: BONNEVILLE DAM TO SPRING CREEK/LITTLE WHITE SALMON NFH

| Treatment | No. Over BON | No. Recaptured | Recapture Prob. | Survival |
| --- | --- | --- | --- | --- |
| Control (AFF) | 41 | 14 | 0.444 | --- |
| Bseine | 343 | 144 | 0.4203 | 0.92 (0.76 – 1.00) |
| Pseine | 252 | 84 | 0.3351 | 0.76 (0.58 – 0.94) |

## Coho Salmon Results

*Description of Release Groups*

In 2011, a total of 1,581 coho salmon were released from both the treatment and control groups between August 24$^{th}$ and October 21$^{st}$ (TABLE 17). All coho were tagged prior to release, except the 27 coho that were previously tagged. An additional five coho tagged in 2011 were not used in the analysis because they were captured in more than one type of gear over the course of the study. In 2012, a total of 1,333 coho salmon were captured and released in the study area between August 28$^{th}$ and October 23$^{rd}$. All coho were tagged prior to release except the 12 previously tagged. All coho tagged in 2012 were used in the analysis.

The average length of coho salmon included in the study was 655.0±69.5 mm FL (mean ±1 SD) in 2011 and differed among control and treatment groups ($F_{2,1582} = 5.05$, $p = 0.007$, TABLE 17). Pairwise comparisons indicated that the beach seine ($p = 0.5$) and purse seine ($p = 0.007$) fish were an average of 1 cm shorter than the control fish. In 2012, the average length of coho salmon included in the study was 621.6±90.2 mm FL and differed among control and treatment fish ($F_{2,1341} = 15.8$, $p < 0.001$). Pairwise comparisons indicated that the beach seine fish were an average of 3 cm longer than the control fish ($p < 0.001$) and that the purse seine fish were an average of 3 cm shorter than the beach seine ($p < 0.001$).

Females represented 41.8% of the total adult coho in 2011 and 45.7 % of the total adult coho in 2012 (TABLE 17). The proportion of females did not differ among treatment and control groups in 2011 ($\chi^2 = 0.1$, df = 2, $p = 0.93$) but did differ among groups in 2012 ($\chi^2 = 8.8$, df = 2, $p = 0.01$). In 2012, the proportion of females in the purse seine treatment group was lower than the beach seine ($\chi^2 = 5.7$, df = 1, $p = 0.01$) and control ($\chi^2 = 6.1$, df = 1, $p = 0.01$) groups but did not differ between the beach seine group and the control group ($\chi^2 = 0.07$, df = 1, $p = 0.8$).

Most coho salmon, 94.4% in 2011 and 96.8% in 2012, were in good condition (condition score 1) at time of release (TABLE 17). In 2011, coho released in a condition described as lethargic or no sign of life upon release (condition score 3-5) differed among control and treatment groups ($\chi^2 = 73.3$, df = 2, $p < 0.001$). Coho in the control group were released in better condition than those released in the beach seine ($\chi^2 = 73.0$, df = 1, $p < 0.001$) and purse seine treatment groups ($\chi^2 = 25.8$, df = 1, $p < 0.001$), and coho in the purse seine treatment group were released in better condition than those in the beach seine treatment group ($\chi^2 = 17.9$, df = 1, $p < 0.001$). In 2012, coho released in a condition described as lethargic or no sign of life upon release (condition score 3-5) differed among control and treatment groups ($\chi^2 = 11.3$, df = 2, $p = 0.003$). Coho in the control group were released in better condition than those released in the beach seine ($\chi^2 = 9.4$, df = 1, $p = 0.002$) and purse seine treatment groups ($\chi^2 = 9.9$, df = 1, $p = 0.002$). Release condition did not differ between the two treatment groups ($\chi^2 = 0$, df = 1, $p = 1.0$).

TABLE 17.—Count, length, sex ratio, and condition of coho released from commercial fishing gear in the Columbia River below Bonneville Dam. Length data are average (1 standard deviation). Condition scores were 1 (vigorous, not bleeding), 2 (vigorous, bleeding), 3 (lethargic, not bleeding), 4 (lethargic, bleeding), and 5 (no signs of life).

| Study Year | Capture Gear | Tags | Fork Length (mm) | Percent Female | Release Condition 1 | 2 | 3 | 4 | 5 | UNK |
|---|---|---|---|---|---|---|---|---|---|---|
| 2011 | Control | 582 | 663.8 (69.5) | 42.5% | 512 | 1 | 0 | 0 | 0 | 69 |
| | BSeine | 297 | 649.7 (100.5) | 40.8% | 224 | 1 | 35 | 2 | 0 | 35 |
| | PSeine | 702 | 649.9 (87.9) | 41.6% | 535 | 6 | 30 | 0 | 0 | 131 |
| | Total | 1581 | 655.0 (84.9) | 41.8% | 1271 | 8 | 65 | 2 | 0 | 235 |
| 2012 | Control | 305 | 609.7 (67.1) | 49.8% | 305 | 0 | 0 | 0 | 0 | 0 |
| | BSeine | 480 | 640.5 (95.0) | 48.5% | 459 | 4 | 17 | 0 | 0 | 0 |
| | PSeine | 548 | 611.9 (94.5) | 40.5% | 527 | 1 | 20 | 0 | 0 | 0 |
| | Total | 1333 | 621.6 (90.2) | 45.7% | 1291 | 5 | 37 | 0 | 0 | 0 |

*Description of Upstream Migration Rates*

Short-term survival of coho salmon was estimated based on tag detections from arrays at Bonneville. Long-term survival was estimated based on tag detections at the McNary Dam arrays. Detection efficiency for coho salmon at Bonneville (97.5% in 2011 and 99.1% in 2012) was estimated based on the number of tags observed above Bonneville which were also observed at Bonneville. Detection efficiency for coho salmon at McNary (94.8% in 2011 and 91.9% in 2012) was estimated based on the number of tags observed above McNary also observed at McNary. Observations used in these calculations included array detections, recoveries, and mortalities recorded in the PTAGIS database.

In 2011, median arrival date for coho salmon from treatment and control groups was September 29th at Bonneville and October 9th at McNary (TABLE 18). The median travel time between the release gear and Bonneville was 1.7 days. Control fish travelled more quickly to Bonneville than fish in either treatment group (control vs. beach seine $D = 0.53$, $p < 0.001$; control vs. purse seine $D = 0.74$, $p < 0.001$), although the difference was just one to two days (FIGURE 10). Travel time between the gear and Bonneville was, on average, 0.5 days slower for purse seine fish than fish released from the beach seine ($D = 0.15$, $p = 0.01$). Median travel time between Bonneville and McNary was 13.0 days. Control fish travelled an average of 4 days more quickly between Bonneville and McNary than purse seine fish (control vs. purse seine $D = 0.19$, $p = 0.02$). Travel time between Bonneville and McNary did not differ between control and beach seine treatment fish ($D = 0.11$, $p = 0.90$) or between beach and purse seine treatment fish ($D = 0.16$, $p = 0.52$).

In 2012, the median arrival date for coho salmon from treatment and control groups was September 23rd at Bonneville and September 25th at McNary (TABLE 18). The median travel time between the release gear and Bonneville was two days. Control fish travelled more quickly to Bonneville than fish in either treatment group (control vs. beach seine $D = 0.26$, $p < 0.001$; control vs. purse seine $D = 0.51$, $p < 0.001$), although the difference was just one to two days (FIGURE 11). Travel time between the gear and Bonneville was, on average, one day slower for purse seine fish than fish released from the beach seine ($D = 0.27$, $p < 0.001$). Median travel time between Bonneville and McNary was ten days. Control fish travelled an average of 2.6 days more quickly between Bonneville and McNary than purse seine fish (control vs. purse seine $D = 0.35$, $p < 0.001$). Travel time between Bonneville and McNary did not differ between control and beach seine treatment fish ($D = 0.21$, $p = 0.09$) or between beach and purse seine treatment fish ($D = 0.16$, $p = 0.36$).

TABLE 18.—Detection of PIT tagged coho at Bonneville and McNary dams. Treatment coho were tagged and released from below Bonneville Dam between river miles 129 and 139.

| Study Year | Detection Site | River Mile | Number of Tags | Median Detection | First Detection | Last Detection |
|---|---|---|---|---|---|---|
| 2011 | Bonneville | 146 | 1,164 | 9/29/2011 | 8/24/2011 | 11/7/2011 |
| | McNary | 292 | 286 | 10/9/2011 | 8/29/11 | 3/22/12 |
| 2012 | Bonneville | 146 | 1,060 | 9/23/12 | 8/29/12 | 11/21/12 |
| | McNary | 292 | 237 | 9/25/12 | 9/4/12 | 11/17/12 |

FIGURE 10.─2011 travel time of PIT tagged coho salmon between release from commercial fishing gear in the Lower Columbia River to Bonneville Dam and McNary Dam. Travel time is shown for control (*a*,*d*), beach seine (*b*,*e*), and purse seine (*c*,*f*) treatments.

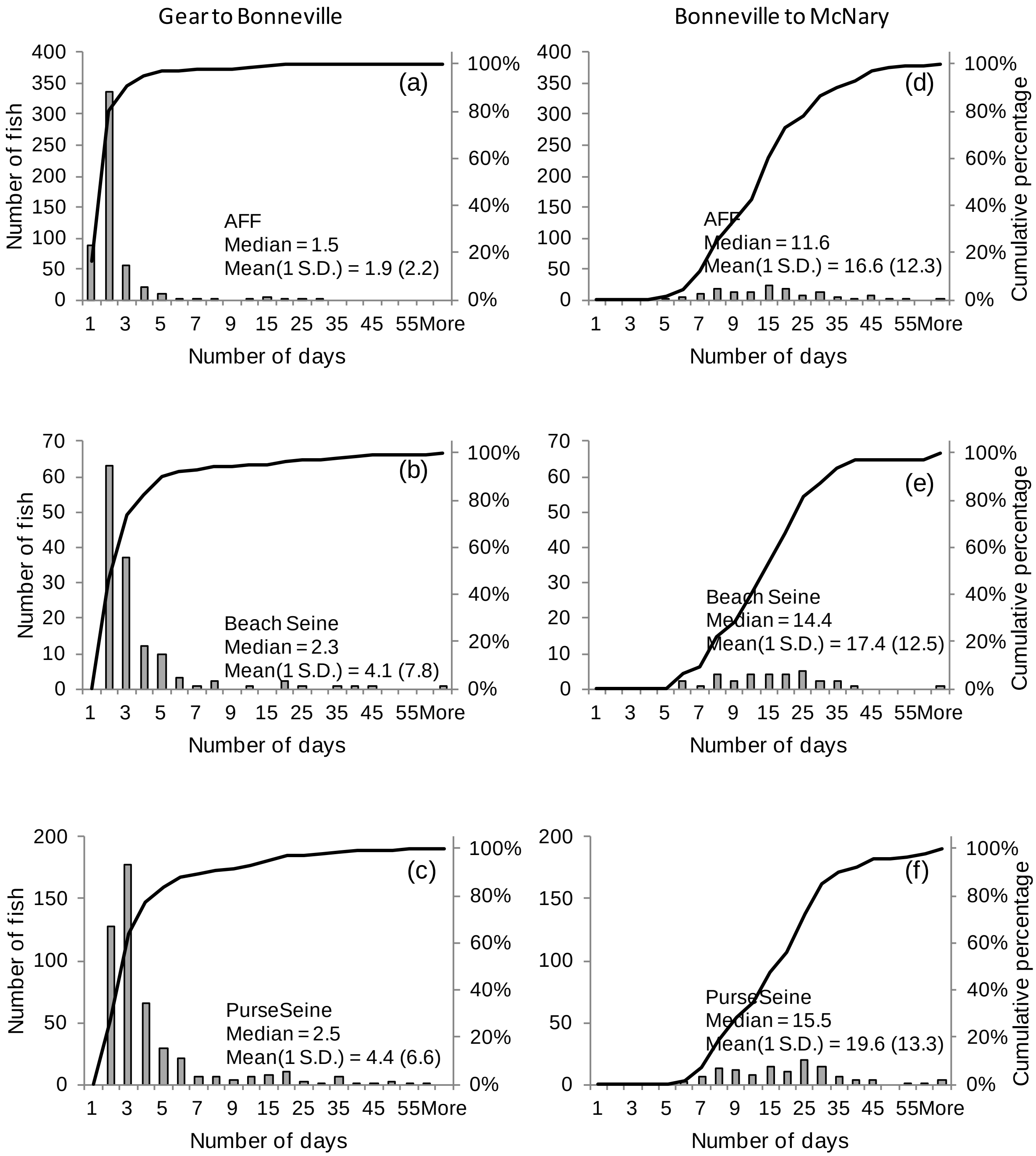
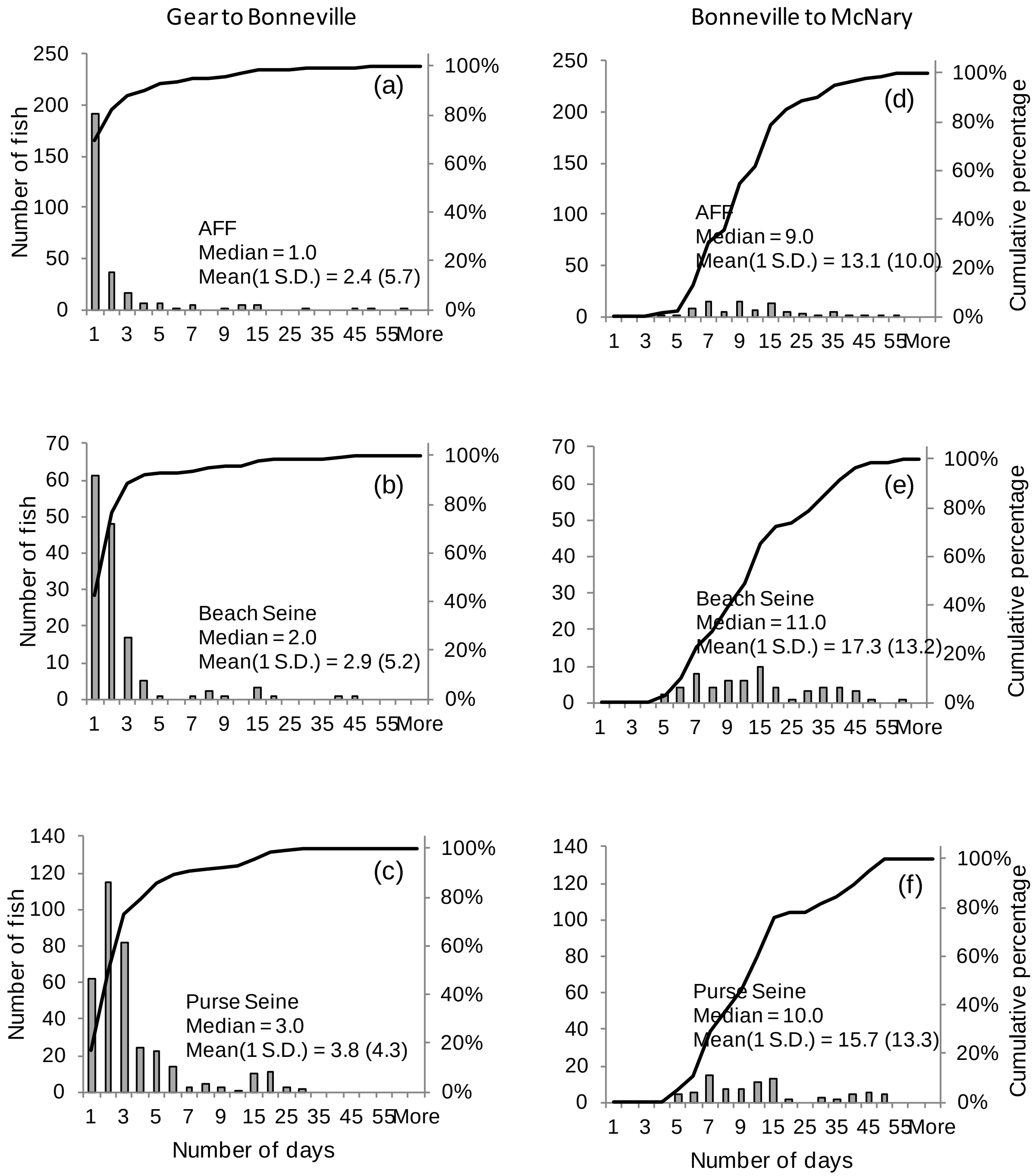


FIGURE 11.─2012 travel time of PIT tagged coho salmon between release from commercial fishing gear in the Lower Columbia River to Bonneville Dam and McNary Dam. Travel time is shown for control (*a*,*d*), beach seine (*b*,*e*), and purse seine (*c*,*f*) treatments.



*Covariates of Recapture Probabilities*

In 2011, coho released earlier in the season had a higher recapture probability at both Bonneville (control and beach seine groups) and McNary dams (beach and purse seine groups) than coho released later in the season (TABLE 19). Recapture probability at Bonneville was also higher for smaller than larger fish released in the control group and the purse seine group. Recapture probability at McNary was higher for male than female coho in the control and purse seine groups.

In 2012, longer coho had a lower recapture probability than shorter coho at both Bonneville (beach and purse seine groups only) and McNary dams (purse seine group only, TABLE 19). Recapture probability at Bonneville was also higher for coho released in good (condition 1-2) than poor (condition 3-5) condition (purse seine group only). Recapture probability at McNary was higher for fish released earlier in the season than those released later (beach and purse seine groups only). Recapture probability at McNary was also higher for male than female coho in the control group.

TABLE 19.—Logistic regression parameters predicting coho salmon recapture probabilities at Bonneville (BON) and McNary (MCN) dams in 2011 and 2012. Statistically significant variables ($p < 0.05$) are indicated with the direction of the correlation (+, -). Non-significant contributions are blank.

| Study Year | Recapture Location | Predictor | AFF | Beach Seine | Purse Seine |
|---|---|---|---|---|---|
| 2011 | BON | Date | – | – | |
| | | Fork Length | – | | – |
| | | Sex | | | |
| | | Release Temperature | | – | |
| | | Release Condition | | | |
| | MCN | Date | | – | – |
| | | Fork Length | | | |
| | | Sex | – | | – |
| | | Release Temperature | + | | |
| | | Release Condition | | | |
| 2012 | BON | Date | | | |
| | | Fork Length | – | | – |
| | | Sex | | | |
| | | Release Temperature | | | |
| | | Release Condition | | | – |
| | MCN | Date | | – | – |
| | | Fork Length | | | – |
| | | Sex | – | | |
| | | Release Temperature | | | |
| | | Release Condition | | | |

*Survival Estimates*

The survival estimates in this section include all coho salmon encountered in the study. Survival estimates of adults only (≥ 47 cm FL) that include immediate mortalities and all recoveries above Bonneville Dam are provided in Appendix G (2011) and Appendix H (2012).

In 2011, cumulative survival, from release to McNary, was estimated to be 0.50 (0.34 – 0.69 95% C.I.) for coho released from the beach seine and 0.77 (0.62 – 0.94 95% C.I.) for coho released from the purse seine (TABLE 20). Survival between the gear and Bonneville was estimated to be 0.50 (0.44 – 0.57 95% C.I.) for fish released from the beach seine and 0.77 (0.72 – 0.81 95% C.I.) for fish released from the purse seine. Survival between Bonneville and McNary was estimated to be 0.86 (0.64 – 0.99 95% C.I.) for fish released from the beach seine and 0.91 (0.77 – 1.00 95% C.I.) for fish released from the purse seine.

In 2012, cumulative survival (from release to McNary) was estimated to be 0.62 (0.46 – 0.81 95% C.I.) for coho released from the beach seine and 0.59 (0.45 – 0.78 95% C.I.) for coho released from the purse seine (TABLE 21). Survival between the gear and Bonneville was estimated to be 0.81 (0.76 – 0.86 95% C.I.) for fish released from the beach seine and 0.84 (0.79 – 89 95% C.I.) for fish released from the purse seine. Survival between Bonneville and McNary was estimated to be 0.93 (0.75 – 0.99 95% C.I.) for fish released from the beach seine and 0.77 (0.60 – 0.96 95% C.I.) for fish released from the purse seine.

TABLE 20.─Coho recapture probabilities and survival of treatment fish in 2011. Recapture probabilities and survival are the median point estimates (and 95% credible intervals, C.I.) from the posterior distribution.

| CUMULATIVE: GEAR TO MCNARY | | | | |
|---|---|---|---|---|
| **Treatment** | **No. Tagged** | **No. Recaptured** | **Recapture Prob.** | **Survival** |
| Control (AFF) | 582 | 134 | 0.23 | --- |
| BSeine | 297 | 33 | 0.11 | 0.50 (0.34 – 0.69) |
| PSeine | 702 | 123 | 0.18 | 0.77 (0.62 – 0.94) |
| SHORT-TERM: GEAR TO BONNEVILLE | | | | |
| **Treatment** | **No. Tagged** | **No. Recaptured** | **Recapture Prob.** | **Survival** |
| Control (AFF) | 582 | 534 | 0.92 | --- |
| Bseine | 297 | 137 | 0.46 | 0.50 (0.44 – 0.57) |
| Pseine | 702 | 493 | 0.70 | 0.77 (0.72 – 0.81) |
| LONG-TERM: BONNEVILLE DAM TO MCNARY | | | | |
| **Treatment** | **No. Over BON** | **No. Recaptured** | **Recapture Prob.** | **Survival** |
| Control (AFF) | 526 | 134 | 0.27 | --- |
| Bseine | 136 | 33 | 0.25 | 0.86 (0.64 – 0.99) |
| Pseine | 491 | 123 | 0.25 | 0.91 (0.77 – 1.00) |

TABLE 21.—Coho recapture probabilities and survival of treatment fish in 2012. Recapture probabilities and survival are the median point estimates (and 95% credible intervals, C.I.) from the posterior distribution.

CUMULATIVE: GEAR TO MCNARY DAM

| Treatment | No. Tagged | No. Recaptured | Recapture Prob. | Survival |
|---|---|---|---|---|
| Control (AFF) | 305 | 79 | 0.26 | --- |
| BSeine | 480 | 75 | 0.16 | 0.62 (0.46 – 0.81) |
| PSeine | 548 | 82 | 0.15 | 0.59 (0.45 – 0.78) |

SHORT-TERM: GEAR TO BONNEVILLE

| Treatment | No. Tagged | No. Recaptured | Recapture Prob. | Survival |
|---|---|---|---|---|
| Control (AFF) | 305 | 281 | 0.92 | --- |
| Bseine | 480 | 356 | 0.74 | 0.81 (0.76 – 0.86) |
| Pseine | 548 | 423 | 0.77 | 0.84 (0.79 – 0.89) |

LONG-TERM: BONNEVILLE DAM TO MCNARY DAM

| Treatment | No. Over BON | No. Recaptured | Recapture Prob. | Survival |
|---|---|---|---|---|
| Control (AFF) | 277 | 79 | 0.30 | --- |
| Bseine | 257 | 75 | 0.27 | 0.93 (0.75 – 0.99) |
| Pseine | 358 | 82 | 0.23 | 0.77 (0.60 – 0.96) |

## Discussion

*Summary*

The cumulative survival of steelhead was consistent across the two years of study and slightly lower for fish released from the beach seine (89-92%) than those released from the purse seine (97-98%). Survival estimated between the gear and Bonneville (96-98%) was comparable to that between Bonneville and McNary dams (92-98%).

The cumulative survival for bright fall Chinook salmon was consistent across both years of study with the exception of the beach seine released fish in 2011. Bright fall Chinook released from the beach seine in 2011 had an estimated survival of 56% which compared to 75% survival for beach seine releases in 2012 and 74% to 78% survival for purse seine releases in both years. Survival estimated between the gear and Bonneville was surprisingly low (68-83%), although survival between Bonneville and McNary dams ranged between 82% and 94%, indicating additional mortality associated with the fishing gear once the fish had passed above Bonneville.

The cumulative survival for tule fall Chinook salmon varied between study years but was consistently higher for fish released from the beach seine (70-90%) than those released from the purse seine (64-70%). The major contributor to the different survival between fishing gears was survival above Bonneville. Survival estimated between Bonneville and Little White Salmon NFH was consistently higher for beach seine fish (89-92%) than for those released from the purse seine (68-76%).

The cumulative survival for coho salmon ranged between 50% and 77% among years and gear types. A notable loss of coho from both gear types occurred below Bonneville; however, delayed mortality of the treatment fish was also measured above Bonneville. Survival of coho salmon above Bonneville ranged from 86% to 91% in 2011 and from 77% to 93% in 2012.

*Study Site Selection*

The test fisheries were conducted between river miles 129 and 144 (rkm 216 and 233) in order to minimize the number of tagged fish at large that would migrate into tributaries and be harvested in ongoing sport and commercial fisheries. In consultation with WDFW fisheries managers in the region, the best opportunity to conduct an unbiased evaluation of long term post-release mortality occurs in this short reach of river where fish can be captured, tagged, released and interrogated for PIT tags in the adult fish passage ladders at Bonneville Dam and other upstream locations.

The test fisheries were conducted throughout the migration period of each species within the lower river from late August through October. Although future commercial fisheries using these gear types are not likely to involve a substantial effort in early August, beginning the test fishing early afforded the test fishers and fishery samplers the opportunity to become familiar with the equipment and processes as the fish abundances increased. Additionally, environmental conditions prior to the normal fishing season, such as lower flows and higher water temperatures, allowed for a more conservative and therefore more rigorous, test of survival probabilities of fish captured in the different gear types operated under different environmental conditions.

The design of this study benefited from the success of a previous study evaluating non-retention mortality of commercial fishing techniques. Our study was conducted in the same location of the Columbia River as a study that evaluated the non-retention mortality of spring Chinook released from tangle nets during the months of April and May (Vander Haegen et al 2004). This previous research also showed that Passive Integrated Transponder (PIT) tags can enable a mark-recapture study with tight confidence levels, thereby decreasing the uncertainty of mortality rates (Ashbrook 2008).

*Migration Timing*

Migration between the gear and Bonneville averaged from 1.0 to 2.5 days across all species. A swim speed could not be accurately calculated for this period because the release locations varied. Migration upstream averaged 6.0 to 13 days between Bonneville and McNary Dam. Bright fall Chinook (6 – 6.1 days, 38.5 to 39.2 km per day) travelled faster than steelhead (8 – 9 days, 26.1 to 29.4 km per day) which travelled faster than coho (10 – 13 days, 18.1 to 23.5 km per day). Migration rates of tule fall Chinook to Little White Salmon NFH and Spring Creek NFH averaged 4.6 to 5.0 days from Bonneville (5.4 to 5.6 km per day).

The migration rates of fish differed among control and treatment groups. Fish in the control groups for all species generally moved more quickly over the entire study, both from the gear to Bonneville and between Bonneville and McNary, than fish released from the beach and purse seines. In addition, for most species and year comparisons, the migration rates of fish captured with the purse seine was slower than either the beach seine or the control group. Although these results might be interpreted as a treatment effect, they could also reflect differences in the behavior of individual fish that made them differentially vulnerable to the fishing gear, particularly when comparing fish captured in the beach and purse seines. Purse-seine captures would be fish migrating mid-channel whereas beach-seine captures would be fish migrating along the shore. Fish using these different migration strategies may be naturally moving at different rates upstream to their spawning grounds.

*Survival Covariates*

We examined five variables (date of release, fork length, sex, release temperature, and release condition) with potential contributions to long-term survival. These variables contributed to varying degrees to the recapture probabilities. In some cases, the contribution of variables differed across control and treatment groups. However, the major contributions were observed in all species and all groups. Specifically, higher recapture probabilities were associated with earlier capture/handling, smaller fish, cooler temperatures at release, and good body condition upon release. These variables were more often predictive of recapture probability in the treatment groups suggesting that the interaction with the gear itself may be enhancing the correlation between each variable and subsequent recapture. If recapture probability is considered a proxy for survival, we can conclude that fish size, fish condition upon release, temporal proximity to spawning (date of capture), and water temperature are all contributing to their likelihood of survival.

*Assumptions of the Survival Estimates*

The survival of bright fall Chinook, tule fall Chinook, and coho salmon between release and Bonneville (50% to 86%) was notably low and contrasted with the survival of steelhead (96% to 98%) over a similar time frame. One explanation for this result is that Chinook and coho salmon are more sensitive than steelhead to capture and handling in commercial fishing gear. In support of this conclusion, Chinook and coho salmon continued to have lower survival than steelhead above Bonneville. However, given that most (95%+) of the Chinook, coho, and steelhead were released in a condition described as "vigorous and not bleeding", the low survival estimated in the one to two days travel time to Bonneville is surprising.

An alternate explanation for the observed survival between the gear and Bonneville is that the recapture probability at Bonneville differed between the control and treatment groups for reasons other than capture in commercial fishing gear (i.e., the treatment). The Ricker two-release method measures survival of the treatment fish relative to the control fish, assuming that the treatment is the only variable which affects the recovery in the second sample. This method assumes that fish behavior in the control and treatment groups would be similar if the treatment had not been applied.

When interpreting the results of this study, we must consider the possibility that the fish captured in commercial gear below Bonneville Dam (i.e., the treatment groups) have a lower tendency to migrate above Bonneville Dam than fish captured at the Bonneville AFF (i.e., the control group). This may occur if fish captured in the commercial gear are more susceptible to additional captures in the river or are more likely to spawn below Bonneville Dam. Although captures of study fish in commercial gear were documented, the recovery of these fish was at too low a rate to compare harvest rates between control and treatment fish. However, both Chinook and coho salmon are known to spawn in areas just downstream of Bonneville Dam. The fishing area selected for this study was deliberately up-stream from the Washougal and Sandy rivers in order to avoid fish that would turn into these rivers from the main stem study area. However, main stem spawning in the areas of Ives and Pierce Island, just below Bonneville Dam, has been observed for bright fall Chinook and coho salmon (Van der Naald et al. 2004), and spawning in the lower extents of small tributaries in this area has also been observed for coho salmon (Holowatz, personal observation). In addition, Bonneville Hatchery was a potential destination for all species and run types in our study. In some cases, we were able to account for fish returning to these locations. For example, study fish returning to Bonneville Hatchery were detected at a PIT array installed in the fish ladder at Bonneville hatchery by WDFW in 2011 and 2012. However, spawners that remained in the main stem or migrated into Columbia River tributaries would not have been accounted for with our survey method. Of note, there are no steelhead spawning areas known in this reach of river and steelhead was the one species which did not have a notable delayed mortality between release and Bonneville.

Several efforts have been made or are in progress to validate the survival estimates for Chinook and coho salmon following release from the commercial fishing gear. In 2012, tule fall Chinook salmon from the Little White Salmon NFH were trucked downstream and released below the study area. Because these fish had already demonstrated a tendency to migrate above Bonneville, they were thought to better meet the assumption that control and treatment fish would undergo similar migration behaviors. Although likely to ensure that fish behavior would be comparable, this strategy did not produce enough "treatment" fish to conduct an estimate of survival using the two-release method as just six of the 500 tule fall Chinook released were captured in the commercial gear. In 2013, this study will be replicated for a third year and an additional study will use radio tags to track the behavior of individual fish released from the commercial fishing gear. This study will investigate the proportion of treatment fish that remain alive in the study area or move out of the study area to spawn in Columbia River tributaries rather than continuing upstream migration to Bonneville Dam.

## References


Ashbrook, C.E. 2008. Selective Fishing and Its Impacts on Salmon: A Tale of Two Test Fisheries. M.Sc. Thesis. School of Fisheries and Aquatic Sciences, University of Washington, Seattle, WA.

Ashbrook, C.E., J. Dixon., K.W. Hassel and E.A. Schwartz. 2008. Estimating Bycatch Survival in a Mark-Selective Fishery. American Fisheries Society Symposium 49: 677-685.

River fisheries project. Pacific Northwest Regional Commission, Portland. OR.

Beiningen, K. T. 1976. Fish runs. Columbia River Fisheries Project. For The Pacific Northwest Regional Commission.

Biomark. No date. Fish Tagging Methods, Biomark Incorporated. www.biomark.com/.../LinkClick.aspx?...Documents%2FPDFs%2FFish+Tagging+Methods

Biomark 601 and FS2001F ISO, Biomark, Inc.; Boise, ID

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

Casella, G. and E. I. George. 1992. Explaining the Gibbs sampler. American Statistics. 46: 167-174.

Craig, J. A. and Hacker, R.L. The History and Development of the Fisheries of the Columbia River. Bulletin of the Bureau of Fisheries No. 32. Approved for publication Aug. 27, 1938. p.175

Donaldson, I.J. and Kramer, F.K. 1971. Fish Wheels of the Columbia River. Binfords & Mort, Publishers.

Goneia, T.E., M.L Keefer., T.C. Bjornn., C.A. Peery, D.H. Bennett., and L.C. Stuehrenberg. 2006. Behavioral thermoregulation and slowed migration by adult fall Chinook salmon in response to high Columbia River water temperatures. Transaction of the American Fisheries Society 135:408-419, 2006.

Holowatz, J.A. Lower Columbia River Alternative Commercial Fishing Gear Evaluation 2010. Washington Department of Fish and Wildlife.

Horner, N. and T.C. Bjornn. 1979. Status of Upper Columbia River Fall Chinook Salmon (Excluding Snake River Population). Idaho Cooperative Fishery Research Unit, University of Idaho, Moscow, Idaho. For the U.S. Fish and Wildlife Service, Boise, Idaho.

Lee, S.M., C. Chen, R. H. Gerlach, and L-H Huang. 2006. Estimation in Ricker's two-release method: a Bayesian approach. Australian N. Z. Journal of Statistics. 48: 157-169.

Lichatowich, J. A. and L. E. Mobrand. 1995. Analysis of Chinook Salmon in the Columbia River from an Ecosystem Perspective. Research Report Prepared for: U.S. Dept. of Energy, Bonneville Power Administration. Project No. 92-1 8. Contract No. DE-AM79-92BP25 105.

Lindsay, R. B., R. Kirk Schroeder, Kenaston, K.R., Toman, R.N. and Buckman M.A. 2004. Hooking Mortality by Anatomical Location and Its Use in estimating Mortality of Spring Chinook Salmon Caught and Released in a River Sport Fishery. North American Journal of Fisheries Management. Vol. 24, Issue 2, 367-378.

Mullen, R.E. Estimates of the Historical Abundance of Coho Salmon, *Oncorhynchus kisutch* (Walbaum), in Oregon Coastal Streams and in the Oregon Production Index Area. Oregon Fish Wildl. Info. Rep. (Fish) 81-5, Portland, OR. 8 p. (1981b).

Psion Workabout Pro, Strategic Mobility Group**;** Schaumburg, IL

Rawding, D. 2010. A Proposal to Estimate Hooking Mortality of Columbia River Chinook Salmon Based Capture-Tag-Recapture Designs using Passive Integrated Transponder (PIT) Tags. Washington Dept. of Fish and Wildlife.

Rawding, D., Buehrens, T.B., Glaser, B. In prep. 2010 Final Report for BPA Project Number: 2010-036-00, Lower Columbia Coded Wire Tag (CWT) Recovery Project.

Selective Fisheries Evaluation Committee 2009 http://www.psc.org/membership_committees_technical_sfec.htm

Smith, Courtland L. 1979. Salmon Fishers of the Columbia. Oregon State University Press, Corvallis, OR. 117 pp.

U.S. Army Corps of Engineers (ACOE). 2011. Annual Fish Passage Report - Columbia and Snake Rivers for Salmon, Steelhead, Shad, and Lamprey. http://cdm16021.contentdm.oclc.org/cdm/landingpage/collection/p16021coll3

Vander Haegen, G.E., Ashbrook, C.E., Yi, K.W., Dixon, J.F. 2004. Survival of spring Chinook salmon captured and released in a selective commercial fishery using gill nets and tangle nets. Fisheries Research 68: 123-133.

Ven der Naald, W., Duff, C., Brooks, R. 2004. Evaluation of fall Chinook and chum salmon spawning below Bonneville Dam: Annual Report 2003-2004. Project Number 1999-003-01 funded by US Department of Energy and Bonneville Power Administration. Oregon Department of Fish and Wildlife.

Washington Department of Fish and Wildlife (WDFW). 2009. Fish and Wildlife Commission Policy Decision. Washington Department of Fish and Wildlife Hatchery and Fishery Reform. Policy Number : C-3619.

Whisler, G.S. 2003. Evaluate Live Capture Selective Harvest Methods for Commercial Salmon Fisheries on The Columbia River. Final Report on the 2001 Field Season. BPA contract #2001-007-00. Objectives 2 and 3.

Zar, J. H. 1999. Biostatistical Analysis, 4th edition. Prentice Hall. Upper Saddle River, New Jersey.

# Appendices

APPENDIX A.— Recapture probabilities and survival of steelhead ≥ 51 cm fork length in 2011. Estimates include immediate mortalities in the fishing gear and all recoveries above Bonneville Dam. Recapture probabilities and survival are the median point estimates (and 95% credible intervals, C.I.) from the posterior distribution.

CUMULATIVE: GEAR TO ALL DETECTIONS ABOVE BONNEVILLE

| Treatment | No. Tagged | No. Recaptured | Recapture Prob. | Survival |
|---|---|---|---|---|
| Control (AFF) | 458 | 342 | 0.77 | --- |
| Bseine | 233 | 164 | 0.70 | 0.92 (0.83-0.99) |
| Pseine | 318 | 249 | 0.78 | 0.98 (0.93-0.99) |

SHORT-TERM: GEAR TO BONNEVILLE

| Treatment | No. Tagged | No. Recaptured | Recapture Prob. | Survival |
|---|---|---|---|---|
| Control (AFF) | 458 | 442 | 0.97 | --- |
| Bseine | 233 | 218 | 0.93 | 0.98 (0.93-1.00) |
| Pseine | 318 | 302 | 0.95 | 0.98 (0.95-1.00) |

LONG-TERM: BONNEVILLE DAM TO ALL DETECTIONS ABOVE BONNEVILLE

| Treatment | No. Over BON | No. Recaptured | Recapture Prob. | Survival |
|---|---|---|---|---|
| Control (AFF) | 442 | 342 | 0.80 | --- |
| Bseine | 218 | 164 | 0.75 | 0.94 (0.86-0.99) |
| Pseine | 302 | 249 | 0.82 | 0.99 (0.95-0.99) |

APPENDIX B.— Recapture probabilities and survival of steelhead ≥ 51 cm fork length in 2012. Estimates include immediate mortalities in the fishing gear and all recoveries above Bonneville Dam. Recapture probabilities and survival are the median point estimates (and 95% credible intervals, C.I.) from the posterior distribution.

| CUMULATIVE: GEAR TO ALL DETECTIONS ABOVE BONNEVILLE | | | | |
|---|---|---|---|---|
| **Treatment** | **No. Tagged** | **No. Recaptured** | **Recapture Prob.** | **Survival** |
| Control (AFF) | 415 | 335 | 0.82 | --- |
| Bseine | 386 | 299 | 0.77 | 0.95 (0.88-0.99) |
| Pseine | 470 | 378 | 0.80 | 0.98 (0.93-1.00) |
| SHORT-TERM: GEAR TO BONNEVILLE | | | | |
| **Treatment** | **No. Tagged** | **No. Recaptured** | **Recapture Prob.** | **Survival** |
| Control (AFF) | 415 | 405 | 0.97 | --- |
| Bseine | 386 | 366 | 0.95 | 0.97 (0.94-0.99) |
| Pseine | 470 | 447 | 0.95 | 0.97 (0.95-1.00) |
| LONG-TERM: BONNEVILLE DAM TO ALL DETECTIONS ABOVE BONNEVILLE | | | | |
| **Treatment** | **No. Over BON** | **No. Recaptured** | **Recapture Prob.** | **Survival** |
| Control (AFF) | 405 | 335 | 405 | --- |
| Bseine | 364 | 299 | 364 | 0.97 (0.91-1.00) |
| Pseine | 447 | 378 | 447 | 0.99 (0.95-1.00) |

APPENDIX C.─ Recapture probabilities and survival of adult bright fall Chinook ≥ 57 cm fork length in 2011. Estimates include immediate mortalities in the fishing gear and all recoveries above Bonneville Dam. Recapture probabilities and survival are the median point estimates (and 95% credible intervals, C.I.) from the posterior distribution.

CUMULATIVE: GEAR TO ALL DETECTIONS ABOVE BONNEVILLE

| Treatment | No. Tagged | No. Recaptured | Recapture Prob. | Survival |
|---|---|---|---|---|
| Control (AFF) | 929 | 513 | 0.55 | --- |
| BSeine | 501 | 166 | 0.33 | 0.60 (0.52-0.69) |
| PSeine | 1133 | 512 | 0.45 | 0.82 (0.75-0.90) |

SHORT-TERM: GEAR TO BONNEVILLE

| Treatment | No. Tagged | No. Recaptured | Recapture Prob. | Survival |
|---|---|---|---|---|
| Control (AFF) | 929 | 852 | 0.92 | --- |
| Bseine | 501 | 309 | 0.62 | 0.67 (0.62-0.72) |
| Pseine | 1133 | 866 | 0.76 | 0.83(0.80-0.86) |

LONG-TERM: BONNEVILLE DAM TO ALL DETECTIONS ABOVE BONNEVILLE

| Treatment | No. Over BON | No. Recaptured | Recapture Prob. | Survival |
|---|---|---|---|---|
| Control (AFF) | 852 | 513 | 0.61 | --- |
| Bseine | 308 | 166 | 0.54 | 0.89 (0.79-0.98) |
| Pseine | 864 | 512 | 0.59 | 0.97 (0.91-1.00) |

APPENDIX D.─ Recapture probabilities and survival of adult bright fall Chinook ≥ 57 cm fork length in 2012. Estimates include immediate mortalities in the fishing gear and all recoveries above Bonneville Dam. Recapture probabilities and survival are the median point estimates (and 95% credible intervals, C.I.) from the posterior distribution.

CUMULATIVE: GEAR TO ALL DETECTIONS ABOVE BONNEVILLE

| Treatment | No. Tagged | No. Recaptured | Recapture Prob. | Survival |
|---|---|---|---|---|
| Control (AFF) | 1037 | 665 | 0.64 | --- |
| BSeine | 1795 | 864 | 0.48 | 0.75 (0.70-0.80) |
| PSeine | 1398 | 663 | 0.47 | 0.74 (0.69-0.80) |

SHORT-TERM: GEAR TO BONNEVILLE

| Treatment | No. Tagged | No. Recaptured | Recapture Prob. | Survival |
|---|---|---|---|---|
| Control (AFF) | 1037 | 978 | 0.94 | --- |
| Bseine | 1795 | 1475 | 0.82 | 0.87 (0.85-0.90) |
| Pseine | 1398 | 1093 | 0.78 | 0.83 (0.81-0.86) |

LONG-TERM: BONNEVILLE DAM TO ALL DETECTIONS ABOVE BONNEVILLE

| Treatment | No. Over BON | No. Recaptured | Recapture Prob. | Survival |
|---|---|---|---|---|
| Control (AFF) | 968 | 665 | 0.69 | --- |
| Bseine | 1381 | 864 | 0.63 | 0.91 (0.86-0.97) |
| Pseine | 1063 | 663 | 0.62 | 0.91 (0.85-0.97) |

APPENDIX E.— Recapture probabilities and survival of adult tule fall Chinook ≥ 57 cm fork length in 2011. Estimates include immediate mortalities in the fishing gear and all recoveries above Bonneville Dam. Recapture probabilities and survival are the median point estimates (and 95% credible intervals, C.I.) from the posterior distribution.

CUMULATIVE: GEAR TO ALL DETECTIONS ABOVE BONNEVILLE

| Treatment | No. Tagged | No. Recaptured | Recapture Prob. | Survival |
|---|---|---|---|---|
| Control (AFF) | 79 | 37 | 0.46 | --- |
| BSeine | 137 | 34 | 0.25 | 0.55 (0.38-0.79) |
| PSeine | 404 | 121 | 0.30 | 0.66(0.51-0.88) |

SHORT-TERM: GEAR TO BONNEVILLE

| Treatment | No. Tagged | No. Recaptured | Recapture Prob. | Survival |
|---|---|---|---|---|
| Control (AFF) | 79 | 67 | 0.84 | --- |
| Bseine | 137 | 71 | 0.52 | 0.62 (0.51-0.74) |
| Pseine | 404 | 280 | 0.69 | 0.83 (0.74-0.93) |

LONG-TERM: BONNEVILLE DAM TO ALL DETECTIONS ABOVE BONNEVILLE

| Treatment | No. Over BON | No. Recaptured | Recapture Prob. | Survival |
|---|---|---|---|---|
| Control (AFF) | 67 | 37 | 0.56 | --- |
| Bseine | 69 | 34 | 0.49 | 0.86 (0.64-0.99) |
| Pseine | 278 | 121 | 0.44 | 0.78 (0.63-0.95) |

APPENDIX F.─ Recapture probabilities and survival of adult tule fall Chinook ≥ 57 cm fork length in 2012. Estimates include immediate mortalities in the fishing gear and all recoveries above Bonneville Dam. Recapture probabilities and survival are the median point estimates (and 95% credible intervals, C.I.) from the posterior distribution.

CUMULATIVE: GEAR TO ALL DETECTIONS ABOVE BONNEVILLE

| Treatment | No. Tagged | No. Recaptured | Recapture Prob. | Survival |
|---|---|---|---|---|
| Control (AFF) | 49 | 23 | 0.49 | --- |
| BSeine | 452 | 200 | 0.44 | 0.89 (0.71-0.99) |
| PSeine | 349 | 127 | 0.36 | 0.74 (0.57-0.91) |

SHORT-TERM: GEAR TO BONNEVILLE

| Treatment | No. Tagged | No. Recaptured | Recapture Prob. | Survival |
|---|---|---|---|---|
| Control (AFF) | 49 | 41 | 0.88 | --- |
| Bseine | 452 | 389 | 0.86 | 0.97 (0.91-1.00) |
| Pseine | 349 | 261 | 0.75 | 0.85 (0.78-0.92) |

LONG-TERM: BONNEVILLE DAM TO ALL DETECTIONS ABOVE BONNEVILLE

| Treatment | No. Over BON | No. Recaptured | Recapture Prob. | Survival |
|---|---|---|---|---|
| Control (AFF) | 38 | 23 | 0.64 | --- |
| Bseine | 339 | 200 | 0.59 | 0.92 (0.77-1.00) |
| Pseine | 245 | 127 | 0.52 | 0.81 (0.67-0.95) |

APPENDIX G.─ Recapture probabilities and survival of adult coho salmon ≥ 47 cm fork length in 2011. Estimates include immediate mortalities in the fishing gear and all recoveries above Bonneville Dam. Recapture probabilities and survival are the median point estimates (and 95% credible intervals, C.I.) from the posterior distribution.

CUMULATIVE: GEAR TO ALL DETECTIONS ABOVE BONNEVILLE

| Treatment | No. Tagged | No. Recaptured | Recapture Prob. | Survival |
|---|---|---|---|---|
| Control (AFF) | 571 | 189 | 0.33 | --- |
| BSeine | 269 | 42 | 0.16 | 0.48 (0.35-0.64) |
| PSeine | 662 | 156 | 0.24 | 0.72(0.59-0.86) |

SHORT-TERM: GEAR TO BONNEVILLE

| Treatment | No. Tagged | No. Recaptured | Recapture Prob. | Survival |
|---|---|---|---|---|
| Control (AFF) | 571 | 533 | 0.93 | --- |
| Bseine | 269 | 132 | 0.49 | 0.53 (0.46-0.59) |
| Pseine | 662 | 482 | 0.73 | 0.78 (0.74-0.82) |

LONG-TERM: BONNEVILLE DAM TO ALL DETECTIONS ABOVE BONNEVILLE

| Treatment | No. Over BON | No. Recaptured | Recapture Prob. | Survival |
|---|---|---|---|---|
| Control (AFF) | 531 | 189 | 0.36 | --- |
| Bseine | 131 | 42 | 0.32 | 0.87(0.66-0.99) |
| Pseine | 480 | 156 | 0.32 | 0.90 (0.77-0.99) |

APPENDIX H.─ Recapture probabilities and survival of adult coho salmon ≥ 47 cm fork length in 2012. Estimates include immediate mortalities in the fishing gear and all recoveries above Bonneville Dam. Recapture probabilities and survival are the median point estimates (and 95% credible intervals, C.I.) from the posterior distribution.

CUMULATIVE: GEAR TO ALL DETECTIONS ABOVE BONNEVILLE

| Treatment | No. Tagged | No. Recaptured | Recapture Prob. | Survival |
|---|---|---|---|---|
| Control (AFF) | 296 | 121 | 0.41 | --- |
| BSeine | 450 | 108 | 0.24 | 0.59 (0.48-0.73) |
| PSeine | 501 | 105 | 0.21 | 0.52 (0.42-0.64) |

SHORT-TERM: GEAR TO BONNEVILLE

| Treatment | No. Tagged | No. Recaptured | Recapture Prob. | Survival |
|---|---|---|---|---|
| Control (AFF) | 296 | 274 | 0.92 | --- |
| Bseine | 450 | 339 | 0.75 | 0.82 (0.76-0.87) |
| Pseine | 501 | 388 | 0.77 | 0.84(0.79-0.89) |

LONG-TERM: BONNEVILLE DAM TO ALL DETECTIONS ABOVE BONNEVILLE

| Treatment | No. Over BON | No. Recaptured | Recapture Prob. | Survival |
|---|---|---|---|---|
| Control (AFF) | 270 | 121 | 0.46 | --- |
| Bseine | 238 | 108 | 0.45 | 0.94 (0.81-1.00) |
| Pseine | 323 | 105 | 0.33 | 0.70 (0.58-0.85) |