Wild Fish Conservancy
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EVALUATION OF POUND NETS AS STOCK SELECTIVE FISHING TOOLS IN THE LOWER COLUMBIA RIVER SUB-BASIN

Prepared by:

Dr. Nick Gayeski, Adrian Tuohy, and Aaron Jorgenson

March 2020

Prepared for:

NOAA Fisheries Service Bycatch Reduction Engineering Program

Photos by Aaron Jorgenson

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AWARD # NA17NMF4720255

BREP FINAL REPORT

Award Period – 1 July 2017 – 31 December 2019

Reporting Period – 1 July 2017 – 31 December 2019

Submitted To:

Derek Orner

NOAA Fisheries

1315 East-West Highway

Silver Spring, MD 20910

Submitted By:

Nick Gayeski, Ph.D.

Adrian Tuohy, M.S.

Aaron Jorgenson, B.S.

Wild Fish Conservancy

P.O Box 402

Duvall, WA 98019

March 2020

ACKNOWLEDGMENTS

This project was made possible with funding received under award NA17NMF4720255 from the National Oceanic and Atmospheric Administration (NOAA) Fisheries Service, in cooperation with the Bycatch Reduction Engineering Program (BREP). We are grateful for additional support and funding provided by the Washington Coastal Restoration Initiative, the Washington Department of Fish and Wildlife (WDFW), the Oregon Department of Fish and Wildlife (ODFW), NOAA Fisheries Service Saltonstall-Kennedy Grant Program, Wild Salmon Center, the Horizons Foundation, and the Patagonia World Trout Grant Initiative. We would like to thank the many people that collaborated and contributed to this study to make it a success: Kurt Beardslee, Jamie Glasgow, Justin Eastman, Joe Verrelli, Blake Joplin, Danielle Dorsch, Brennan Helwig, James Fletcher-Healy, and Allen Mitchell of Wild Fish Conservancy (WFC); Dr. John Skalski and Dr. Thomas Quinn of the University of Washington; Lisa Harlan, Ryan Lothrop, and Bill Tweit of WDFW; commercial fishers Jon Blair Peterson and Billie Delaney; fish buyer, processor, and fisher Mike Clark of C&H Classic Smoked Fish; Seattle chef Renee Erickson of Sea Creatures; Shane Anderson of North Fork Studios; the community of Cathlamet, WA; and volunteer Mary Valentine. The statements, findings, conclusions, and recommendations from this report are those of WFC and do not necessarily reflect the views of NOAA Fisheries.

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II. ABSTRACT

Gill nets and other conventional harvest techniques used in mixed-stock commercial salmon fisheries frequently result in bycatch mortality, impacting Endangered Species Act (ESA)-listed wild salmonid populations and constraining fishing opportunities in the U.S Pacific Northwest. To address the problem, studies were conducted in the lower Columbia River, WA evaluating the potential of commercial salmon traps for stock-selective harvest and bycatch mortality reduction. Expanding upon a 2016 pilot study, WA State's first commercial fish trap since 1934 was constructed and operated under a variety of tidal stages, light levels, and weather conditions between August–September 2017 and May–October 2019. Post-release survival of bycatch was estimated through paired release-recapture in 2017 and a combination of paired-release recapture and net pen holding in 2019. Results demonstrated that the fish trap effectively targeted hatchery reared fall Chinook (*Oncorhynchus tshawytscha*) and coho salmon (*O. kisutch*) while reducing bycatch mortality rates relative to conventional commercial gears. During the late-summer and fall 2017 study period, the relative cumulative survival effect over a 400 km migration ranged from 0.944 ($\widehat{SE}$= 0.046) for steelhead (*O. mykiss*) to 0.995 ($\widehat{SE}$= 0.078) for fall Chinook salmon. Investigating salmonid survival through two separate techniques in 2019, a substantially modified fish trap design demonstrated no detectable cumulative survival effect and a significant improvement over the 2017 prototype trap design. Through paired release-recapture, the relative cumulative survival effect over a 400-km migration was 1.017 ($\widehat{SE}$ = 0.032) for adult sockeye salmon (*O. nerka*). For adult coho salmon held captive for a 48-h post-release period, survival was 1.000 (CI ($S \geq 0.978$) = 0.95). These results suggest that modified fish traps can achieve essentially 100% survival of salmonid bycatch and provide evidence that the gear may be effective in addressing existing ESA constraints in summer and fall commercial salmon fisheries of the lower Columbia River.

III. EXECUTIVE SUMMARY

With continuation of salmonid hatchery programs in the Columbia River Basin and elsewhere in the U.S Pacific Northwest, development and implementation of selective commercial gear for improved targeting of hatchery-origin fishes and reduction of bycatch impacts has been recognized as a necessary means to enable and expand sustainable commercial fishing opportunities while minimizing mortality of threatened and endangered salmonids under the Endangered Species Act (ESA). To benefit wild salmonid recovery and fisheries of the lower Columbia River, Wild Fish Conservancy (WFC) received funding from the National Oceanic and Atmospheric Administration (NOAA) Fisheries Service Bycatch Reduction Engineering Program (BREP) to expand upon a 2016 pilot study evaluating the potential of an experimental fish trap (or, 'pound net') for selective harvest and ecological monitoring. The project had three major goals: 1) test and refine deployment and operation of a fish trap in the lower Columbia River; 2) determine the effectiveness of the harvest method in capturing salmon relative to conventional gears; and 3) evaluate the ability of the gear to protect non-target species through identification of capture and release conditions, immediate survival, and post-release survival of Chinook salmon (*Oncorhynchus tshawytscha*) and steelhead trout (*O. mykiss*).

The experimental trap was successfully constructed by WFC and a local commercial fisher in August 2017. The completed fish trap represented the first of its kind since 1934 in WA State waters of the Columbia River. Engineering modifications were made based upon previous experiences in the 2016 pilot season and the designs of other alternative fishing gears tested throughout the Pacific Northwest. Test fishing and research activities proceeded from 26 August through 27 September 2017. Similar to prior alternative gear evaluations in the lower Columbia River, WFC utilized a paired release-recapture methodology with Passive Integrated Transponder (PIT) tags to estimate the relative post-release survival effect from the experimental trap. Upstream detections of tagged and released fall Chinook salmon and summer steelhead trout exposed to commercial capture procedures were compared to that of a control source of fish through the Cormack-Jolly-Seber (CJS) method. Total catch, CPUE, capture/release conditions, immediate survival, and CPUE covariates were also measured and analyzed.

By 27 September 2017, a total of 2,848 treatment and control Chinook salmon and steelhead trout were PIT-tagged and released at the experimental trap site. All tagged fish were queried for upstream detections at mainstem dam PIT tag arrays. Unique tag detection histories were recovered through the PIT Tag Recovery Information System (PTAGIS).

Results demonstrated that the prototype fish trap effectively targeted commercially viable quantities of hatchery reared fall Chinook and coho salmon (*O. kisutch*) while reducing cumulative bycatch mortality rates relative to conventional and alternative commercial gears. During the 2017 study period, 7,129 salmonids were captured and released. The relative cumulative survival effect to McNary Dam ranged from 0.944 ($\widehat{SE}$= 0.046) for adult summer steelhead to 0.995 ($\widehat{SE}$= 0.078) for adult fall Chinook salmon.

Expanding upon the 2017 BREP study, the experimental fish trap was substantially modified to eliminate air exposure, handling, and crowding of fishes during the final moment of capture. The modified gear was quantitatively evaluated in the lower Columbia River during the spring and early-summer of 2019. Similar to the 2017 BREP study, the project had three major goals: 1) test and refine deployment and operation of a modified fish trap (incorporating a new passive spiller design) in currently untested spring and summer fisheries under a host of varying environmental and ecological conditions; 2) determine the effectiveness of the harvest method in capturing salmon and shad relative to previously tested alternative gears; and 3) evaluate the ability of the gear to protect non-target species through identification of capture/release conditions, immediate survival, and post-release survival of sockeye (*O. nerka*) and spring/summer Chinook salmon.

During the spring 2019 study, salmon returns to the Columbia River were poor, representing less than half of the most recent 10-year average. As a result of low spring Chinook salmon return forecasts, test fishing was postponed to early-May at the request of NOAA Fisheries Service and the Washington Department of Fish and Wildlife (WDFW) to ensure impacts to ESA-listed species were not exceeded within the basin. Fishing was further restricted in June and July to protect ESA-listed sockeye salmon and steelhead. Despite these setbacks (in addition to challenges posed by drifting woody debris during the spring freshet), a total of 1,992 salmonids were captured in the spring and early-summer of 2019. Of the catch, 1,237 salmonids were PIT-tagged for paired release-recapture.

Supplementing the BREP paired release-recapture studies, a coho salmon post-release survival study was conducted in the fall of 2019 through the Saltonstall-Kennedy (S-K) program. For this study, a total of 121 coho salmon captured with the modified fish trap design were held captive in a net pen over a 48-h post-release observation period to estimate post-release survival.

Analyzing survival of captured and released fishes through two separate techniques, the 2019 modified trap design demonstrated no detectable post-release survival effect and a significant improvement over the 2017 prototype trap design. Estimated through a paired release-recapture CJS methodology, the relative cumulative survival effect over a 400-km migration was 1.017 ($\widehat{SE} = 0.032$) for adult sockeye salmon (*O. nerka*). For adult coho salmon held captive for a 48-h post-release period, survival was 1.000 (CI ($S \geq 0.978$) = 0.95). Given these promising results, it is likely that employment of recent fish trap engineering advancements and further research in late-summer and fall fisheries may identify improvements upon established 2017 release survival rates for fall Chinook salmon and summer steelhead trout.

Findings described in this BREP final report and associated peer-reviewed publications have been formally reviewed by WDFW and the Columbia River Technical Advisory Committee (TAC) for application by Columbia River resource management agencies. Although further research is recommended, results of this multi-year study show that modified fish traps have potential to nearly eliminate salmonid bycatch mortality in summer and fall fisheries of the lower Columbia River for the benefit of the environment, fisheries management, and the commercial fishing industry.

IV. PURPOSE

A. Description of the Problem

Background

In waters around the globe, the ecosystem hosts a variety of fish stocks that coexist in sympatry (Knudsen et al. 2000). Commercial fishers utilize specialized fishing gears to target fish stocks that are deemed desirable through market forces for consumption and profit (National Marine Fisheries Service [NMFS] 2011). In their efforts to capture specific stocks of commercial value, almost all fishermen encounter other species that are present within the ecosystem regardless of a gear's specialized intent. These fisheries in which multiple stocks are encountered in a geographical region by a specified gear-type are labeled "mixed-stock" fisheries (Lloyd 1996; Knudsen et al. 2000).

Bycatch inevitably occurs in mixed-stock fisheries when fishermen capture non-target stocks or species that may "drop out" during the fishing process or be intentionally discarded and returned to the ecosystem (NMFS 2011). Fishermen may choose to discard components of their catch if certain species, sizes, or sexes are not profitable or if government regulations prohibit retention. In instances where a fishing gear inflicts little damage to species encountered or all stocks are of sufficient health to sustain fishery impacts, bycatch may not pose a substantial risk to a fishery. However, any mixed-stock fishery that contains a threatened species or weakened stock may inflict detrimental impacts if a fishing activity causes significant bycatch mortality (Chopin and Arimoto 1995; Lloyd 1996; Gayeski et al. 2018b). The severity of the impact of bycatch is the product of the quantity of fish encountered and the bycatch mortality rate inflicted by the gear in use. In some regions of the world where species or populations of evolutionary importance are threatened with the prospect of extinction, bycatch impacts may be significant enough to extinguish renewable resources, alter ecosystem dynamics, and close regional fisheries of substantial economic, cultural, and spiritual importance (Kappel 2005; Lichatowich 2013).

Since the late 1800s, wild salmonids of the U.S Pacific Northwest have declined dramatically from cumulative effects of harvest, habitat loss, dams, and hatchery production (Lichatowich 1999). Various wild salmonid populations were extirpated shortly after the arrival of Europeans to the region, and many salmonid population groups that remain are now listed under the U.S Endangered Species Act (ESA) (Nehlsen at al. 1991; Anderson 1993; Quinn 2005). At present, the primary limiting factors to wild salmonid recovery remain harvest, habitat loss, dams, and hatchery production, with climate change recently recognized as a growing threat to ESA-listed salmonids (Crozier 2016; Lichatowich et al. 2017; Gayeski et al. 2018a).

The effect of harvest on wild salmonids is frequently compounded by hatchery production (National Research Council 1996; Lichatowich et al. 2017). By enhancing fisheries through hatchery production, resource managers increase mixed-stock fishing effort and bycatch mortality to threatened wild stocks that co-mingle with hatchery stocks during ocean rearing and the spawning migration. State, tribal, and federal (both U.S. and Canadian) agencies manage harvest to maximize catch of hatchery-origin fish—attempting to address the genetic and ecological problems associated with escapement of hatchery fish (Naish et al. 2007; Chilcote et al. 2011; Lichatowich 2013), while minimizing mortality to wild stocks mixed within regional fisheries (Canada DFO 2005; WFWC 2009; ODFW 2013). However, bycatch mortality and mixed-stock harvest can impede recovery efforts of ESA-listed stocks in lacking fishing gears that can selectively harvest targeted stocks (such as hatchery-origin fish) while leaving non-targeted fish (such as wild fish) unharmed (Wright 1993; Flagg et al. 1995; Gayeski et al. 2018b). Although mortality rates differ between species and fisheries across the West Coast, spring Chinook salmon (*Oncorhynchus tshawytscha*) bycatch mortality from conventional gill nets ranges from 49% to 43% in the lower Columbia River (Vander Haegen et al. 2004). Considering the severe impact of gill nets on captured stocks, resource managers often approve the harvest and sale of wild salmon that may be ESA listed (ODFW 2017b). Furthermore, conventional harvest practices can reduce the diversity, size, fecundity, and age structure of wild populations, thus diminishing their survival, reproductive success, and capacity for adaptation to global climate change (Ricker 1981; Hamon et al. 2000; Lewis et al. 2015).

Given the depressed status of wild Pacific Northwest salmonids and the inadequacy of conventional gears for selective harvest of hatchery-origin salmon, regional management agencies have drastically constrained commercial salmon fishing opportunities in order to foster salmonid recovery (Martin 2008; NWFSC 2015). Despite these efforts and many others, ESA-listed wild salmonid stocks have not recovered, and fishing opportunities have become increasingly limited (Lichatowich et al. 2017; Price et al. 2017; Gayeski et al. 2018a). Failure to achieve Pacific salmonid recovery and continued mixed-stock harvest of salmon in marine settings have further altered ecosystem dynamics. The populations of southern resident killer whales (*Orcinus orca*) and other apex predators have declined to historic lows due to reductions in the quantity and size of marine prey (e.g., Chinook salmon) and other factors (Ford et al. 2010; Ayres et al. 2012; Lewis et al. 2015; Lacy et al. 2017).

Alternative Commercial Gear Testing

With continuation of hatchery production programs throughout the region (Lichatowich et al. 2017), implementation of alternative selective fishing gears for improved targeting of hatchery-origin fish and reduction of wild-origin bycatch has been recognized as a necessary means for recovering ESA-listed salmonids and sustaining participation of fishing communities (WFWC 2009; WFWC 2013; ODFW 2013). Removal of the adipose fin from hatchery-origin fish enables visual differentiation between wild and hatchery stocks (Ashbrook 2008). To capitalize on advancements in stock identification, meet ESA recovery objectives, and maximize utilization of fisheries allocations, resource management agencies in the states of Washington and Oregon were directed to develop and implement alternative fishing gear to maximize catch of hatchery-origin fish with minimal mortality to native salmonids (WFWC 2009; WFWC 2013; ODFW 2013). Although alternative gear research conducted in the region has demonstrated some limited success (Vander Haegen et al. 2004; Ashbrook 2008; WDFW 2014), few viable alternative fishing practices to date have been identified and implemented to address problems associated with mixed-stock harvest of hatchery-origin salmonids (Gayeski et al. 2018a).

Table IV-1. Lower Columbia River cumulative survival estimates from four different gear-types and associated 95% confidence intervals (if available) (TAC 2008[a]; IFSP 2014[b]; WDFW 2014[c];

WDFW and ODFW Joint Staff 2018[d]; TAC 2018[e]). *Note that gill net and tangle net release survival rates for fall Chinook salmon and steelhead are only assumed and have not been studied.

Gear	Fall Chinook Survival	Steelhead Survival
Gillnet (8-8.75’’)	0.520[b]*	0.552[a]*
Tangle net (3.75’’)	0.764[e]*	0.764[d]*
Beach seine	0.750 (0.710 – 0.790)[c]	0.920 (0.820 – 1.000)[c]
Purse seine	0.780 (0.720 – 0.850)[c]	0.980 (0.930 – 1.000)[c]

Fish Trap Technology

Recognizing the limitations of previously evaluated alternative commercial gears in reducing stock-specific bycatch mortality rates, fisheries scientists and managers alike have recommended fish traps, or ‘pound nets’ as another potential alternative to gill nets (Ashbrook 2008; Tuohy 2018). The fish trap was a historically effective and popular indigenous and commercial gear used in salmon fisheries of the U.S. Pacific Northwest (Cobb 1930; Lichatowich 1999). The fishing method was banned in Washington State in 1934 and Oregon in 1948 due to the perceived contribution of the gear to salmon decline in these mostly unregulated fisheries (WA State Session Laws 1935; Johnson, Chapman, and Schoning 1948; Higgs 1982). Contrary to the specified intent of the ban, resource managers failed to reduce total fishing effort and meet biologically acceptable escapement goals after 1934 (Johnson, Chapman, and Schoning 1948; Boxberger 1989; Lichatowich 2013). Shortly after the elimination of fish traps and other fixed-gears, Columbia River and Puget Sound salmon fisheries collapsed (Licahtowich 1999).

Figure IV-1. Salmon brailed from a fish trap in Puget Sound in the early 20th Century.

Fish traps are a form of fixed gear, meaning that the tool remains deployed in one place to passively capture fishes (Cobb 1921). Three separate forms of traps historically existed in Pacific Northwest salmon fisheries:

1) Pile/pound net traps: constructed of stout wood pilings driven into benthic sediment of rivers and estuaries.

2) Stake/stone traps: constructed of wood stakes/stones in shallow estuaries or small rivers.

3) Floating traps: anchored with concrete and chain in locations where piles cannot be driven due to depth or substrate.

Consisting of a series of pilings, stakes, or anchors and attached web fences that extend from the high-water mark toward the river or estuary bottom, traps funnel returning adult salmonids from the 'lead' (a fine-meshed wall positioned perpendicular to shore) through a maze of mesh compartments in which fish rarely escape (Cobb 1921). Captured salmonids instinctively move against the current into progressively smaller compartments of a fish trap ('heart', 'spiller', and 'live well', respectively) (Cobb 1930; Tuohy et al. 2019). The final compartment has dimensions appropriate for operators to sort the catch for harvest or release with little to no air exposure and handling (Tuohy 2018). In contrast with gill nets and other conventional fishing gears, salmonids remain free-swimming within a fish trap and selected mesh dimensions minimize or prevent entanglement altogether (Tuohy et al. 2019). This low-impact, live capture process reduces physical and physiological impairment to fish that commonly arises from use of conventional commercial fishing practices, thereby increasing product quality and the likelihood of wild salmonid bycatch survival (Baker and Schindler 2009; Burnley et al. 2012; Raby et al. 2015). Furthermore, when used in fluvial settings, the fish trap does not deprive killer whales of the opportunity to secure marine food resources required for their survival (Ford et al. 2010; Gayeski et al. 2018b). Consequently, there may be many marketing advantages to using fish traps and significant value added to seafood products.

Columbia River Pound Net Testing

In 2013, the non-profit organization Wild Fish Conservancy (WFC), the Washington Department of Fish and Wildlife (WDFW), and commercial fisherman Blair Peterson of Cathlamet, WA collaborated on a project to develop the first fish trap prototype in Washington State waters in nearly eighty years. Ultimately, the goal of this project was to identify an effective fishing technology for the reduction of bycatch impacts to ESA-listed salmonids. Based on historical blueprints of Columbia River traps and inspired by stock-selective successes in the Lummi Island reef net fishery, the fish trap was constructed in the Cathlamet Channel of Wahkiakum County at river kilometer (rkm) 67 where salmon traps were once common prior to Washington State's ban of fixed-gear in 1934 (WA State Session Laws 1935). In this pilot season, procedures for operation were developed. Lacking existing performance data for fish traps, an evaluation of the gear was initiated in 2016. Test fishing targeted fall Chinook and coho salmon to examine the potential of the gear to capture salmon while minimizing immediate mortality of fishes (Tuohy 2018).

The fish trap was operated for 258-h over 30-d between 26 August and 29 September 2016 (Tuohy 2018). A total of 2,153 salmonids were captured throughout the study, with 2,144 salmonids (99.58% of catch) released in a vigorous and lively condition (Table IV-2). A total of nine coho salmon jacks were killed (7 of hatchery origin; 2 wild), for an immediate mortality rate of 0.42%. From these results, immediate survival for all ages of Chinook salmon and steelhead trout was 100%. Adult coho salmon immediate survival was 100%; combined immediate survival for all ages of the species was 98.87%. Ultimately, these findings demonstrated that fish traps could capture salmon with very high rates of immediate survival. Showing adequate promise to help resolve an important harvest and hatchery problem in the lower Columbia River, support was gained from resource managers to further assess post-release survival from a modified fish trap in 2017 through a paired release-recapture study.

Table IV-2. Stock-specific immediate mortality during the 2016 study period.

Species	Total Captured	Mortalities (Adults)	Mortalities (Jacks)	Immediate Mortality	Immediate Survival
Chinook	534	0	0	0.0000	1.0000
Coho	796	0	9	0.0113	0.9887
Chum	5	0	0	0.0000	1.0000
Sockeye	2	0	0	0.0000	1.0000
Steelhead	816	0	0	0.0000	1.0000

B. Objectives

To develop innovative and effective fishing technologies for the reduction of bycatch impacts to ESA-listed salmon and benefit of U.S fisheries, WFC and a local commercial fisher constructed and monitored the performance of an experimental fish trap in the lower Columbia River during the late-summer and fall of 2017, and again during the spring and early-summer of 2019 with a modified passive spiller design. Specifically, objectives were to determine the effectiveness of the gear in capturing targeted salmonid and shad stocks for harvest and research while reducing mortality of released fishes relative to the performance of previously tested commercial gears in the lower Columbia River. Environmental covariates, catch-per-unit-effort (CPUE), capture conditions, bycatch, immediate survival, and post-release survival were assessed. Methods similar to Vander Haegen et al. (2004), Ashbrook (2008), and WDFW (2014) for experimental seine and tangle net operations were employed to maintain consistency for comparison of results between studies, with minor alterations to improve precision and reduce bias of survival estimates. Like previous alternative gear tests, this study had three major goals:

1) Test and refine deployment/operation of a fish trap under modern conditions of the Columbia River and a host of varying seasonal environmental and ecological conditions.

2) Determine the effectiveness of the harvest method in capturing salmonids relative to conventional gears. Directly estimate species-specific CPUE.

3) Evaluate the ability of the trap to release fish unharmed during commercial harvest or research operations through identification of immediate and post-release survival of Chinook salmon, sockeye salmon, coho salmon, and steelhead trout.

Assessing CPUE from the experimental trap and estimating survival through paired release-recapture and net pen holding, this study investigated the effectiveness of the alternative gear in capturing targeted stocks with improved survivorship of released fishes relative to previously tested commercial gears. Providing precise and unbiased estimates of cumulative survival to fisheries managers may enable implementation of low-impact selective harvest and/or research tools for the rejuvenation of working waterfronts and the recovery of wild salmonids.

Questions:

- How do cumulative survival estimates from an experimental trap compare to other commercial gears tested in the lower Columbia River?
- How does stock-specific CPUE from the modified 2017 trap compare to the performance of the trap in 2016 and other commercial gears operating in the lower Columbia River?
- What environmental covariates explain CPUE at the trap site?
- Are fish traps feasible for operation during spring and early-summer months in the lower Columbia River given varying seasonal river conditions?
- Does inclusion of a modified passive spiller design (reducing air exposure, handling, crowding, and net contact) improve fish survival over the 2016-2018 prototype design?

Null-Hypotheses:

A) Cumulative survival of salmonids from the experimental trap is equal to or less than that of previously tested gears in the lower Columbia River.
B) CPUE of fall Chinook and coho salmon from the experimental trap is equal to or less than that of conventional gears used in the lower Columbia fall fishery. CPUE cannot be explained by environmental covariates.
C) The fish trap is not feasible for commercial or research operations during spring and early-summer seasons in the lower Columbia River due to high flows, drifting woody debris, and other biological factors.
D) Salmonids captured with a modified passive spiller design (reducing air exposure, handling, crowding, and net contact) have equivalent release-survival relative to salmonids captured with the 2016-2018 prototype design.

Alternative Hypotheses:

A) Cumulative survival of salmonids from the experimental trap is greater than that of previously tested gears in the lower Columbia River.
B) CPUE of fall Chinook and coho salmon from the experimental trap is greater than that of conventional gears used in the lower Columbia fall fishery. CPUE can be explained in part by environmental covariates.
C) The fish trap is feasible for commercial or research operations during spring and early-summer seasons in the lower Columbia River.
D) Salmonids captured with a modified passive spiller design (reducing air exposure, handling, crowding, and net contact) have greater release-survival relative to salmonids captured with the 2016-2018 prototype design.

V. APPROACH

A. Description of the Work Performed

Trap Design and Modifications

Based on historical trap designs, photographs, and anecdotes from the 1880s through the 1930s, 44 untreated 16-inch diameter wood pilings (40.64 cm) were driven approximately 3 m to 5 m apart in the Columbia River, Cathlamet Channel of Wahkiakum County, WA at river kilometer (rkm) 67. This study site was a historically successful trapping location in the late 19th and early 20th centuries and was locally known for high densities of salmon and steelhead trout. The Cathlamet Channel is 1.1 km wide at this point in the river, with a maximum depth of 6.1 m at high tide and minimum depth of 3.3 m at low tide.

The experimental trap prototype consisted of a lead (~90 m), jigger (~10 m), heart, tunnel, and spiller (6 m x 6 m x 9 m) (Figure V-1). Black nylon mesh with a stretch of 3-1/8 inches (7.94 cm) was selected for application to the lead, jigger, and heart pilings in 2017. The heart mesh was reduced to 2-1/2 inches (6.35 cm) to reduce wedging of jacks in 2019. The spiller and tunnel were constructed of 2-1/2 inch (6.35 cm) knotless nylon mesh from 2017 - 2019. These mesh sizes were selected to minimize both entanglement of fishes and drag within the water column. All compartment nets were secured to the pilings from the bottom of the riverbed to ~1 m above the high-water mark, spanning ~8 m vertically.

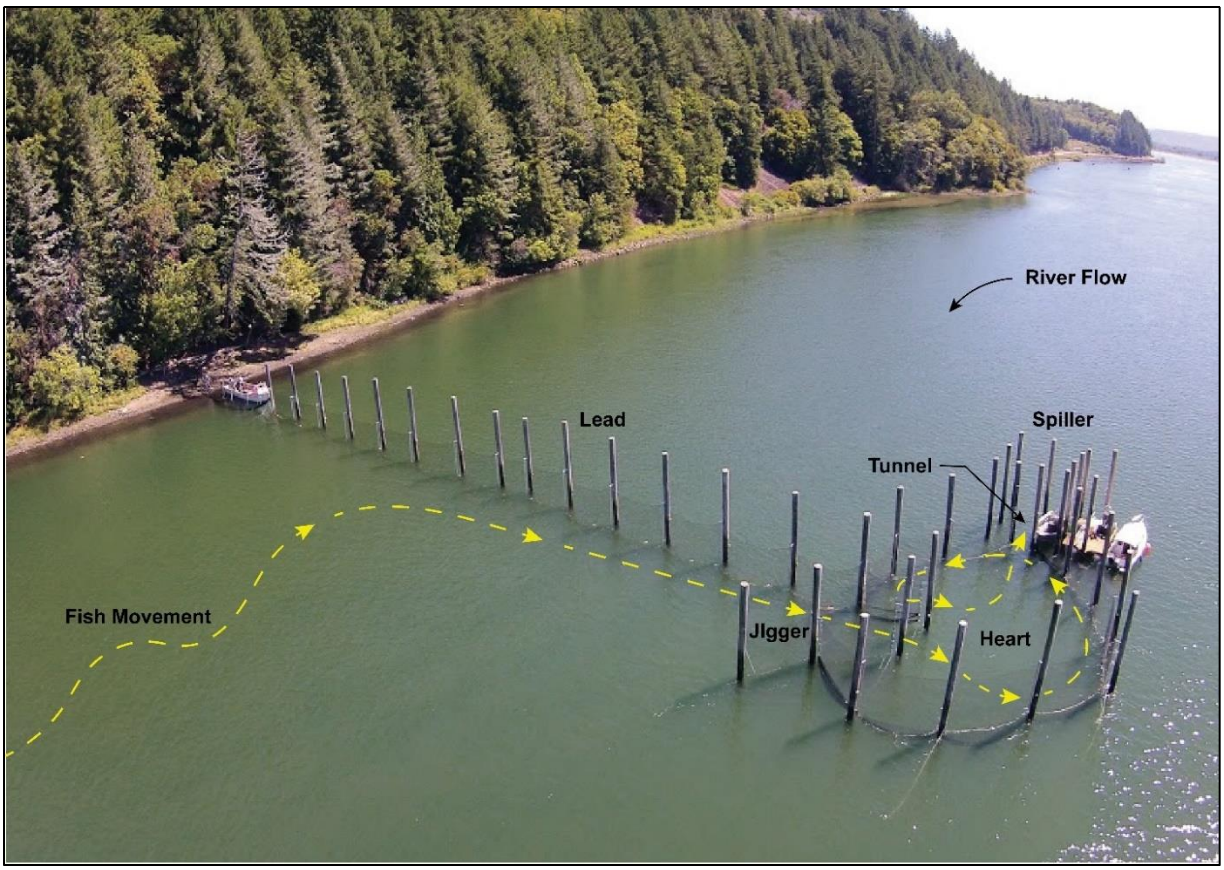

Figure V-1. The fish trap consisted of a lead, jigger, heart, tunnel, and spiller.

The spiller/tunnel complex was engineered for deployment and retrieval to and from the river bottom with line and pulley. Weights (27 kg) at each corner of the spiller compartment enabled gravity to draw the mesh flush to the river bottom during each soak period. A solar-powered electric winch was installed near the top of the pilings to pull the bottom mesh of the spiller upward through the water column to the shallows during each haul to allow captured fishes to be accessed swiftly from the depths of the river with minimal air exposure and stress in 2017 (henceforth, the “prototype” treatment). Adjacent to the spiller, a pontoon dock enabled fish transferred from the spiller compartment to be sorted within the confines of a perforated aluminum framed live-well (2.13 m x 0.61 m). Within this compartment, all fish remained free-swimming and submerged with continuously circulating river water. With the completion of a set, a small door to the live-well was opened allowing all captured fishes to swim upstream with minimal handling and air exposure.

Modifications to the experimental trap design and operations were made in 2017 to increase capture efficiency and reduce physical and physiological damages to captured fishes relative to the 2016 pilot study design (Tuohy 2018). The following modifications were made to each component of the trap:

1) Lead and heart nets – WFC staff dove to the river bottom to ensure nets were fully descended to the sediment to minimize escapement points and increase capture of benthic oriented species (e.g., Chinook salmon).

2) Spiller – The mesh size was reduced to 2-1/2’’ (6.50 cm) stretch knotless black nylon material to minimize gilling and wedging of jacks. Furthermore, the shape of the spiller bunt was arced toward the spiller door and curved in the corners to increase the tendency of fish to naturally migrate out the spiller door and into the live-well during lift.

3) Spiller lifting system – 1/4’’ (6.35 mm) stainless steel cables were attached on the inside of each spiller piling to guide deployment and lift of the spiller along steel rings at each net-piling attachment point (replacing aluminum poles as the guiding mechanism). This effort was made to reduce friction during lifting and lowering of the spiller compartment, increase the speed of lift for more efficient spills and soaks, and ensure the spiller and tunnel were resting flush with the riverbed during all periods of deployment to increase capture efficiency.

4) Winch lifting point –The lifting point of the spiller was raised from 9.14 m above the riverbed to 11.58 m to improve the ability of fishers to effectively complete sets during the highest tides and spill fish more efficiently.

5) Heart apex – A 1.50 m X 7.62 m panel of 2 ½’’ (6.50 cm) stretch knotless black mesh (referred to as the “fish gate”) was installed at the outlet of the heart to reduce escapement of fish from the heart compartment during lifting of the spiller and to increase buildup of fish within the heart prior to initiation of each succeeding soak period. The “fish gate” could be lifted or lowered along 1/4’’ (6.35 mm) stainless steel cable through a system of line, pulley, and weights.

6) Marine mammal deterrent – A marine mammal gate with 8.26 cm diameter rectangular aluminum frame was installed at the entrance to the heart compartment of the trap to prevent entry of seals and sea lions while enabling passage of salmonids for capture (Figure V-2). This gate consisted of a series of vertical 3.81 cm diameter aluminum bars spaced at 25.4 cm

increments along the frame and was constructed with hinges to enable staff to open and close the gate depending on the abundance of marine mammals within the vicinity of the study location.

Figure V-2. Marine mammal gate deployed at the entrance to the heart of the trap to prevent entry of mammals and enable passage of fish.

The following modifications were made in 2019 to further increase survival of captured and released fishes relative to the prototype design and enable operations during spring and early-summer periods with high river flow and drifting woody debris:

1) Spiller – A modified passive capture design (henceforth, the 'modified treatment') was implemented in 2019 by adding a new upstream tunnel to the existing spiller compartment (Figure V-3). This upstream tunnel (6.35-cm knotless-nylon mesh) passively funneled migrating fishes individually (or in small schools less than ten) from the spiller to the shallows of an attached upstream live well. The live well was aluminum framed with 3.81-cm knotless-nylon mesh walls. It was equipped with two parallel chambers (2.74 × 0.61 × 0.76 m) and a mesh pivot capture door near the outlet of the upstream spiller tunnel. Operators could open or close the pivot door to passively capture migrating fishes in one chamber while enabling the vacant chamber to occupy. Within the live well, the free-swimming catch could be comfortably sorted for harvest, or data collection and passive release through an upstream mesh exit door. This 2019 modified trapping process largely eliminated fish air exposure, handling, crowding, and net contact associated with the 2017 prototype trapping process (with the intent of improving salmonid survival and reproductive success post-release).

2) Lead nets – An improved line and pulley system was installed at each lead pile to enable faster lifting and lowering of the lead net during periods of high river flow and abundant woody debris.

3) Heart nets – The mesh size was reduced to 2-1/2'' (6.50 cm) stretch knotless black nylon material to minimize gilling and wedging of jacks at the downstream heart panel. Additionally, the heart apron (a section of net at the base of the heart that stacks on the riverbed to account for inconsistencies in bathymetry) was extended 1.5 m (a total of 2.4 m) toward the center of the heart along the riverbed and weighted with heavy steel chain to eliminate potential entry points for marine mammals below heart nets.

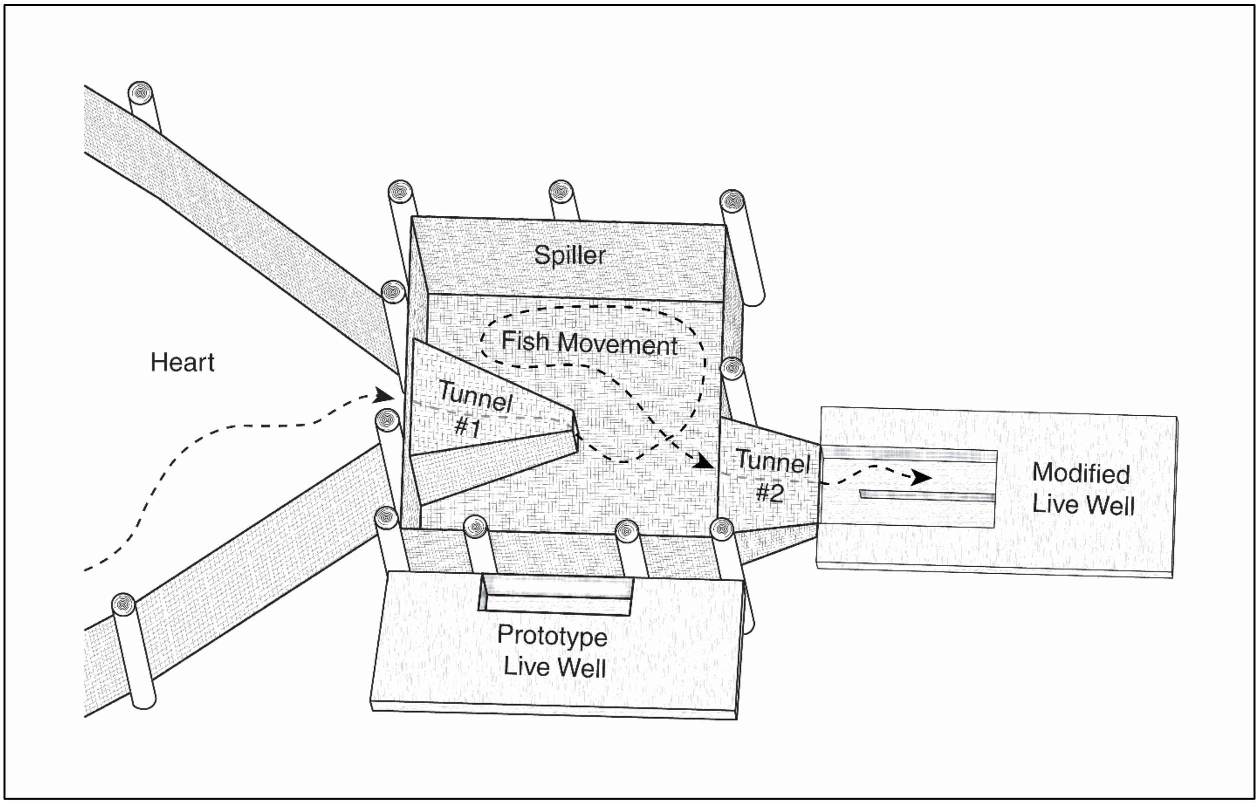

Figure V-3. Diagram of the modified passive treatment design. The addition of upstream tunnel #2 passively funneled free-swimming fishes in the spiller to a new upstream live-well for capture and release. This design mostly eliminated the need for the electric winch and reduced air exposure, handling, crowding, and net contact associated with the 2017 prototype process.

<u>Field Protocol</u>

The BREP study was conducted at the experimental trap site from 26 August through 27 September 2017, and again from 5 May through 3 July 2019. These research periods represented the peak of fall Chinook salmon, coho salmon, sockeye salmon, and summer steelhead upriver migration in the lower Columbia River (Johnson, Chapman, and Schoning 1948; Burgner 1991; Healey 1991; Sandercock 1991). Hatchery-origin Chinook and coho salmon are commercially targeted for harvest within Columbia River fisheries. Specific populations of wild-origin steelhead trout, Chinook salmon, coho salmon, chum salmon, and sockeye salmon are ESA listed and constitute common bycatch stocks that dramatically constrain commercial fisheries of the region (Martin 2008; NFSC 2015).

Testing proceeded in the following manner. Three people were present on site, including two trained WFC employees, a commercial fisherman, or volunteers from the region. WFC staff were primarily involved in the deployment and retrieval of the gear, capture and handling of fishes, tagging, positioning of the work vessel, and snorkel surveillance. A WFC observer or University intern was responsible for recording data directly through computer software and by hand with pencil and paper for backup and reference.

When all participants were prepared, the trap spiller was deployed to the river bottom by releasing lines and disengaging the electric winch brake. The tunnel door was opened by tightening the harness pulley line, initiating the soak period and enabling the capture of fishes. Observers noted the beginning set time, tidal stage, tide height (m), water temperature (ºC; Extech), and presence of marine mammals. The tunnel door remained open to fish passage until the desired soak period ended or the capacity of the spiller had been reached.

Once the soak period had ended (generally 3 – 60 minutes), the tunnel door was closed by releasing the tunnel harness line, preventing further entry or escape. An observer turned on a live-streaming video recorder through the application “Periscope” and noted the end set time, tidal stage, tide height, water temperature, and presence of marine mammals. The spiller bottom was then carefully lifted utilizing an electric winch to concentrate captured fishes toward the spiller door (positioned adjacent to the live-well of the sorting deck) (Figure V-4). All fish experiencing this procedure were noted to be of the prototype treatment group.

Figure V-4. A haul of salmon is concentrated toward to spiller door through the prototype spilling method in August 2017.

Alternatively, fish could be captured one-by-one utilizing the modified passive spiller design in 2019 (Figure V-3; Figure V-5). This technique enabled the spiller to be deployed throughout the duration of daily sampling, with retrieval occurring only at the conclusion of a sampling event. With the new upstream tunnel open to passage, fish passively entered the modified live-well for sorting (Figure V-5). All fish experiencing this procedure were noted to be of the modified spiller treatment group.

Figure V-5. WFC staff wait to passively entrap sockeye salmon one-by-one through the modified passive spiller method in June 2019.

Once salmonids and bycatch species were captured in a live well (Figure V-6), all specimens were individually counted, measured (FL), and identified for species type, origin (hatchery/wild), and capture condition (lively, lethargic, bleeding, lively/bleeding, lethargic/bleeding, dead) (WDFW 2014). A subsample of Chinook salmon, sockeye salmon, and steelhead were Passive Integrated Transponder (PIT) tagged for paired release-recapture and/or fin-clipped for genetic sample; these fish were placed into the recovery chamber of the live-well with recirculating freshwater (Farrell et al. 2001). After documentation of abnormalities and/or injuries, all fish (hatchery and wild) were passively released through the live-well door to resume the upriver migration. WFC staff further conducted routine snorkel and free-dive surveys at low tide to determine any potential maintenance needs or immediate mortalities at nets which remained deployed. These field methods enabled documentation of capture/release conditions, bycatch, immediate survival, and CPUE.

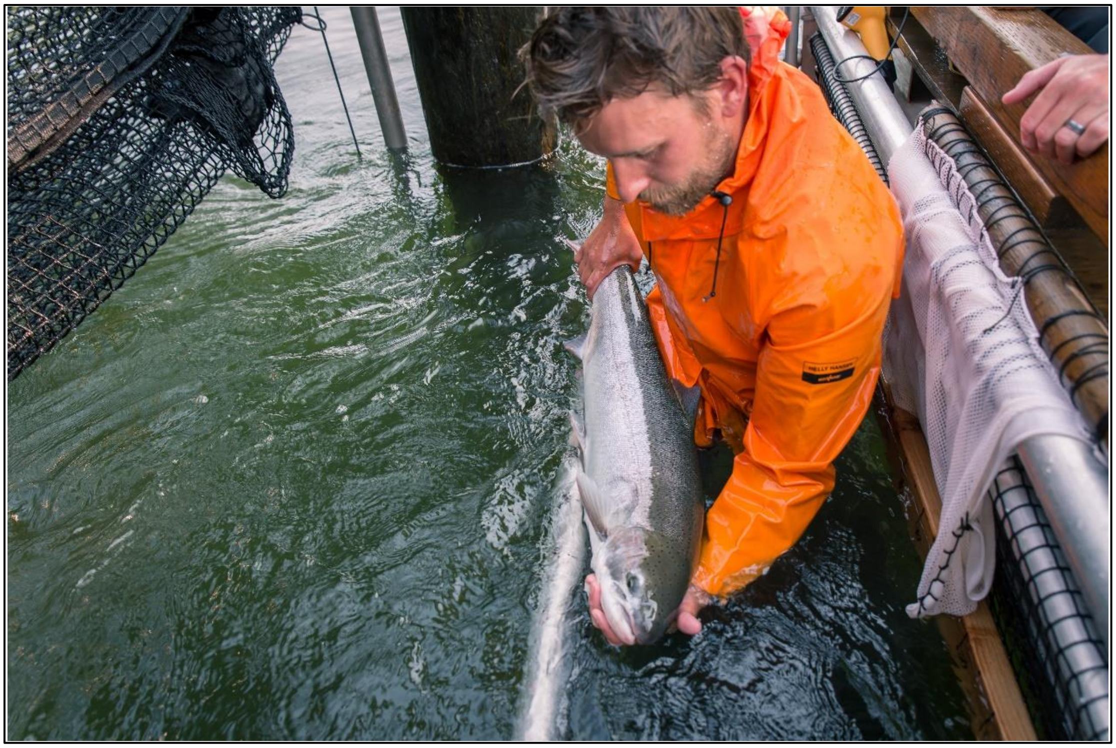

Figure V-6. A hatchery-origin steelhead is released from the prototype live-well after being measured, PIT tagged, and fin-clipped for genetic sample.

Cormack-Jolly-Seber Survival Analysis

A paired release-recapture methodology was utilized to estimate post-release survival from the experimental trap to upstream detection points (Cormack 1964). Control and treatment groups of randomly sampled Chinook salmon, sockeye salmon, and steelhead trout were sourced at the study location, tagged, and released for detection at upstream dams. During each test fishing day, control and treatment tagging sessions were generally assigned alternately and large sample sizes were achieved. These methods were employed to reduce potential for violation of model assumptions: (1) the fate of each fish is independent, (2) control and treatment fish have equivalent handling and tagging survival, (3) control and treatment fish have equivalent stock-composition, marine mammal predation, harvest pressures, environmental stressors, and tag loss, (4) all treatment fish have equal survival and recovery probabilities, (5) all control fish have equal survival and recovery probabilities, and (6) survival from handling/tagging effects is independent of in-river upstream survival. It must be noted, however, that there was some limitation to alternating control and treatment group tagging events due to light conduction and water clarity, which affected the ability of field staff to randomly handle the catch.

Treatment groups experienced commercial capture procedures and were split amongst two separate treatments depending on the year of operation:

1) Prototype treatment: represented by individuals lifted en masse by the electric winch and spilled from the fish trap spiller to the live-well with mesh, line, and pulley. This commercial process involved some minimal air exposure, net contact, handling, and crowding. The winch-

and-spill treatment was operated exclusively from 2016-2018, and minimally in 2019 to discern potential differences in release survival between modified treatment and control groups.

2) Modified passive spiller treatment: represented by individuals that passively swam one-by-one through the new upstream tunnel from the spiller compartment to an upstream live-well. This low-impact commercial process mostly eliminated air exposure, net contact, handling, and crowding associated with the prototype spilling process. The treatment was operated in 2019 to distinguish potential differences in release-survival from prototype treatment and control groups.

All Chinook salmon, sockeye salmon, and steelhead trout captured in 2017 and 2019 were scanned for existing PIT tags with a Biomark 601 reader. If existing PIT tags were detected, codes were recorded directly into a computer database using P4 software (PTAGIS 2017); these fish were then passively released from the live-well chamber. In the absence of an existing PIT tag, Chinook salmon, sockeye salmon, and steelhead were tagged in the peritoneal cavity (as approved by the FDA) with a 12.5 mm 134.2 kHz full duplex PIT tag and an MK-25 Rapid Implant Gun (Figure V-7) (Biomark, Boise, ID). These fish were then scanned to document the tag number. Additionally, a subset of Chinook, sockeye, and steelhead received non-lethal 2 mm fin clips for genetic analysis to address any potential biases from violation of model assumptions. Tissue samples were stored in 97% ethyl alcohol and unique genetic sample numbers were recorded simultaneously with a specimen's PIT tag code utilizing P4 software. With tagging and fin-clipping procedures complete, fish were released from the live-well recovery chamber for upstream detection at mainstem dam PIT tag arrays (WDFW 2014).

Figure V-7. Biomark 601 reader, MK-25 Rapid Implant Gun, and 12.5 mm 134.2 kHz full duplex PIT tags used for the mark-recapture study.

Similar to previous alternative gear studies, control groups of Chinook salmon, sockeye salmon, and steelhead trout were passively captured, tagged, and released for detection upstream to control for the effects of handling/tagging on adult salmonid survival and potential tag drop-out. Free-swimming fish unexposed to potentially damaging commercial spilling processes were sourced on an individual basis with a rubberized dip net, enabling investigators to handle, PIT-tag, and release adult fish for detection upriver in a low-impact manner. This control sourcing technique was likely less stressful than procedures used in Columbia River purse seine, beach seine, and tangle net studies, during which control group fish were trapped at the Bonneville Dam adult fish passage facility, dip netted, PIT-tagged, trucked downriver to the test fishing location (rkm 225), and transferred from a truck into the water to repeat the upriver migration for a second time (Vander Haegan et al. 2004; Ashbrook 2008; WDFW 2014). Consequently, survival in our study is likely biased lower relative to past studies[1].

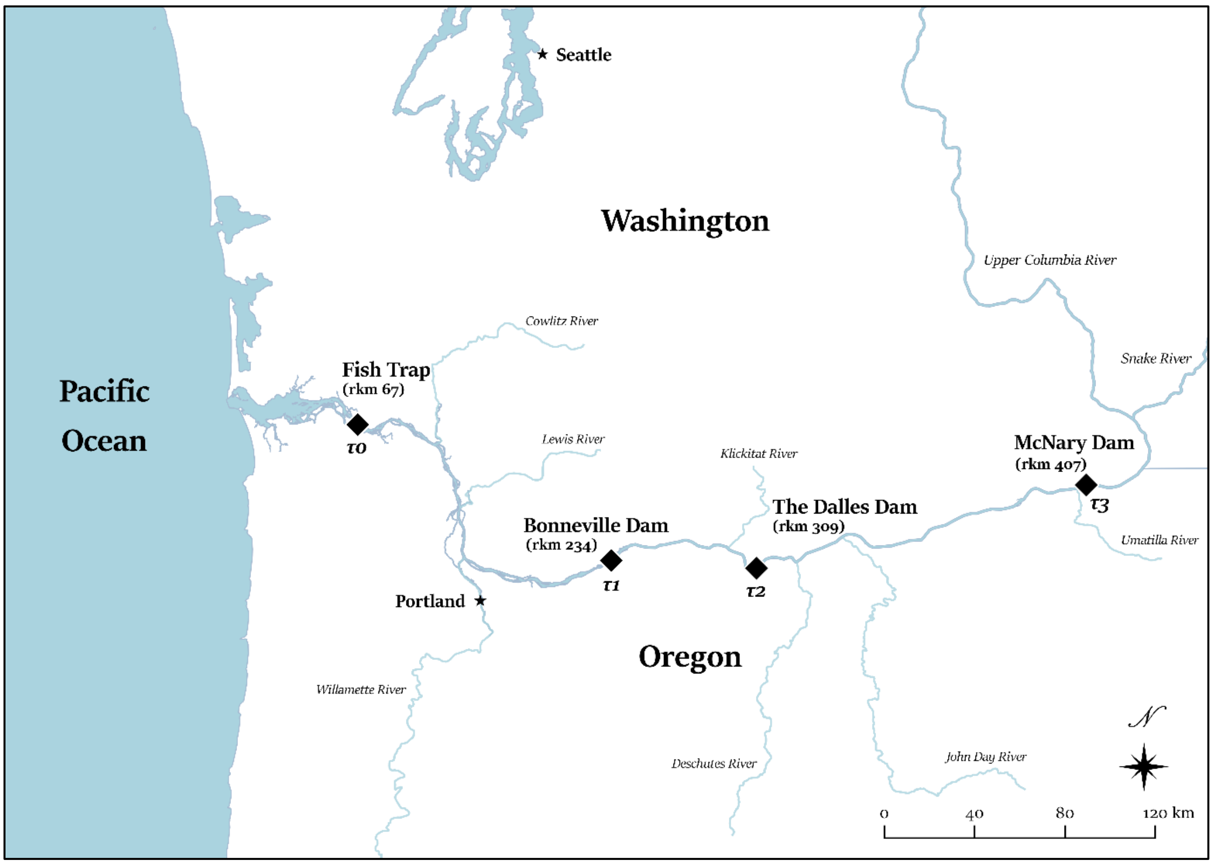

Figure V-8. Map of the Columbia River study region and mainstem dam PIT-tag arrays.

[1] It must be noted that investigators considered use of a control group that had been PIT-tagged during the juvenile life-history stage at hatchery facilities in the Columbia Basin. However, this strategy was considered flawed for the following reasons: (1) PIT-tagged juveniles returning as adults to the Columbia River would not experience the same adult handling and tagging process required for the treatment group, and therefore, the control group would not serve one of its primary purposes (controlling for the effects of handling/tagging on adult salmonid survival and potential tag drop-out); (2) estimation of relative survival in the 150 km river reach below Bonneville Dam would be impossible given the absence of an effective lower river array; (3) comparisons to previous alternative gear results from the lower Columbia River would be biased, with the treatment effect on survival from the trap representing an estimate of the joint probability of survival from both the commercial gear and the handling/PIT-tagging process.

A pair of Cormack (1964) single release–recapture models (a special case of the Cormack–Jolly–Seber model; Cormack 1964; Jolly 1965; Seber 1965) was used to estimate post-release survival of treatment Chinook salmon, sockeye salmon, and summer steelhead relative to controls (τ) between the capture and release site (rkm 67) and upstream detection sites at Bonneville Dam (rkm 234), The Dalles Dam (rkm 309), and McNary Dam (rkm 470) on the Columbia River mainstem (Figure V-8). The joint probability of survival and detection was also estimated for pooled detection sites above McNary Dam. The joint-tagging model helped to separate the effects of survival from detection and to adjust for the control effects of handling and tagging (Cormack 1964; Jolly 1965; Seber 1965). Analogous to prior Columbia River alternative gear survival studies that used the Ricker relative recovery method (Ricker 1958; Ashbrook 2008; WDFW 2014), immediate survival (τ_0) from capture to release from the gear (rkm 67), short-term survival (τ_1) from release to Bonneville Dam (rkm 234), long-term survival from Bonneville Dam to McNary Dam (rkm 470) (τ_2 and τ_3), and cumulative survival ($\tau_0 \times \tau_1 \times \tau_2 \times \tau_3$) from initial capture at the trap site to McNary Dam were estimated (Figure V-8). However, use of the Cormack (1964) release–recapture model for this study enabled estimation and correction for possible differences in treatment-specific detection probabilities (Cormack 1964; Jolly 1965; Seber 1965). Furthermore, it must be noted that the capture/release site used for this fish trap study differed from that used in previous post-release survival studies. The tag-and-release locations for purse-seine, beach-seine, and tangle-net studies were between rkm 209 and 233 of the Columbia River (Ashbrook 2008; WDFW 2014). Our experimental trap was located at rkm 67. The consequence is that survival in this study is measured over a greater distance and duration and hence might be expected to be biased lower than that of past studies.

A Cormack (1964) single release–recapture model was used to describe the observed detection histories of the tagged fish at four upstream detection sites (i.e., Bonneville, The Dalles, and McNary dams and detection sites above McNary Dam). Potential detection histories for tagged control and treatment group fish (along with model probabilities of occurrence in the paired Cormack–Jolly–Seber model) are described as follows (Table V-1 and Table V-2):

Table V-1. Potential detection histories for control group fish. A “1” denotes detection and “0” nondetection at the four upstream detection locations.

History	Probability of Occurrence (Control)	Count
1111	s1*p21*s2*p22*s3*p23* λ	m_{1111}
0111	s1*q21*s2*p22*s3*p23* λ	m_{0111}
1011	s1*p21*s2*q22*s3*p23*λ	m_{1011}
0011	s1*q21*s2*q22*s3*p23*λ	m_{0011}
1101	s1*p21*s2*p22*s3*q23*λ	m_{1101}
0111	s1*q21*s2*p22*s3*q23*λ	m_{0111}
1001	s1*p21*s2*q22*s3*q23*λ	m_{1001}
0001	s1*q21*s2*q22*s3*q23*λ	m_{0001}
1110	s1*p21*s2*p22*s3*p23*(1-λ)	m_{1110}
0110	s1*q21*s2*p22*s3*p23*(1-λ)	m_{0110}
1010	s1*p21*s2*q22*s3*p23*(1-λ)	m_{1010}
0010	s1*q21*s2*q22*s3*p23*(1-λ)	m_{0010}
1100	s1*p21*s2*p22*((1-s3)+(s3*q23)*(1-λ))	m_{1100}

0100	s1*q21*s2*p22*((1-s3)+(s3*q23)*(1-λ))	m_{0100}
1000	s1*p21*((1-s2)+(s2*q22)*((1-s3)+(s3*q23)*(1-λ)))	m_{1000}
0000	(1-s1)+s1*q21*((1-s2)+s2*q22*((1-s3)+s3*q23*(1-λ)))	m_{0000}

Table V-2. Potential detection histories for treatment group fish. A "1" denotes detection and "0" nondetection at the four upstream detection locations.

History	Probability of Occurrence (Treatment)	Count
1111	(s1*t1)*p11*(s2*t2)*p12*(s3*t3)*p13*(λ*t4)	m_{1111}
0111	(s1*t1)*q11*(s2*t2)*p12*(s3*t3)*p13*(λ*t4)	m_{0111}
1011	(s1*t1)*p11*(s2*t2)*q12*(s3*t3)*p13*(λ*t4)	m_{1011}
0011	(s1*t1)*q11*(s2*t2)*q12*(s3*t3)*p13*(λ*t4)	m_{0011}
1101	(s1*t1)*p11*(s2*t2)*p12*(s3*t3)*q13*(λ*t4)	m_{1101}
0111	(s1*t1)*q11*(s2*t2)*p12*(s3*t3)*q13*(λ*t4)	m_{0111}
1001	(s1*t1)*p11*(s2*t2)*q12*(s3*t3)*q13*(λ*t4)	m_{1001}
0001	(s1*t1)*q11*(s2*t2)*q12*(s3*t3)*q13*(λ*t4)	m_{0001}
1110	(s1*t1)*p11*(s2*t2)*p12*(s3*t3)*p13*(1-(λ*t4))	m_{1110}
0110	(s1*t1)*q11*(s2*t2)*p12*(s3*t3)*p13*(1-(λ*t4))	m_{0110}
1010	(s1*t1)*p11*(s2*t2)*q12*(s3*t3)*p13*(1-(λ*t4))	m_{1010}
0010	(s1*t1)*q11*(s2*t2)*q12*(s3*t3)*p13*(1-(λ*t4))	m_{0010}
1100	(s1*t1)*p11*(s2*t2)*p12*((1-(s3*t3))+(s3*t3*q13)*(1-(λ*t4)))	m_{1100}
0100	(s1*t1)*q11*(s2*t2)*p12*((1-(s3*t3))+(s3*t3*q13)*(1-(λ*t4)))	m_{0100}
1000	(s1*t1)*p11*((1-(s2*t2))+(s2*t2*q12)*((1-(s3*t3))+(s3*t3*q13)*(1-(λ*t4))))	m_{1000}
0000	(1-s1*t1)+s1*t1*q11*((1-s2*t2)+s2*t2*q12*((1-s3*t3)+s3*t3*q13*(1-(λ*t4))))	m_{0000}

The joint likelihood for the tagging study was expressed as a product of two multinomial distributions: the first describing the probability of seeing the control capture histories, and the second describing the probability of the treatment histories:

$$L\left(s_i,\tau_i,\underset{\sim}{p}_{ci},\underset{\sim}{p}_{ti},\lambda \mid R_c,\underset{\sim}{m}_{ci},R_t,\underset{\sim}{m}_{ti}\right)=\binom{R_c}{\underset{\sim}{m}_{ci}}\prod_{i=1}^{16}P_{ci}^{m_{ci}}\cdot\binom{R_t}{\underset{\sim}{m}_{ti}}\prod_{i=1}^{16}P_{ti}^{m_{ti}} \quad \text{(V.1)}$$

where

R_c = number of control group fish tagged and released,

m_{ci} = number of control group fish with detection history i ($i = 1, \cdots, 16$)

P_{ci} = probability of capture history i for the control group (e.g., $p_{c1111} = s_1{*}p_{c1}{*}s_2{*}p_{c2}{*}s_3{*}p_{c3}{*}\,\lambda$),

R_t = number of treatment group fish tagged and released,

m_{ti} = number of treatment group fish with detection history i ($i = 1, \cdots, 16$)

P_{ti} = probability of capture history i for the treatment,

i = detection history.

In tables V-1 and V-2, the model parameters are defined as follows:

s_i = survival probability in reach i for control group fish ($i = 1, \cdots, 3$),

p_{ci} = probability of detection at location i for control group fish ($i = 1, \cdots, 3$),

p_{ti} = probability of detection at location i for treatment group fish ($i = 1, \cdots, 3$),

τ_i = treatment effect on survival in reach i ($i = 1, \cdots, 4$),

λ = joint probability of survival and detection in reach 4 for control group fish (e.g., $\lambda = s_4 * p_4$),

With four upstream detection locations, there were $2^4 = 16$ possible unique detection histories. The four-digit capture histories were denoted by a "1" if detected at a location, a "0" otherwise. In the final reach above McNary Dam only the joint probability of survival and detection could be estimated (λ).

Unique detection histories of control and treatment group fish were downloaded from PTAGIS (PIT-tag Information System), operated by the Pacific State Marine Fisheries Commission (which provides public access to all PIT-tag detection data throughout the Columbia River Basin). The tagging data were uploaded to Program USER (User Specified Estimation Routine) to calculate maximum likelihood estimates of survival, standard error, and 95% profile likelihood confidence intervals (Kalbfleisch and Sprott 1970; Hudson 1971; Skalski and Millspaugh 2006) (http://www.cbr.washington.edu/analysis/apps/user). Likelihood ratio tests (LRT) were performed to identify the most parsimonious models for describing the capture process at $\alpha = 0.05$ two-tailed (Kendall and Stuart 1977).

In the situation where the reduced model ($p_{ci} = p_{ti}$) was statistically equivalent to the full model ($p_{ci} \neq p_{ti}$) and detection probabilities were equated between treatment and control groups (as determined by the LRT), the method of moments estimator for the treatment effect on survival within a given reach was equivalent to that of previous alternative gear studies of the lower Columbia River which used the Ricker relative recovery method:

$$\tau = \frac{\left(\frac{m_{ti}}{R_t}\right)}{\left(\frac{m_{ci}}{R_c}\right)} \qquad \text{(V.2)}$$

In this reduced model form—which mirrors the Ricker relative recovery method—survival of tagged fish to a common location was estimated by comparing the upstream recovery probability of the treatment group to that of the control group of tagged fish released at the same location. Therefore, selection of the reduced model with equivalent detection probabilities between treatment and control groups resulted in the following comparisons to the work of WDFW (2014):

τ_1 = Short-term survival (from capture and release to Bonneville Dam),

$\tau_2 * \tau_3$ = Long-term survival (from Bonneville Dam to McNary Dam),

$\tau_0 * \tau_1 * \tau_2 * \tau_3$ = Cumulative survival (from capture and release to McNary Dam).

Genetic Analysis

To ensure that there was equivalent stock composition between treatment and control groups (random assignment), the Conservation Genetics Lab (University of Montana) and the Eagle Fish Genetics Lab (Idaho Department of Fish and Game) analyzed 507 randomly selected Chinook salmon genetic samples (241 control; 266 treatment) with Columbia River basin-specific single-nucleotide polymorphism markers. Chinook salmon were selected for genetic analysis due to this species' propensity to return to tributaries below main-stem arrays in the study region (in contrast with steelhead, which were primarily destined for hatcheries and spawning grounds above McNary Dam). Since approximately 20% of Columbia River basin fall Chinook Salmon were forecasted to return to spawning grounds and hatcheries of major tributaries below Bonneville Dam (including the Willamette, Cowlitz, Lewis, and Kalama rivers; ODFW 2017a), genetic tests were used to assign individuals to natal populations either below or above Bonneville Dam with a 90% probability threshold (Piry et al. 2004; Miller et al. 2018). Given that Chinook salmon and steelhead were randomly sampled and assigned to groups in identical fashion, Chinook salmon genetic analyses were assumed to be sufficient for determining overall random assignment to treatment and control groups for both Chinook salmon and steelhead.

Generalized linear modeling (GLM) based on a log-link and Poisson error structure was used in R (R Development Core Team 2008) to test the null hypothesis of homogeneity of Chinook salmon population assignment to control and treatment groups at the $\alpha \leq 0.05$ significance level. This GLM test of homogeneity was used to evaluate the assumptions of random arrangement of fish to control and treatment groups. However, genetic population assignment in the Columbia River basin remains coarse due to the homogenizing effects from hatchery genetic introgression, limiting finer-scale genetic assignment and evaluation of stock composition equivalence (Myers et al. 2006; Hess et al. 2014).

Net Pen Holding Study

As a supplement to BREP paired release-recapture studies, a net pen holding study was performed for coho salmon in fall 2019 similar to those conducted by Buchanan et al. (2002) and Takata and Johnson (2018). Due to the migratory nature of coho salmon (which tend to spawn below mainstem Columbia River dams), paired release-recapture has typically been ineffective in the absence of a very large sample size (WDFW 2014). As a result, coho salmon survival from prior alternative gear investigations has been directly estimated via net-pen holding in the lower Columbia River (Takata and Johnson 2018). This holding study was therefore performed to provide comparable data to past studies while complementing the BREP release-recapture studies.

From August through October 2019, a commercial test fishery took place at the experimental trap to evaluate the performance of the gear in a commercial selective harvest setting. During the months of September and October (mirroring the timeframe of Takata and Johnson (2018)), adult coho salmon (> 47 cm FL) randomly captured at the trap through the modified commercial treatment process were transferred one-by-one with a rubberized dip net to a designated temporary holding chamber of the live well until a sample of approximately 20 fish was retained. With the desired sample size achieved after a four to eight-hour collection period, investigators sealed outlets to all spiller tunnels and turned on a field video camera for recording (GoPro Hero 7 Black). Coho salmon were once again enumerated, identified by origin (adipose fin clipped or unclipped), noted for capture condition ("lively", "lethargic", or "no signs of life"), and released from the live well by hand to the sealed spiller compartment (now functioning as a net pen holding chamber with dimensions roughly equivalent to Takata and Johnson (2018)). Once the last fish was released into the net pen, investigators initiated a 48-h observation period and noted the date, time, water temperature (°C; Extech), and presence of marine mammals. For collection of all 48-h holding samples, trap operators randomly selected the first ~20 adult coho salmon that migrated into the live well from the spiller. As in prior studies conducted by Takata and Johnson (2018), coho salmon that exhibited prior injuries unrelated to the commercial gear were excluded from the holding study.

Post-release survival of coho salmon was estimated by holding and observing six treatment groups of fish (mean = 20, min = 13, max = 34) for a 48-h period. To determine fish mortalities during the holding period, treatment groups were checked twice daily at regular intervals from above and below the water surface (via snorkel survey). At the end of the 48-h holding period, all fish were cleared from the holding pen to a live well through the 2017 prototype line-and-pulley method (Tuohy et al. 2019). These fish were then enumerated, measured (FL), scanned for PIT tags, identified for species type and origin (hatchery/wild), noted for condition, and released. Post-release survival was directly estimated by a binomial proportion (p = # survived/# total) with associated binomial variance. In the case of no observed mortality, a lower one-tailed interval estimate of survival was calculated using the method in Skalski (1981). As in all prior lower Columbia River holding studies, the effects of confinement on coho salmon were not controlled (Takata and Johnson 2018).

<u>Determining CPUE</u>

This project focused primarily on release survival of fishes and the study design provided no means to precisely and accurately compare capture efficiency of trap operations to that of the conventional gill net fishery. Nevertheless, CPUE (defined by the number of fish captured by a gear-type divided by soak length hours and the mean number of active fishing vessels) was calculated for Chinook salmon and coho salmon throughout the 2017 study period and compared to that of gill nets in the 2017 lower Columbia River non-Indian commercial fall Chinook and coho salmon fishery (ODFW 2017a). CPUE results were compared during overlapping weeks of operation (adjusted by one day to account for the migration time of fish between Zone 2 at the fish trap site to Zone 4 where the gill net fleet operated in 2017). Both hatchery and wild-origin Chinook and coho salmon were used in this coarse comparison of CPUE as wild-origin salmon were retained in the 2017 lower Columbia River non-Indian commercial fishery. In the spring and early-summer of 2019, commercial salmon fisheries below Bonneville Dam were not permitted preventing CPUE comparison to trap operations.

Regression Analysis of CPUE

Multiple linear regression was conducted to determine the covariates that best explain 2017 CPUE at the experimental trap. An $\alpha \leq 0.05$ was used for statistical significance. Covariates considered for this analysis included daily returns to Bonneville Dam (5 days after a given test fishing day to account for the mean migration time of Chinook and steelhead from the test site to Bonneville Dam), time of day (day, night, dawn, or dusk), tide height (m), tidal stage (ebb, flood, high-water, or low-water), water temperature (ºC), use of the marine mammal gate (open or closed), and the intercept term (Table V-3). The most parsimonious model was selected through the backwards-elimination/deletion approach (Burnham and Anderson 1998). Stock-specific CPUE represented the response variable, which was log transformed to account for right skewness of the data and anticipated multiplicative effects. Association of each covariate with the response variable (positive or negative) was determined independently of the regression model on a single-factor basis.

Table V-3. Descriptors of covariates used in multiple regression to explain stock-specific CPUE.

Covariate	Unit of Measure	Description
Bonneville Dam Counts	Total salmonids	Total number of salmonids of a species passing Bonneville Dam five days after CPUE measurement.
Mean Tide Height	Meters	Mean tide height throughout the duration of a soak period.
Water Temperature	ºC	Water temperature at the river surface during the soak period.
Tidal Stage	Categorical	Tide stage (ebb, flood, high-water, low-water) at the end of the soak period.
Time of Day	Categorical	Time of day the set was performed (dawn, day, dusk, night).
Marine Mammal Gate Position	Categorical	Position of the marine mammal gate: open (0), closed (1).

B. Project Management

Dr. Nick Gayeski (PhD), WFC Principle Investigator

Dr. Gayeski (Redmond, WA) co-managed the BREP study. He contributed to study design and statistical analysis. Gayeski is co-author of the final BREP report and the published manuscript in *Fisheries* titled "Survival of Salmonids from an Experimental Commercial Fish Trap (Tuohy et al. 2019; https://doi.org/10.1002/fsh.10292).

Adrian Tuohy (M.S.), WFC Project Manager

Mr. Tuohy (Seattle, WA) co-managed the study. He co-led permitting, trap engineering, construction, field staff management, test fishing operations, field data collection, and data management. He collaborated with the Principal Investigator for the statistical analysis and contributed toward the dissemination of all research findings. He authored a published master's thesis on BREP research (Tuohy 2018), co-authored the final BREP report, co-authored the published *Fisheries* manuscript (Tuohy et al. 2019), and co-authored a second manuscript submitted to the North American Journal of Fisheries Management titled "Modified Commercial Fish Trap to Help Eliminate Salmonid Bycatch Mortality (Tuohy et al. 2020).

Aaron Jorgenson (B.S.), WFC Project Manager

Mr. Jorgenson (Tacoma, WA) co-managed the study. He co-led trap engineering, construction, field staff management, test fishing operations, field data collection, and data management. He contributed toward the 2019 statistical analysis and co-authored the final report and manuscript submitted to the North American Journal of Fisheries Management (Tuohy et al. 2020). Jorgenson played an important role as staff photographer, GIS specialist, and CAD drafter throughout the project.

Jon Blair Peterson, Commercial Fisher

Mr. Peterson (Cathlamet, WA) permitted and established the fish trap research project in 2013 at a location his father and grandfather had operated fish traps in the early 20th Century. He is a third-generation salmon trap fisher and gill netter in the lower Columbia River, WA. Peterson contributed to fish trap construction, research operations, and discussions with resource managers from 2016-2019.

Mike Clark, Commercial Fisher and Fish Processor

Mr. Clark (Cathlamet, WA) assisted with trap operations from 2018-2019 and participated in discussions with WDFW and WFC regarding the advancement of the gear to a commercial harvest setting.

Billie Delaney, Commercial Fisher

Ms. Delaney (Astoria, OR) contributed to trap construction, operations, and project development from 2017-2019.

VI. FINDINGS

A. Actual Accomplishments and Findings - 2017

Total Catch

The experimental trap was fished for 290.5-h over 33-d between 26 August and 27 September 2017. During this period, 381 sets were performed with the prototype line-and-pulley spiller treatment with a median soak length of 36 minutes (min = 6 min; max = 336 min; mean = 46 min; SD = 36 min). The median time between the conclusion of a treatment soak and re-deployment was approximately 3 minutes.

A total of 7,129 salmonids were captured and released. Mean daily catch was 215 salmonids with a maximum catch of 506 on 8 September and a minimum of 4 on 27 September (Figure VI-1). Total catch was composed of 49.1% coho salmon (3501 total; 52.4% ad-clipped; 16.4% jack salmon), 37.4% Chinook salmon (2670 total; 47.9% ad-clipped; 16.3% jack salmon), 12.9% summer steelhead trout (921 total; 80.9% ad-clipped; 10.5% B-run (> 78cm)), 0.4% resident/residualized *O. mykiss* (29 total; 77.8% ad-clipped), and 0.1% *Oncorhynchus spp.* (8 total) (Figure VI-2). In addition to salmonid catch, 3 American shad, 1 largemouth bass, 1 common carp (*Cyprinus carpio*), and 1 peamouth (*Mylocheilus caurinus*) were captured and released throughout the study period.

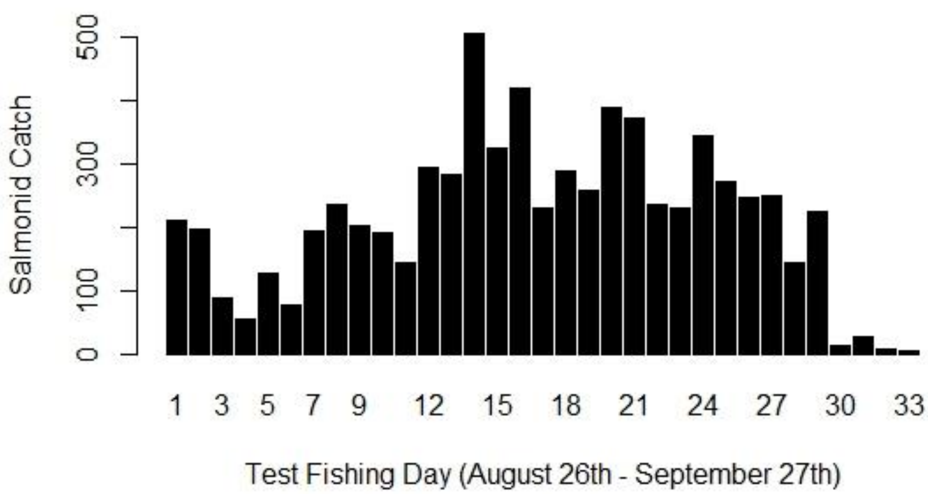

Figure VI-1. Total 2017 catch of Chinook, coho, and steelhead throughout the test fishing period.

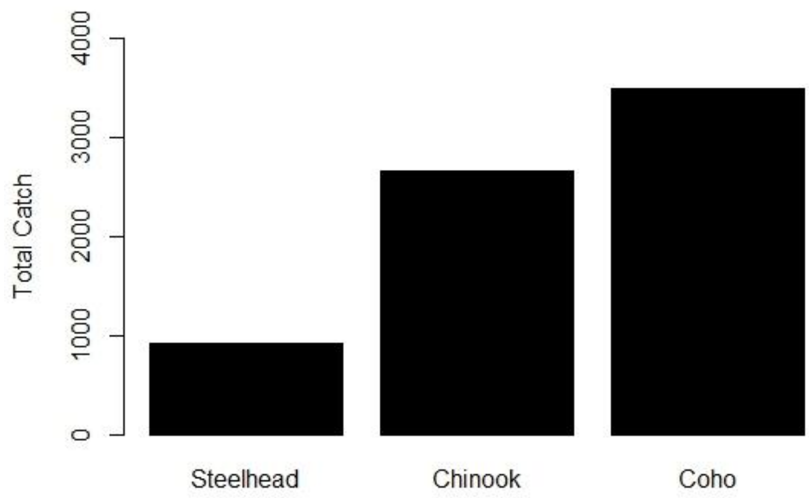

Figure VI-2. Salmonid catch by species from 26 August through 27 September 2017.

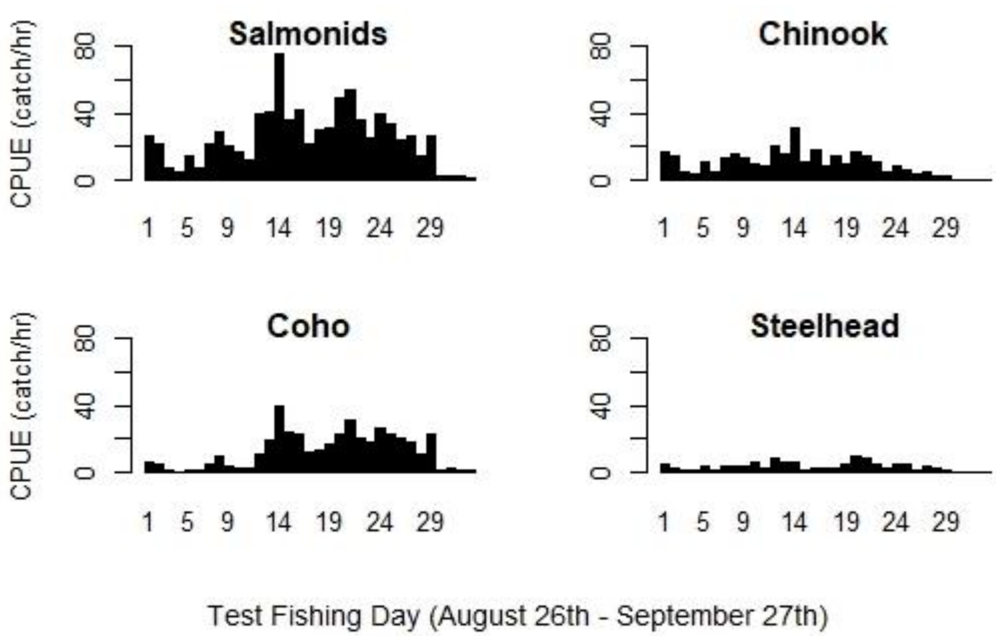

Figure VI-3. Daily CPUE (catch/h) of all salmonids, Chinook salmon, coho salmon, and steelhead trout from 26 August through 27 September 2017.

<u>CPUE</u>

Mean salmonid CPUE after 290.5-h of total fishing effort was 24.54/h (Figure VI-3). Daily CPUE for all salmonids peaked at 75.5 salmonids/h on 9 September (mean = 25.2, SD = 16.8). For coho salmon, daily CPUE peaked at 39.3/h on 7 September (mean = 12.5, SD = 10.5).

Chinook salmon daily CPUE peaked at 30.9/h on 8 September (mean = 9.4, SD = 7.0). Steelhead daily CPUE peaked at 9.4/h on 14 September (mean = 3.3, SD = 2.5). Analyzing 381 unique sets performed throughout the study period with the prototype treatment, Chinook CPUE per set ranged from 0 to 225 chinook/h (median = 5.90, mean = 15.48, SD = 27.67). Coho CPUE per set ranged from 0 to 290 coho/h (median = 7.20, mean = 21.27, SD = 37.75). Steelhead CPUE per set ranged from 0 to 110 steelhead/h (median = 1.85, mean = 4.92, SD = 9.74).

CPUE of Chinook and coho salmon were analyzed during two periods in which the 2017 August and early-fall lower Columbia River non-Indian commercial Chinook and coho salmon gill net fisheries took place (ODFW 2017a). Tables VI-1 and VI-2 summarize the results during these two short overlapping periods for the experimental trap and the commercial gill net fleet. CPUE in this case represents total catch of a stock divided by the mean number of deliveries (a proxy for the number of fishing vessels) and total hours of operation. Mean CPUE for the experimental trap was 5.50 and 6.61 for Chinook and coho salmon respectively. Mean CPUE for the average gillnetter was 3.02 for Chinook salmon and 0.18 for Coho salmon. During these overlapping periods of operation, the trap outperformed the average gillnetter by a factor of 1.82 for Chinook salmon and 35.98 for coho salmon (Tables VI-1 and VI-2). It must be noted, however, that the period for comparison between gears was minimal and further investigation of relative CPUE is necessary. Ideally, gears should be compared side-by-side and simultaneously under real-world commercial fishing conditions, rather than a research setting.

Table VI-1. Catch results for the experimental trap during weeks in which the lower Columbia River non-Indian commercial gill net fleet operated in 2017. CPUE represents daily stock-specific catch divided by the number of vessels and the number of hours fished in a day.

Date	Vessels	Effort (Hours)	Chinook Total	Chinook CPUE	Coho Total	Coho CPUE
26-Aug	1	12.85	128	9.96	46	3.58
27-Aug	1	13.62	129	9.47	47	3.45
28-Aug	1	13.35	52	3.90	17	1.27
29-Aug	1	12.72	40	3.15	3	0.24
30-Aug	1	12.80	90	7.03	11	0.86
31-Aug	1	13.25	49	3.70	15	1.13
16-Sep	1	13.28	67	5.04	137	10.31
17-Sep	1	12.78	40	3.13	171	13.38
18-Sep	1	13.08	75	5.73	231	17.66
19-Sep	1	12.78	48	3.75	185	14.47

Table VI-2. Catch results for the lower Columbia River non-Indian commercial gillnet fleet. CPUE represents daily stock-specific catch divided by the estimated number of vessels and the number of hours fished in a day.

Date	Estimated Vessels	Effort (Hours)	Chinook Total	Chinook CPUE	Coho Total	Coho CPUE

8/27-8/28	122	9	5544	5.05	129	0.12
8/29-8-30	112	9	1805	1.79	20	0.02
8/31-9/1	96	9	1563	1.81	12	0.01
9/17-9/18	107	10	3651	3.41	404	0.38
9/19-9/20	69	10	1788	2.59	309	0.45

Regression Analysis of CPUE

Multiple linear regression was used to explain variation in species-specific CPUE for the 381 sets performed in 2017. Through the backwards-elimination/deletion approach, only water temperature was determined to be non-significant of all considered covariates explaining Chinook salmon CPUE. The following model was selected for Chinook salmon:

$$\ln(CPUE_{chinook} + 1) = \beta_0 + \beta_1 \text{ (Tidal Stage}_i) + \beta_2 \text{ (Tide Height)} + \beta_3 \text{ (Time of Day}_i) + \beta_4 \text{ (MMG Position}_i) + \beta_5 \text{ (Bonneville Count)} + \varepsilon$$

Modeling through the R-platform, all partial regression coefficients were statistically significant at the $P \leq 0.05$ significance level through last-entry analysis (Table VI-3). The association and significance of each coefficient is described in order of association (positive vs. negative), followed by statistical significance: daily Bonneville Dam count (P ($|t| \geq 5.139$) < 0.001, association = positive), the intercept term (P ($|t| \geq 4.025$) < 0.001), mean tide height (P ($|t| \geq 3.099$) $= 0.002$, association = positive), tide stage (flood tide) (P ($|t| \geq -5.780$) < 0.001, association = negative), MMG position (P ($|t| \geq -3.896$) < 0.001, association = negative), and time of day (night) (P ($|t| \geq -2.213$) $= 0.028$, association = negative). Although all covariates had statistically significant impacts on the response variable and the model was significant at the $P \leq 0.05$ level (P ($|F_{9,343}| \geq 11.67$) < 0.001), only a small proportion of the total variation in Chinook salmon CPUE was explained through the multiple regression model ($R^2 = 0.235$).

Table VI-3. Summary of covariates from the multiple regression model used to explain Chinook salmon CPUE, ranked by association and *P*-value for last entry into the model. Association was determined independently of the multiple regression model on a single-factor basis.

Independent Variable	*P*-value	*t*-value	Association	Coefficient	$\widehat{SE}$
Bonneville Dam Count	0.000	5.139	+	4.61e-05	8.96e-06
Intercept Term	0.000	4.025	+	1.213	0.302
Mean Tide Height	0.002	3.099	+	0.124	0.040
Tidal Stage (Flood)	0.000	-5.780	-	-0.861	0.149
Marine Mammal Gate	0.000	-3.896	-	-0.666	0.171
Time of Day (Night)	0.028	-2.213	-	-0.725	0.327

Through the backwards-elimination/deletion approach, only water temperature and marine mammal gate position were determined to be non-significant of all considered covariates explaining coho salmon CPUE. The following model was selected for coho salmon:

$$\ln(CPUE_{coho} + 1) = \beta_0 + \beta_1 (\text{Tidal Stage}_i) + \beta_2 (\text{Tide Height}) + \beta_3 (\text{Time of Day}_i) + \\ + \beta_4 (\text{Bonneville Count}) + \varepsilon$$

Through last-entry analysis, all partial regression coefficients were statistically significant at the $P \leq 0.05$ significance level with the exception of mean tide height, which was significant at the 0.10 level (Table VI-4). The association and significance of each coefficient is described in order of association (positive vs. negative), followed by statistical significance: daily Bonneville Dam count (P ($|t| \geq 10.423$) < 0.001, association = positive), the intercept term (P ($|t| \geq 3.269$) = 0.001), mean tide height (P ($|t| \geq 1.678$) = 0.094, association = positive), tide stage (flood tide) (P ($|t| \geq -3.131$) = 0.002, association = negative), and time of day (night) (P ($|t| \geq -2.920$) = 0.004, association = negative). Although the majority of these covariates had statistically significant impacts on the response variable and the model was significant at the $P \leq 0.05$ level (P ($|F_{8,372}| \geq 18.71$) < 0.001), only a small proportion of the total variation in coho salmon CPUE was explained through the multiple regression model ($R^2 = 0.287$).

Table VI-4. Summary of covariates from the multiple regression model used to explain coho salmon CPUE, ranked by association and *P*-value for last entry into the model. Association was determined independently of the multiple regression model on a single-factor basis.

Independent Variable	*P*-value	*t*-value	Association	Coefficient	$\widehat{SE}$
Bonneville Dam Count	0.000	10.423	+	5.27e-04	5.06e-05
Intercept Term	0.001	3.269	+	0.884	0.270
Mean Tide Height	0.094	1.678	+	0.065	0.039
Tidal Stage (Flood)	0.002	-3.131	-	-0.449	0.143
Time of Day (Night)	0.004	-2.920	-	-0.917	0.314

Of all considered covariates explaining summer steelhead CPUE, only water temperature was determined to be non-significant. The following model was selected for steelhead trout:

$$\ln(CPUE_{steelhead} + 1) = \beta_0 + \beta_1 (\text{Tidal Stage}_i) + \beta_2 (\text{Tide Height}) + \beta_3 (\text{Time of Day}_i) + \\ \beta_4 (\text{MMG Position}_i) + \beta_5 (\text{Bonneville Count}) + \varepsilon$$

Through last-entry analysis, all partial regression coefficients were statistically significant at the $P \leq 0.05$ significance level with the exception of the intercept term (Table VI-5). The association and significance of each coefficient is described in order of association (positive vs. negative), followed by statistical significance: daily Bonneville Dam count (P ($|t| \geq 5.323$) < 0.001, association = positive), mean tide height (P ($|t| \geq 3.941$) < 0.001, association = positive), time of day (day) (P ($|t| \geq 2.208$) = 0.028, association = positive), time of day (dusk) (P ($|t| \geq 2.277$) = 0.023, association = positive), MMG position (P ($|t| \geq -4.181$) < 0.001, association = negative), tide stage (flood tide) (P ($|t| \geq -3.505$) = 0.001, association = negative), and time of day (night) (P ($|t| \geq -2.822$) = 0.001, association = negative). Although all covariates had statistically significant impacts on the response variable and the model was significant at the $P \leq 0.05$ level (P ($|F_{9,349}| \geq 12.46$) < 0.001), only a small proportion of the total variation in steelhead trout CPUE was explained through the multiple regression model ($R^2 = 0.243$).

Table VI-5. Summary of covariates from the multiple regression model used to explain summer steelhead CPUE, ranked by association and *P*-value for last entry into the model. Association was determined independently of the multiple regression model on a single-factor basis.

Independent Variable	*P*-value	*t*-value	Association	Coefficient	$\widehat{SE}$
Bonneville Dam Count	0.000	5.323	+	5.31e-04	9.98e-05
Mean Tide Height	0.002	3.941	+	0.119	0.030
Time of Day (Dusk)	0.023	2.277	+	0.523	0.230
Time of Day (Day)	0.028	2.208	+	0.388	0.176
Marine Mammal Gate	0.000	-4.181	-	-0.521	0.125
Tidal Stage (Flood)	0.001	-3.505	-	-0.403	0.115
Time of Day (Night)	0.001	-2.822	-	-0.711	0.252

Total Tagged Fish and Upstream Detections

A total of 2,848 Chinook salmon and steelhead trout were PIT-tagged throughout the study period. Random sampling and assignment of control and treatment tagging sessions resulted in fairly equal representation of mixed-stock throughout the fishing period for both control and treatment groups (Figures VI-4 and VI-5). In addition, 13 previously tagged fish were recaptured at the trap (most of which were previously tagged at the trap site). However, this small group of previously tagged fish was excluded from the analysis due to the potential difference in handling survival from those that had undergone the standard tagging procedure. Of the tagged fish, 2,066 were Chinook salmon (976 control; 1090 treatment) and 782 were steelhead trout (379 control; 403 treatment). Through a PTAGIS database query on 30 January 2018, there were 1,848 detections of unique WFC tag codes from 43 active PIT tag arrays throughout the Columbia River Basin. A total of 35 detections were made downstream of the trap site on the Oregon side at the Columbia River Estuary array. Chinook and steelhead were detected in locations hundreds of kilometers upstream at arrays including the lower Okanagan and lower South Fork Clearwater.

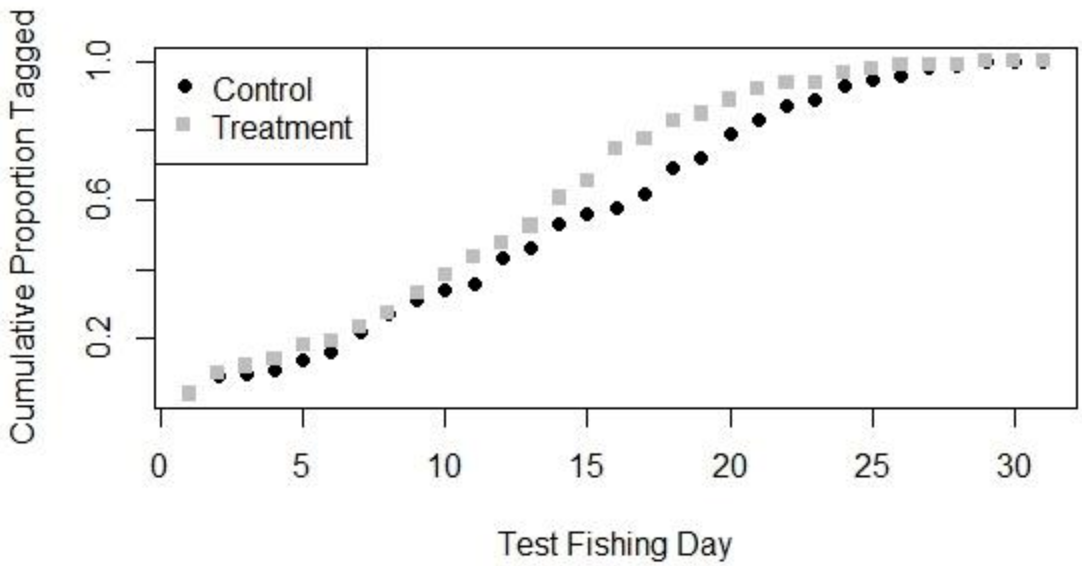

Figure VI-4. Cumulative proportion of tagged Chinook salmon control and treatment groups.

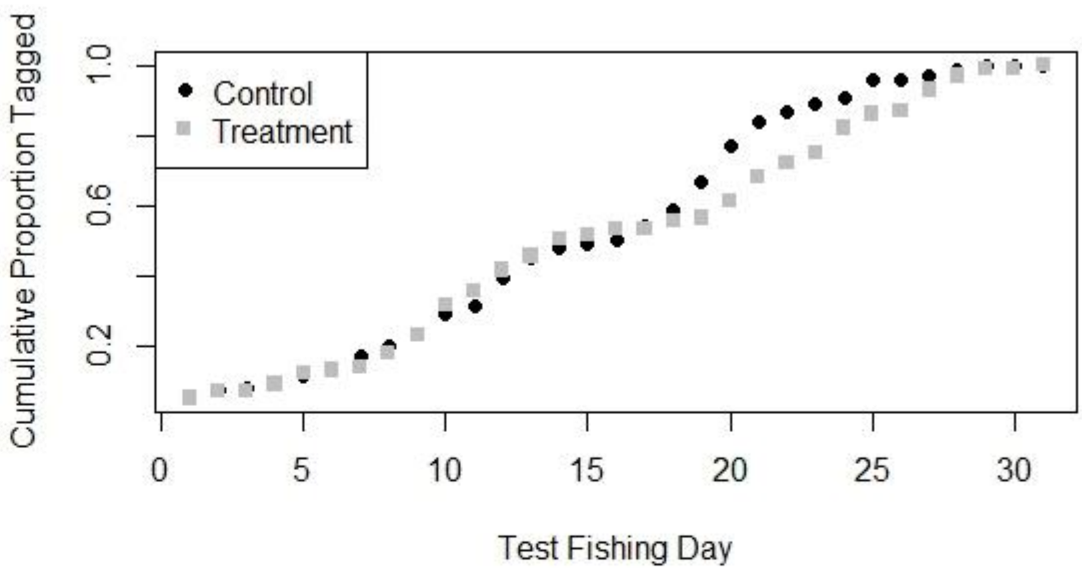

Figure VI-5. Cumulative proportion of tagged steelhead trout control and treatment groups.

Total Fin-clip Samples and Genotyping

Fin-clip samples were obtained from 2,828 Chinook salmon and steelhead trout throughout the study period, representing 99.3% of the tagged population (including recaptures). Of these samples, 2,046 were Chinook salmon (964 control; 1082 treatment); 772 were steelhead trout (380 control; 402 treatment). A random sub-sample of 507 Chinook fin-clip samples were selected from four discrete time periods—separately for control and treatment samples—in proportion to their abundance within each period (Table VI-6). These samples were analyzed with the appropriate set of Columbia basin-specific SNP markers to assign individuals to defined population groups below and above Bonneville Dam.

Table VI-6. Chinook fin-clip samples randomly selected for population group assignment.

Period	Control	Treatment
One (8/26 - 9/2)	65	75
Two (9/3 - 9/10)	74	125
Three (9/11 - 9/18)	85	56
Four (9/19 - 9/27)	17	10
N	241	266

Of the 507 genetic samples submitted for population group assignment, only 11 samples (6 control, 5 treatment) could not be genotyped with high confidence to reporting groups either above or below Bonneville Dam (Miller et al. 2018). Eliminating these 11 samples from the dataset, 496 were successfully assigned (Table VI-7). Through GLM/log-linear analysis, there was no significant association between control and treatment groups and Columbia Basin population group assignment (P ($\chi_1^2 \geq 0.000$) = 1.000). From these results, stock-composition appears equivalent between control and treatment groups at the $P \leq 0.05$ significance level.

Table VI-7. Contingency table of assigned Columbia Basin population groups for control and treatment Chinook salmon. The observed frequency in each cell is shown, with the frequency expected (in parentheses) if there is no association between control and treatment group and population group assignment.

	Control	Treatment	Frequency
Below Bonneville Populations	47 *(46.91)*	52 *(52.09)*	99
Above Bonneville Populations	188 *(188.10)*	209 *(208.91)*	397
Frequency	235	261	496

Immediate Survival

Throughout the duration of the study, there were a total of nine immediate mortalities out of 7,135 fish captured (Table VI-8). Of these mortalities, only two were adult fish (1 Chinook; 1 coho) with the remainder being jacks or resident/residualized salmonids < 300 mm FL (1 Chinook; 4 coho; 2 *O. mykiss*). The two adult mortalities occurred for unknown reasons in the spiller compartment, but were likely caught in a fold of the spiller mesh during lift. Two jack mortalities occurred from wedging in the spiller mesh, with the remainder resulting from wedging in the downstream panel of the heart (typically after noted marine mammal encounters). From these results, immediate mortality of steelhead was zero (immediate survival $\hat{\tau}_0 = 1.000$). For adult Chinook and coho salmon, immediate mortality was 0.0004 (immediate survival $\hat{\tau}_0 = 0.9996$; $\widehat{SE} = 0.0004$) and 0.0003 respectively (immediate survival $\hat{\tau}_0 = 0.9997$; $\widehat{SE} = 0.0003$).

Table VI-8. Immediate salmonid mortalities during the 2017 study period. *O. mykiss** represents resident or residualized hatchery-origin *O. mykiss* < 300 mm. Note that mortality and survival rates presented below are for all ages of a species (jacks and adults combined).

Species	Total Captured	Mortalities (Adults)	Mortalities (Adults and Jacks)	Immediate Mortality (All Ages)	Immediate Survival (All Ages)
Chinook	2670	1	2	0.0007	0.9993
Coho	3501	1	5	0.0014	0.9986
Steelhead	921	0	0	0.0000	1.0000
*O. mykiss**	29	n/a	2	0.0689	0.9311

Fall Chinook Salmon Fork-length and Migration Timing

Of the tagged Chinook salmon population, the mean fork length included in the study was 739.3 mm (max = 1,000, min = 500, SD = 85.1). Mean fork length was 734.0 mm ($\widehat{SE} = 2.7$) for the control group and 744.1 ($\widehat{SE} = 2.6$) for the treatment group. Although biologically insignificant, mean fork length was statistically different between the two groups at the $P \leq 0.05$ significance level ($P(|t_{2067}| \geq 2.71) = 0.007$).

The median arrival date for Chinook salmon was 12 September at Bonneville Dam and 22 September at McNary Dam (Table VI-9). The median travel time between release and Bonneville was 6-d, with a mean of 6.5-d (CI $(6.3 \leq \widehat{T} \leq 6.7) = 0.95$). Mean travel time was 6.1-d ($\widehat{SE} = 0.13$) for the control group and 6.9-d ($\widehat{SE} = 0.13$) for the treatment group. Analyzed through a two-sample t-test, the control group travelled more quickly to Bonneville than the treatment group at the $P \leq 0.05$ significance level ($P(|t_{1189}| \geq 4.627) < 0.001$). The median travel time between release from the gear to McNary was 13-d, with a mean of 14.7-d (CI $(14.19 \leq \widehat{T} \leq 15.22) = 0.95$). Mean travel time was 14.5-d ($\widehat{SE} = 0.38$) for the control group and 14.9-d ($\widehat{SE} = 0.36$) for the treatment group. Travel time of control and treatment Chinook salmon did not differ to McNary at the $P \leq 0.05$ significance level ($P(|t_{490}| \geq 0.795) = 0.427$).

Table VI-9. First, last, and median detection date for tagged fall Chinook salmon.

Detection Site	River km	Number of Tags	Median Detection	First Detection	Last Detection
Bonneville	233	1191	9/13/2017	8/29/2017	10/14/2017
McNary	470	492	9/22/2017	9/5/2017	10/27/2017

Fall Chinook Salmon Survival

Retrieving unique capture histories for control and treatment Chinook salmon through PTAGIS, the following cell counts were entered into Program USER to estimate post-release survival (Table VI-10):

Table VI-10. Control and treatment cell counts for all possible capture histories at four mainstem river detection locations. A "1" denotes detection and "0" nondetection at each upstream detection location in order from lowest to highest rkm (Bonneville Dam, The Dalles Dam, McNary Dam, and pooled detection points upstream of McNary Dam). *N* denotes the total number tagged in each group.

History	Control Count	Treatment Count
1111	133	128
0111	1	1
1011	3	0
0011	0	0
1101	0	0
0101	0	0
1001	0	0
0001	0	0
1110	95	127
0110	1	1
1010	0	2
0010	0	0
1100	98	120
0100	1	2
1000	243	242
0000	401	467
N	**976**	**1090**

Given cell counts for each unique capture history (Table VI-10), the relative post-release survival effect was estimated within three upstream mainstem river reaches through the CJS method (Table VI-11). LRT found no significant difference in PIT tag array detection efficiencies for control and treatment groups at the $P \leq 0.05$ significance level ($P\ (\chi^2_3 \geq 0.364) = 0.948$), resulting in a reduced model with common detection probability (i.e., $p_{ci} = p_{ti}$, $i = 1, \cdots, 3$). Results of the reduced model are presented in Table VI-11. Relative post-release survival was high from release to Bonneville Dam at $\hat{\tau}_1 = 0.970$ ($\widehat{SE} = 0.036$). The treatment group outperformed the control group between Bonneville Dam and The Dalles Dam, with survival increasing in this reach to $\hat{\tau}_2 = 1.060$ ($\widehat{SE} = 0.051$). Post-release survival declined slightly but remained high at $\hat{\tau}_3 = 0.968$ ($\widehat{SE} = 0.049$) from The Dalles Dam to McNary Dam. Accounting for immediate adult survival ($\hat{\tau}_0 = 0.9996$; $\widehat{SE} = 0.0004$), cumulative survival ($\tau_0 * \tau_1 * \tau_2 * \tau_3$) over a 400 km migration from release to McNary Dam was 0.995 ($SE = 0.078$).

Table VI-11. Post-release survival point-estimates for adult fall Chinook salmon released from the experimental trap and associated profile likelihood 95% confidence intervals.

River Reach	**Survival Point Estimate**
Immediate survival (τ_0)	0.9996 (0.998 – 1.000)
Gear to Bonneville Dam (τ_1)	0.970 (0.901 – 1.044)
Bonneville Dam to The Dalles Dam (τ_2)	1.060 (0.965 – 1.166)
The Dalles Dam to McNary Dam (τ_3)	0.968 (0.877 – 1.070)
Cumulative ($\tau_0 * \tau_1 * \tau_2 * \tau_3$)	0.995 (0.924 – 1.071)

Utilizing detection points chosen by WDFW (2014) to estimate relative short-term, long-term, and cumulative survival of salmon released from purse and beach seines, the cumulative survival effect ($\tau_0 * \tau_1 * \tau_2 * \tau_3$) from capture at the trap site to McNary Dam (~400 km upstream; 13-d median travel duration) was estimated at 0.995 ($\widehat{SE}$ = 0.078) for fall Chinook salmon (Table VI-12). Short-term post-release survival from the gear to Bonneville (τ_1) was estimated at 0.970 ($\widehat{SE}$ = 0.036). Long-term post-release survival of Chinook salmon from Bonneville to McNary ($\tau_2 * \tau_3$) was estimated at 1.026 ($\widehat{SE}$ = 0.071). Utilizing methodology employed by Vander Haegen et al. (2004) and Ashbrook (2008) for evaluation of tangle nets—where detection at any of the mainstem dams qualified successfully surviving the post-release experience—post-release survival (τ_1) was 0.970 ($\widehat{SE}$ = 0.036).

Table VI-12. Fall Chinook post-release survival point estimates and associated profile likelihood 95% confidence intervals from the experimental trap, employing detection points selected by WDFW (2014).

CUMULATIVE: GEAR TO MCNARY

Treatment	No. Tagged	No. Recaptured	Recapture Prob.	Survival
Control	976	233	0.239	---
Fish Trap	1090	259	0.238	0.995 (0.924 - 1.071)

SHORT-TERM: GEAR TO BONNEVILLE

Treatment	No. Tagged	No. Recaptured	Recapture Prob.	Survival
Control	976	575	0.589	---
Fish Trap	1090	623	0.572	0.970 (0.901 – 1.044)

LONG-TERM: BONNEVILLE TO MCNARY

Treatment	No. Over BON	No. Recaptured	Recapture Prob.	Survival
Control	575	233	0.405	---
Fish Trap	623	259	0.416	1.026 (0.934 – 1.129)

Summer Steelhead Trout Fork-length and Migration Timing

Of the tagged steelhead trout population, the mean fork length included in the study was 642.7 mm (max = 1000, min = 500, SD = 82.3). Mean fork length for the control group was 641.5 mm ($\widehat{SE}$ = 4.2) and 643.8 mm ($\widehat{SE}$ = 4.1) for the treatment group. Analyzed through a two-sample t-test (log-transformed to account for right skewness), mean fork length was statistically equivalent between the two groups at the $P \leq 0.05$ significance level (P ($|t_{789}| \geq 0.496$) = 0.620).

The median arrival date for steelhead was 18 September at Bonneville Dam and 30 September at McNary Dam (Table VI-13). The median travel time between release and Bonneville was 6.0-d, with a mean of 8.0-d (CI ($7.57 \leq \widehat{T} \leq 8.49$) = 0.95). Mean travel time was 7.9-d ($\widehat{SE}$ = 0.33) for the control group and 8.2-d ($\widehat{SE}$ = 0.33) for the treatment group. Analyzed through a two-sample t-test, travel time of control and treatment steelhead from release to Bonneville did not differ at the $P \leq 0.05$ significance level (P ($|t_{622}| \geq 0.741$) = 0.459). The median travel time between release from the gear to McNary was 18.0-d, with a mean of 21.7-d (CI ($20.78 \leq \widehat{T} \leq 22.66$) = 0.95). Mean travel time was 21.9-d ($\widehat{SE}$ = 0.68) for the control group and 21.5-d ($\widehat{SE}$ = 0.68) for the treatment group. Travel time of control and treatment steelhead trout did not differ to McNary at the $P \leq 0.05$ significance level (P ($|t_{529}| \geq -0.375$) = 0.708).

Table VI-13. First, last, and median detection date for tagged steelhead trout.

Detection Site	River Mile	Number of Tags	Median Detection	First Detection	Last Detection
Bonneville	233	624	9/18/2017	8/31/2017	10/26/2017
McNary	470	531	9/30/2017	9/13/2017	12/12/2017

Summer Steelhead Trout Survival

Retrieving unique capture histories for control and treatment summer steelhead trout through PTAGIS, the following cell counts were entered into Program USER to estimate post-release survival (Table VI-14):

Table VI-14. Control and treatment cell counts for all possible capture histories at four mainstem river detection locations. A “1” denotes detection and “0” nondetection at each upstream detection location in order from lowest to highest rkm (Bonneville Dam, The Dalles Dam, McNary Dam, and pooled detection points upstream of McNary Dam).

History	Control Count	Treatment Count
1111	256	255
0111	0	3
1011	0	0
0011	0	0
1101	1	2
0101	0	0

1001	0	0
0001	0	1
1110	10	7
0110	0	0
1010	0	0
0010	0	0
1100	17	22
0100	0	0
1000	24	30
0000	71	83
N	**379**	**403**

Post-release survival of summer steelhead was estimated for three upstream mainstem river reaches through the CJS method (Table VI-15). LRT found no significant difference in PIT tag array detection efficiencies for control and treatment groups at the $P \leq 0.05$ significance level (P ($\chi^2_3 \geq 6.874$) = 0.076), resulting in selection of the reduced model with common detection probability. Relative post-release survival was high from release to Bonneville Dam, at $\hat{\tau}_1$ = 0.977 ($\widehat{SE}$ = 0.035). Post-release survival remained high in subsequent reaches between Bonneville Dam and The Dalles Dam and between The Dalles Dam and McNary Dam, increasing to $\hat{\tau}_2$ = 0.983 ($\widehat{SE}$ = 0.024) and $\hat{\tau}_3$ = 0.983 ($\widehat{SE}$ = 0.022) respectively. Accounting for immediate survival ($\hat{\tau}_0$ = 1.000), cumulative survival ($\tau_0 * \tau_1 * \tau_2 * \tau_3$) over a 400 km migration from release to McNary Dam was 0.944 (SE = 0.046).

Table VI-15. Post-release survival point-estimates for adult steelhead trout released from the experimental trap and associated profile likelihood 95% confidence intervals.

River reach	Survival point estimate
Immediate survival (τ_0)	1.000 (0.995 – 1.000)
Gear to Bonneville Dam (τ_1)	0.977 (0.911 – 1.048)
Bonneville Dam to The Dalles Dam (τ_2)	0.983 (0.935 – 1.032)
The Dalles Dam to McNary Dam (τ_3)	0.983 (0.939 – 1.028)
Cumulative ($\tau_0 * \tau_1 * \tau_2 * \tau_3$)	0.944 (0.880 – 1.012)

Utilizing detection points chosen by WDFW (2014) to estimate relative short-term, long-term, and cumulative survival of steelhead released from purse and beach seines, the cumulative survival effect ($\tau_0 * \tau_1 * \tau_2 * \tau_3$) from the experimental trap to McNary Dam (~400 km upstream; 18-d median travel duration) was estimated at 0.944 ($\widehat{SE}$ = 0.046) for summer steelhead trout (Table VI-16). Short-term post-release survival of steelhead from the gear to Bonneville Dam (τ_1) was estimated at 0.977 ($\widehat{SE}$ = 0.035). Long-term post-release survival of steelhead from Bonneville to McNary Dam ($\tau_2 * \tau_3$) was estimated at 0.966 ($\widehat{SE}$ = 0.032). Employing the methodology of

Vander Haegen et al. (2004) and Ashbrook (2008) for evaluation of tangle nets, post-release survival (τ_1) was 0.977 ($\widehat{SE}$ = 0.035).

Table VI-16. Summer steelhead post-release survival point estimates and associated profile likelihood 95% confidence intervals from the experimental trap, employing detection points selected by WDFW (2014).

CUMULATIVE: GEAR TO MCNARY				
Treatment	No. Tagged	No. Recaptured	Recapture Prob.	Survival
Control	379	267	0.704	---
Fish Trap	403	268	0.665	0.944 (0.880 - 1.012)
SHORT-TERM: GEAR TO BONNEVILLE				
Treatment	No. Tagged	No. Recaptured	Recapture Prob.	Survival
Control	379	308	0.813	---
Fish Trap	403	320	0.794	0.977 (0.911 - 1.048)
LONG-TERM: BONNEVILLE TO MCNARY				
Treatment	No. Over BON	No. Recaptured	Recapture Prob.	Survival
Control	308	267	0.867	---
Fish Trap	320	268	0.838	0.966 (0.919 - 1.014)

Marine Mammal Encounters

Of 381 total sets performed, the marine mammal gate was deployed 81 times due to the presence of mammals in the vicinity of the study location. On 11 separate occasions, harbor seals (*Phoca vitulina*) or California sea lions (*Zalophus californianus*) entered the heart of the trap. In most of these situations, marine mammals entered when trap operators were caught off-guard, could not sight the animals, or could not close the marine mammal gate in time. Only in 4 of 11 instances of marine mammal entry was the gate effectively deployed. During these instances, entry was likely achieved through small gaps between the gate frame and the river bottom or the heart mesh lead line and the river bottom when river and tidal currents were strong. With a total of 4 mammal entries during 81 gate closure events, the gate demonstrated a deterrent success rate of 95.1%. In all situations of marine mammal entry, the spiller compartment was lifted and mammals departed within minutes. No physical injury of mammals was observed throughout the duration of the study period. However, unknown fish species were observed being taken by marine mammals on five separate occasions.

B. Actual Accomplishments and Findings - 2019

Total Catch

The experimental trap was fished 360.3-h over 40-d between 5 May and 3 July 2019. During this period, 43 sets were performed with incorporation of the modified treatment process. Mean daily fishing effort was 9.0-h (min = 3.1; max = 12.7; SD = 2.7). A total of 1,992 salmonids were captured, including 675 Chinook salmon juvenile outmigrants (Figure VI-6). Total non-juvenile catch (1,317 salmonids) was composed of 68.0% sockeye salmon (896 total; 0% ad-clipped), 12.2% Chinook salmon (161 total; 72.9% ad-clipped; 11.2% jack salmon), 19.2% steelhead trout (254 total; 74.8% ad-clipped), 0.08% resident/residualized *O. mykiss* (1 total; 0% ad-clipped), and 0.4% *O. clarkii* (5 total) (Figure VI-7). In addition to salmonid catch, American shad (357 total), largescale sucker (*Catostomus macrocheilus)* (13 total), northern pikeminnow (*Ptychocheilus oregonensis*) (4 total), starry flounder (*Platichthys stellatus*) (3 total), pacific lamprey (*Entosphenus tridentatus*) (2 total), and peamouth (*Mylocheilus caurinus*) (1 total) were captured throughout the study period.

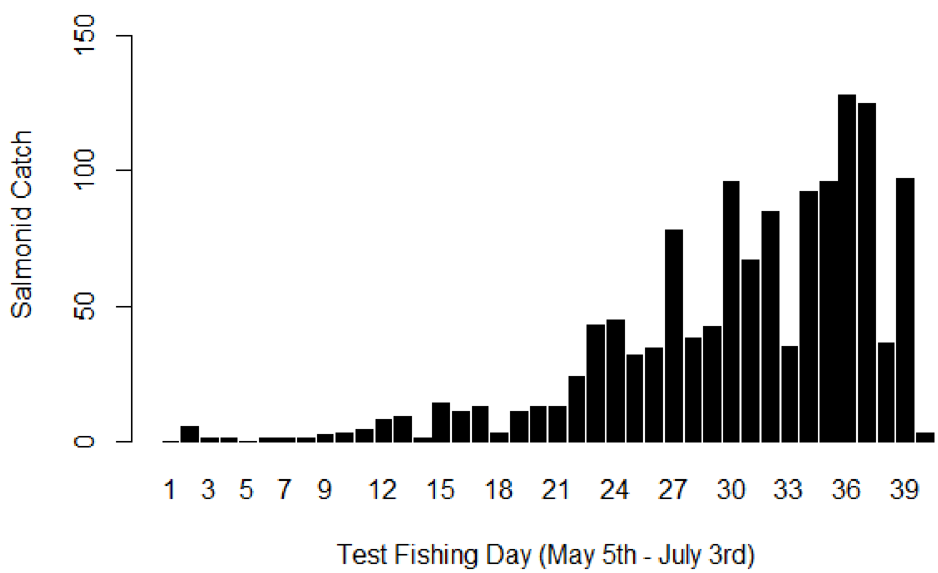

Figure VI-6. Total 2019 catch of non-juvenile Chinook, sockeye, and steelhead from 5 May - 3 July 2019.

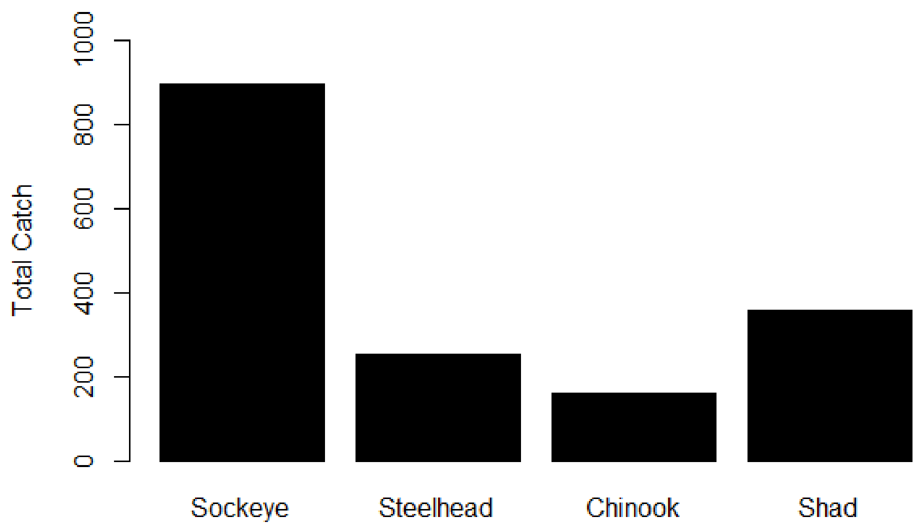

Figure VI-7. Non-juvenile catch by species from 5 May - 3 July 2019.

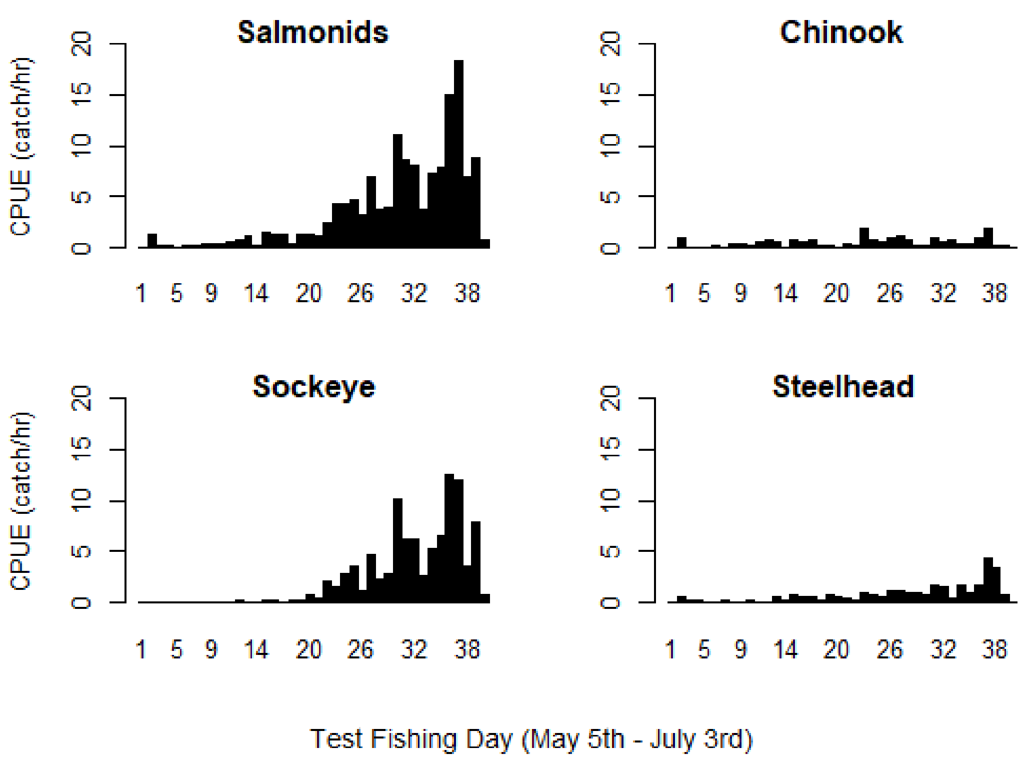

Figure VI-8. Daily CPUE (catch/h) of all salmonids, Chinook salmon, sockeye salmon, and steelhead trout from 5 May through 3 July 2019.

<u>CPUE</u>

Daily CPUE for combined non-juvenile salmonids peaked at 18.3 salmonids/h on 26 June (mean = 3.6, SD = 4.3) (Figure VI-8). Chinook salmon were present at the start of the study on 5 May. Chinook salmon daily CPUE peaked at 1.9/h on 26 June (mean = 0.4, SD = 0.4). Steelhead were also present at the start of the study on 5 May. Steelhead daily CPUE peaked at 4.4/h on 26 June (mean = 0.7, SD = 0.9). Sockeye salmon were first captured at the trap site on 28 May. CPUE peaked at 12.5/h on 25 June (mean = 2.4, SD = 3.4), with the species remaining relatively abundant at the trap site until fishing ceased on 3 July. In addition to salmonid catch, American shad were first captured on 15 May and were relatively abundant at times throughout the study period with catch of this species peaking at 5.9/h on 2 June (mean = 0.9, SD = 1.3).

<u>Total Tagged Fish</u>

A total of 995 spring/summer Chinook and sockeye salmon were PIT-tagged throughout the study period. In addition, four previously tagged fish were recaptured at the trap (two of which were previously tagged at the trap site). However, this small group of previously tagged fish was excluded from the analysis due to the potential difference in handling survival from those that had undergone the standard tagging procedure. Of the tagged fish, 849 were sockeye salmon (402 control; 447 pooled treatment; 309 modified passive treatment; 138 prototype spilled treatment), and 146 were Chinook salmon (71 control; 75 pooled treatment; 43 modified passive treatment; 32 prototype spilled treatment). The sample size for tagged sockeye salmon exceeded targets of the project, enabling robust analysis of release survival. However, the sample size for spring/summer Chinook salmon proved mostly insufficient for precise estimation of survival.

Beyond the goals of the project, late-winter and early-summer run steelhead encountered at the trap were PIT-tagged between May and June (119 control; 33 modified treatment; 90 prototype treatment). Based on run timing, most of these fish were likely of lower basin Skamania stock origin (Byrne et al. 2018). Due to sample size limitations for mark and recapture and the tendency of Skamania stock to remain downstream of mainstem dams, steelhead PIT-tag data proved insufficient for analysis in 2019.

During the spring and early-summer study period, sampling and assignment of control and treatment tagging sessions resulted in fairly equal representation of mixed stock for sockeye salmon control and treatment groups. However, due to a small sample size, the Chinook salmon sampling effort between control and treatment groups was relatively unequal over time (Figures VI-9 - VI-10).

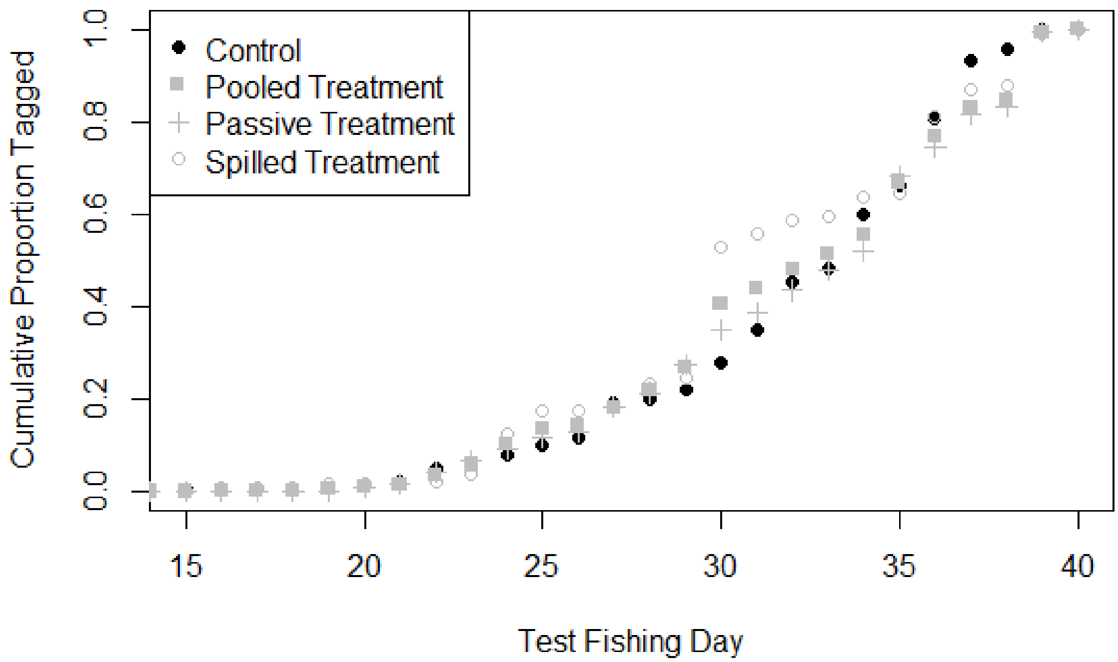

Figure VI-9. Cumulative proportion of tagged sockeye salmon control and treatment groups.

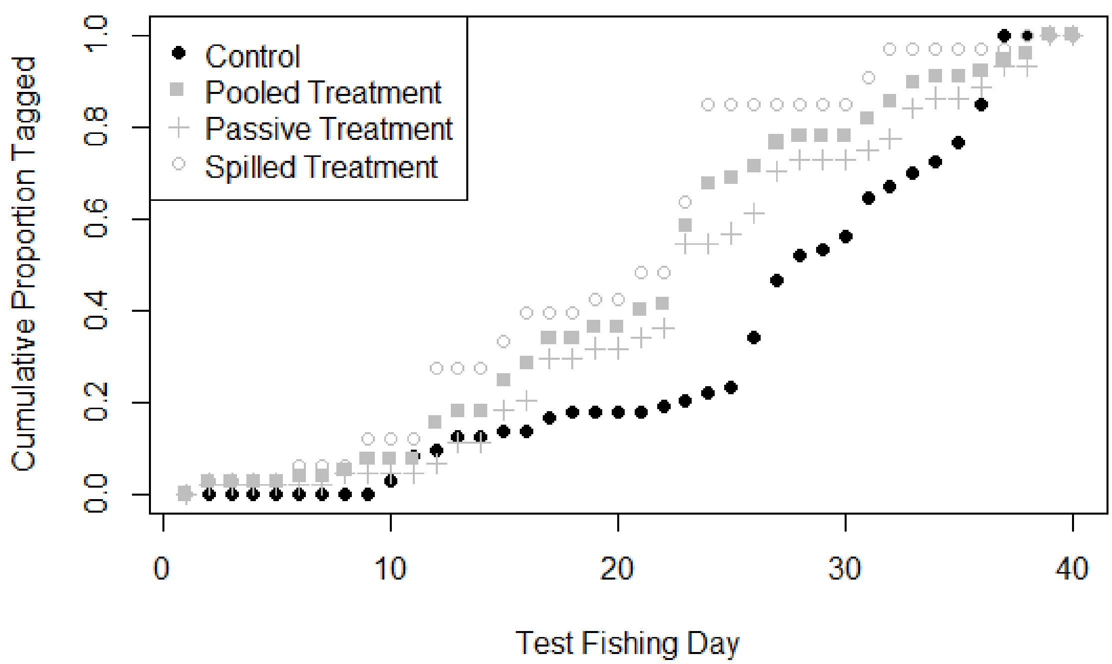

Figure VI-10. Cumulative proportion of tagged Chinook salmon control and treatment groups.

Total Fin-clip Samples and Genotyping

Genetic tissue samples were obtained from 990 PIT-tagged Chinook and sockeye salmon throughout the study period, representing 99.5% of the tagged population. Of these samples, 844 were sockeye (399 control; 307 modified treatment; 138 prototype treatment), and 146 were Chinook salmon (71 control; 43 modified treatment; 32 prototype treatment). In addition, genetic samples were obtained from 100% of PIT-tagged steelhead trout. Although genetic analysis is unnecessary for sockeye salmon (which are almost all destined for migration above Bonneville Dam), genetic assignment is essential for estimation of spring/summer Chinook release survival due to the migratory nature of the species in the basin and the small number of PIT-tag samples available for analysis. If resource managers choose to use 2019 spring/summer Chinook data, it is highly recommended that results of genetic assignment are utilized to ensure that the model assumption of stock-composition equivalence is met for Chinook salmon.

Immediate Survival

Throughout the duration of the study, there were a total of five immediate adult salmonid mortalities, all of which were small bodied sockeye salmon < 400 mm FL (Table VI-17). Two sockeye mortalities occurred for unknown reasons in the spiller compartment. Three sockeye mortalities occurred from wedging in a panel of the jigger/heart (the only component of the heart mesh that remained 3-1/8'' and had not been modified to 2-1/2" knotless mesh). From these results, immediate mortality of adult Chinook salmon and steelhead was zero (immediate survival $\hat{\tau}_0 = 1.000$); immediate mortality of sockeye salmon was 0.006 (immediate survival $\hat{\tau}_0 = 0.994$; $\widehat{SE} = 0.002$).

Table VI-17. Immediate non-juvenile salmonid mortalities during the 2019 BREP study period.

Species	Total Captured	Mortalities (Non-Juveniles)	Immediate Mortality	Immediate Survival
Chinook	161	0	0.000	1.000
Sockeye	896	5	0.006	0.994
Steelhead	254	0	0.000	1.000

Beyond adult and jack salmonids, there were 252 immediate juvenile Chinook salmon outmigrant mortalities from wedging or gilling in the 2-1/2'' knotless spiller mesh or 1-1/2'' knotless live-well mesh. Of these juvenile outmigrants (< 250 mm FL), 91% were ad-clipped suggesting hatchery origins. Furthermore, eight largescale suckers, one starry flounder, and three pikeminnow immediate mortalities occurred from wedging or gilling in the 3-1/8'' knotted lead and jigger mesh.

Sockeye Salmon Fork-length and Migration Timing

Of 849 tagged sockeye salmon (402 control; 309 modified treatment; 138 prototype treatment), the mean fork length included in the study was 413.6 mm (max = 650, min = 300, $\widehat{SE}$ = 2.44). Mean fork length was 414.8 mm ($\widehat{SE}$ = 3.54) for the control group, 417.8 ($\widehat{SE}$ = 4.04) for the modified treatment group, and 401.0 ($\widehat{SE}$ = 6.04) for the prototype treatment group. Analyzed through one-way ANOVA, mean fork length was equivalent between control and modified treatment groups at the $P \leq 0.05$ significance level ($P_{passive}$ ($|t_{846}| \geq 0.55$) = 0.581); however, the control group fork length was statistically greater than the prototype treatment group (P_{winch} ($|t_{846}| \geq -1.97$) = 0.049).

The median arrival date for sockeye salmon was 27 June at Bonneville Dam (Table VI-18). The median travel time between release and Bonneville was 3.8-d, with a mean of 4.1-d (CI ($4.0 \leq \widehat{T} \leq 4.2$) = 0.95). Mean travel time was 3.9-d ($\widehat{SE}$ = 0.07) for the control group, 3.9-d ($\widehat{SE}$ = 0.08) for the passive treatment group, and 5.2-d ($\widehat{SE}$ = 0.14) for the prototype treatment group. Analyzed through one-way ANOVA, there were differences between treatment and control group migrations (P ($|F_{2,735}| \geq 39.97$) < 0.001). Migration timing was equivalent between control and passive treatment groups (P ($|t| \geq -0.208$) = 0.835). However, there was a significant difference in migration timing between the prototype treatment group and the control group to Bonneville Dam (P ($|t| \geq 8.441$) < 0.001).

To McNary Dam, the median arrival date for sockeye salmon was 2 July (Table VI-18). The median travel time between release from the gear to McNary Dam was 8.7-d, with a mean of 9.0-d (CI ($8.8 \leq \widehat{T} \leq 9.2$) = 0.95). Mean travel time was 8.8-d ($\widehat{SE}$ = 0.12) for the control group, 8.7-d ($\widehat{SE}$ = 0.13) for the passive treatment group, and 10.5-d ($\widehat{SE}$ = 0.23) for the prototype treatment group. Analyzed through one-way ANOVA, there were differences between treatment and control group migrations (P ($|F_{2,665}| \geq 23.42$) < 0.001). Migration timing was equivalent between control and passive treatment groups (P ($|t| \geq -0.483$) = 0.630). However, there was a significant difference in migration timing between the prototype treatment group and the control group to McNary Dam (P ($|t| \geq 6.343$) < 0.001).

Table VI-18. First, last, and median detection date for tagged sockeye salmon. Note that some tagged sockeye salmon evaded detection at both Bonneville and McNary Dams, but were detected farther upriver; these fish were not included in the migration timing analysis.

Detection Site	River Mile	Number of Tags	Median Detection	First Detection	Last Detection
Bonneville	233	738	6/27/2019	6/7/2019	7/13/2019
McNary	470	668	7/2/2019	6/12/2019	8/11/2019

Sockeye Salmon Survival

The sockeye salmon relative post-release survival effect was estimated for the modified passive spiller capture method (modified treatment) and the prototype spilling capture method (prototype treatment). Additionally, the pooled treatment effect was estimated combining data from the two treatments (modified treatment + prototype treatment). This pooling technique was used to accommodate a small sample size for the prototype treatment group. Retrieving unique capture histories for control and treatment sockeye salmon through PTAGIS, the following cell counts were entered into Program USER to estimate post-release survival through the CJS method (Table VI-19):

Table VI-19. Control and treatment cell counts for all possible capture histories at four mainstem river detection locations. A "1" denotes detection and "0" nondetection at each upstream detection location in order from lowest to highest rkm (Bonneville Dam, The Dalles Dam, McNary Dam, and pooled detection points upstream of McNary Dam).

History	Control Count	Modified Treatment Count	Prototype Treatment Count	Pooled Treatment Count
1111	287	241	65	306
0111	12	3	2	5
1011	4	3	0	3
0011	0	0	0	0
1101	14	3	3	6
0101	1	1	0	1
1001	0	0	0	0
0001	1	1	0	1
1110	17	11	19	30
0110	1	2	1	3
1010	0	0	0	0
0010	0	0	0	0
1100	23	10	9	19
0100	1	0	0	0
1000	16	10	4	14
0000	25	24	35	59
N	**402**	**309**	**138**	**447**

Modified Treatment

LRT found no significant difference in PIT-tag array detection probabilities for control and modified treatment groups (P ($\chi^2_3 \geq 5.543$) = 0.136), resulting in the selection of a reduced model with a common detection probability for control and treatment fish by location. Post-release survival for the modified treatment group compared to the control group was high from release to Bonneville Dam at $\hat{\tau}_1 = 0.983$ ($\widehat{SE} = 0.021$) (Table VI-20). The treatment group survived at a higher rate than the control group in the two river reaches defined between Bonneville Dam and McNary Dam with relative survival estimated at $\hat{\tau}_2 = 1.008$ ($\widehat{SE} = 0.016$)

and $\hat{\tau}_3$ = 1.033 ($\widehat{SE}$ = 0.019) respectively. Accounting for immediate sockeye salmon survival ($\hat{\tau}_0$ = 0.994; $\widehat{SE}$ = 0.002), cumulative relative survival ($\tau_0 * \tau_1 * \tau_2 * \tau_3$) for the modified treatment group from capture at the trap site to McNary Dam (~400 km upstream; 8-d median travel duration) was estimated to be 1.017 ($\widehat{SE}$ = 0.032) (Table VI-20).

Utilizing detection points chosen by WDFW (2014) to estimate relative short-term, long-term, and cumulative survival of salmon released from purse and beach seines, short-term relative post-release survival from the gear to Bonneville (τ_1) was estimated at 0.983 ($\widehat{SE}$ = 0.021) (Table VI-21). Long-term relative post-release survival from Bonneville to McNary ($\tau_2 * \tau_3$) was estimated at 1.040 ($\widehat{SE}$ = 0.025). Cumulative relative survival ($\tau_0 * \tau_1 * \tau_2 * \tau_3$) from the trap site to McNary Dam (~400 km upstream; 8-d median travel duration) was estimated at 1.017 ($\widehat{SE}$ = 0.032) for sockeye salmon exposed to the modified treatment (Table VI-21).

Prototype Treatment

Between 28 May and 3 July, a total of 32 spiller hauls were performed with the prototype treatment design, of which only 21 hauls resulted in the capture of sockeye salmon. LRT found no significant difference in PIT-tag array detection probabilities for control and prototype treatment groups (P ($\chi^2_3 \geq$ 2.864) = 0.413), resulting in the selection of a reduced model with a common detection probability for the fish at a location. Short-term relative post-release survival from the gear to Bonneville Dam was estimated at $\hat{\tau}_1$ = 0.796 ($\widehat{SE}$ = 0.041) (Table VI-20). Between Bonneville Dam and the Dalles Dam (τ_2), relative survival was nearly equivalent to the control group at $\hat{\tau}_2$ = 1.004 ($\widehat{SE}$ = 0.024). Relative survival remained high in the final reach between The Dalles Dam and McNary Dam at $\hat{\tau}_3$ = 0.974 ($\widehat{SE}$ = 0.035). Nevertheless, survival of sockeye salmon exposed to the prototype treatment was significantly different from exposure to the modified fish trap treatment (P ($|Z| \geq$ 4.963) < 0.001; Table VI-20), with cumulative relative survival from release to McNary Dam estimated at 0.774 ($\widehat{SE}$ = 0.051).

Utilizing detection points chosen by WDFW (2014) to estimate relative short-term, long-term, and cumulative survival of salmon released from purse and beach seines, short-term relative post-release survival from the prototype gear to Bonneville (τ_1) was estimated at 0.796 ($\widehat{SE}$ = 0.041) (Table VI-21). Long-term relative post-release survival from Bonneville to McNary ($\tau_2 * \tau_3$) was estimated at 0.978 ($\widehat{SE}$ = 0.041). Cumulative relative survival ($\tau_0 * \tau_1 * \tau_2 * \tau_3$) from the prototype treatment to McNary Dam was estimated at 0.774 ($\widehat{SE}$ = 0.051) (Table VI-21).

Pooled Treatments

Between pooled treatment (modified treatment + prototype treatment) and control groups, LRT found no significant difference in PIT-tag array detection probabilities (P ($\chi^2_3 \geq$ 4.749) = 0.191), resulting in the selection of a reduced model with a common detection probability. Post-release survival for the pooled treatment group compared to the control group was estimated at $\hat{\tau}_1$ = 0.925 ($\widehat{SE}$ = 0.021) from release to Bonneville Dam (Table VI-20). Survival between the pooled treatment group and the control group was nearly equivalent between Bonneville Dam and McNary Dam with relative survival estimated at $\hat{\tau}_2$ = 1.007 ($\widehat{SE}$ = 0.015) and $\hat{\tau}_3$ = 1.017 ($\widehat{SE}$ = 0.019) respectively. Accounting for immediate sockeye salmon survival ($\hat{\tau}_0$ = 0.994; $\widehat{SE}$ = 0.002), cumulative relative survival ($\tau_0 * \tau_1 * \tau_2 * \tau_3$) for the pooled treatment group was estimated at 0.942 ($\widehat{SE}$ = 0.031) (Table VI-20).

Utilizing detection points chosen by WDFW (2014), short-term relative post-release survival of the pooled treatment group from the gear to Bonneville (τ_1) was estimated at 0.925 ($\widehat{SE}$ = 0.021) (Table VI-21). Long-term relative post-release survival from Bonneville to McNary ($\tau_2 * \tau_3$) was estimated at 1.024 ($\widehat{SE}$ = 0.024). Incorporating immediate survival of 0.994 ($\widehat{SE}$ = 0.002) for the sockeye salmon species, cumulative relative survival ($\tau_0 * \tau_1 * \tau_2 * \tau_3$) for the pooled treatment group to McNary Dam was estimated at 0.942 ($\widehat{SE}$ = 0.031) (Table VI-21).

Table VI-20. Post-release survival point-estimates for adult sockeye salmon released from the experimental fish trap and associated profile likelihood 95% confidence intervals.

River reach	Modified treatment survival point estimate	Prototype treatment survival point estimate	Pooled treatment survival point estimate
Immediate survival (τ_0)	0.994 (0.988 – 0.998)	0.994 (0.988 – 0.998)	0.994 (0.988 – 0.998)
Gear to Bonneville (τ_1)	0.983 (0.942 – 1.024)	0.796 (0.712 – 0.872)	0.925 (0.884 - 0.967)
Bonneville to Dalles (τ_2)	1.008 (0.974 – 1.041)	1.004 (0.948 – 1.045)	1.007 (0.977 – 1.038)
Dalles to McNary (τ_3)	1.033 (0.995 – 1.072)	0.974 (0.899 – 1.033)	1.017 (0.980 – 1.056)
Cumulative ($\tau_0 * \tau_1 * \tau_2 * \tau_3$)	1.017 (0.974 – 1.059)	0.774 (0.673 - 0.872)	0.942 (0.902 – 0.986)

Table VI-21. Sockeye salmon relative post-release survival point estimates and associated profile likelihood 95% confidence intervals from the experimental fish trap, employing detection points selected by WDFW (2014).

Treatment	No. Tagged	No. Recaptured	Recapture Prob.	Relative Survival
CUMULATIVE: GEAR TO MCNARY				
Treatment	No. Tagged	No. Recaptured	Recapture Prob.	Relative Survival
Control	402	337	0.838	---
Modified Treatment	309	265	0.858	1.017 (0.974 - 1.059)
Prototype Treatment	138	90	0.652	0.774 (0.673 - 0.872)
Pooled Treatments	447	355	0.794	0.942 (0.900 - 0.984)
SHORT-TERM: GEAR TO BONNEVILLE				
Treatment	No. Tagged	No. Recaptured	Recapture Prob.	Relative Survival
Control	402	377	0.938	---
Modified Treatment	309	285	0.922	0.983 (0.942 - 1.024)
Prototype Treatment	138	103	0.746	0.796 (0.712 - 0.872)
Pooled Treatments	447	388	0.868	0.925 (0.884 - 0.966)
LONG-TERM: BONNEVILLE TO MCNARY				

Treatment	No. Over BON	No. Recaptured	Recapture Prob.	Relative Survival
Control	377	337	0.894	---
Modified Treatment	285	265	0.930	1.040 (1.006 - 1.074)
Prototype Treatment	103	90	0.874	0.978 (0.891 - 1.051)
Pooled Treatments	388	355	0.915	1.024 (0.994 - 1.057)

Spring/Summer Chinook Salmon Fork-length and Migration Timing

Of 146 tagged spring/summer Chinook salmon (71 control; 43 modified treatment; 32 prototype treatment), the mean fork length included in the study was 745.2 mm (max = 1,100, min = 400, $\widehat{SE}$ = 10.31). Mean fork length was 753.3 mm ($\widehat{SE}$ = 14.82) for the control group, 749.2 ($\widehat{SE}$ = 19.04) for the modified treatment group, and 721.9 ($\widehat{SE}$ = 22.07) for the prototype treatment group. Analyzed through one-way ANOVA, mean fork length was equivalent between control and treatment groups at the $P \leq 0.05$ significance level ($P_{passive}$ ($|t_{143}| \geq -0.17$) = 0.865, P_{winch} ($|t_{143}| \geq -1.18$) = 0.239).

The median arrival date for spring/summer Chinook salmon was 20 June at Bonneville Dam (Table VI-22). The median travel time between release and Bonneville was 5.0-d, with a mean of 6.6-d (CI ($5.9 \leq \hat{T} \leq 7.4$) = 0.95). Analyzed through one-way ANOVA, there was no difference between treatment and control group migrations to Bonneville Dam (P ($|F_{2,112}| \geq 2.49$) = 0.088).

To McNary Dam, the median arrival date for spring/summer Chinook salmon was 26 June (Table VI-22). The median travel time between release and McNary Dam was 11.7-d, with a mean of 12.6-d (CI ($11.7 \leq \hat{T} \leq 13.5$) = 0.95). Analyzed through one-way ANOVA, there was no difference between treatment and control group migrations to McNary Dam (P ($|F_{2,83}| \geq$ 0.205) = 0.815).

Table VI-22. First, last, and median detection date for tagged spring/summer Chinook salmon.

Detection Site	River Mile	Number of Tags	Median Detection	First Detection	Last Detection
Bonneville	233	114	6/20/2019	5/12/2019	7/8/2019
McNary	470	85	6/26/2019	6/6/2019	7/14/2019

Spring/Summer Chinook Salmon Survival

The total sample size for tagged spring/summer Chinook salmon (n_{total} = 146) was mostly insufficient for analysis. Given sample size limitations for each Chinook salmon treatment group, only the pooled treatment effect was analyzed combining data from the two treatments (modified treatment + prototype treatment).

Retrieving unique capture histories for control and pooled treatment spring/summer Chinook salmon through PTAGIS, the following cell counts were entered into Program USER to estimate post-release survival through the CJS method (Table VI-23):

Table VI-23. Control and treatment cell counts for all possible capture histories at four mainstem river detection locations. A “1” denotes detection and “0” nondetection at each upstream detection location in order from lowest to highest rkm (Bonneville Dam, The Dalles Dam, McNary Dam, and pooled detection points upstream of McNary Dam).

History	Control Count	Pooled Treatment Count
1111	40	42
0111	0	0
1011	0	0
0011	0	0
1101	0	0
0101	0	0
1001	1	0
0001	0	0
1110	1	1
0110	0	0
1010	0	0
0010	0	0
1100	8	6
0100	0	0
1000	9	6
0000	12	20
N	**71**	**75**

Pooled Treatments

Between pooled treatment (modified treatment + prototype treatment) and control groups, LRT found no significant difference in PIT-tag array detection probabilities, resulting in the selection of a reduced model with a common detection probability. Post-release survival for the pooled treatment group compared to the control group was estimated at $\hat{\tau}_1 = 0.882$ ($\widehat{SE} = 0.078$) from release to Bonneville Dam (Table VI-24). Survival between the pooled treatment group exceeded that of the control group between Bonneville Dam and McNary Dam with relative survival estimated at $\hat{\tau}_2 = 1.030$ ($\widehat{SE} = 0.072$) and $\hat{\tau}_3 = 1.066$ ($\widehat{SE} = 0.090$) respectively. Cumulative relative survival ($\tau_0 * \tau_1 * \tau_2 * \tau_3$) for the pooled treatment group from capture at the trap site to McNary

Dam (~400 km upstream; 11-d median travel duration) was estimated at 0.969 ($\widehat{SE}$ = 0.136) (Table VI-24).

Table VI-24. Post-release survival point-estimates for adult spring/summer Chinook salmon released from the experimental trap and associated profile likelihood 95% confidence intervals.

River reach	Pooled treatment survival point estimate
Immediate survival (τ_0)	1.000 (0.998 – 1.000)
Gear to Bonneville Dam (τ_1)	0.882 (0.736 – 1.048)
Bonneville Dam to The Dalles Dam (τ_2)	1.030 (0.891 – 1.193)
The Dalles Dam to McNary Dam (τ_3)	1.066 (0.898 – 1.277)
Cumulative ($\tau_0 * \tau_1 * \tau_2 * \tau_3$)	0.969 (0.808 – 1.151)

Utilizing detection points chosen by WDFW (2014) to estimate relative short-term, long-term, and cumulative survival of salmon released from purse and beach seines, short-term relative post-release survival of spring/summer Chinook salmon from the gear to Bonneville (τ_1) was estimated at 0.882 ($\widehat{SE}$ = 0.078) (Table VI-25). Long-term relative post-release survival from Bonneville to McNary ($\tau_2 * \tau_3$) was estimated at 1.098 ($\widehat{SE}$ = 0.120). Cumulative relative survival ($\tau_0 * \tau_1 * \tau_2 * \tau_3$) from the trap site to McNary Dam (~400 km upstream; 11 d median travel duration) was estimated at 0.969 ($\widehat{SE}$ = 0.136) for spring/summer Chinook salmon (Table VI-25).

Table VI-25. Spring and summer Chinook salmon relative post-release survival point estimates and associated profile likelihood 95% confidence intervals from the experimental fish trap, employing detection points selected by WDFW (2014).

CUMULATIVE: GEAR TO MCNARY

Treatment	No. Tagged	No. Recaptured	Recapture Prob.	Relative Survival
Control	71	42	0.592	---
Pooled Treatments	75	43	0.573	0.969 (0.808 - 1.151)

SHORT-TERM: GEAR TO BONNEVILLE

Treatment	No. Tagged	No. Recaptured	Recapture Prob.	Relative Survival
Control	71	59	0.831	---
Pooled Treatments	75	55	0.733	0.882 (0.736 – 1.048)

LONG-TERM: BONNEVILLE TO MCNARY

Treatment	No. Over BON	No. Recaptured	Recapture Prob.	Relative Survival
Control	59	42	0.712	---
Pooled Treatments	55	43	0.782	1.098 (0.951 - 1.272)

Steelhead Results

The total sample size for tagged late-winter and early-summer run steelhead (119 control; 33 modified treatment; 90 prototype treatment) proved insufficient for analysis of relative survival. Furthermore, 77.3% of tagged steelhead from control and treatment groups did not pass over mainstem dams ($n_{detected.bonneville}$ = 55), suggesting that late-winter/early-summer run steelhead encountered from May through June were mostly Skamania stock destined for lower basin tributaries below mainstem dam detection points (Byrne et al. 2018).

Table VI-26. Control and treatment cell counts for all possible capture histories at four mainstem river detection locations. A "1" denotes detection and "0" nondetection at each upstream detection location in order from lowest to highest rkm (Bonneville Dam, The Dalles Dam, McNary Dam, and pooled detection points upstream of McNary Dam).

History	Control Count	Pooled Treatment Count
1111	4	5
0111	0	0
1011	0	0
0011	0	0
1101	0	0
0101	0	0
1001	0	0
0001	0	0
1110	0	3
0110	0	0
1010	0	0
0010	0	0
1100	3	1
0100	0	0
1000	11	28
0000	101	86
N	**119**	**123**

Coho Salmon Survival

As a supplement to the 2019 BREP study, a coho salmon holding study was conducted between 27 September and 30 October 2019. During the research period, water temperatures ranged from 19.2 ºC to 12.1 ºC (mean = 15.79 ºC). Encountering 3,521 adult coho salmon at the trap site, there were zero adult coho salmon immediate mortalities resulting in an immediate survival rate of $\hat{S}$ = 1.000 with a 95% lower confidence interval of CI ($S \geq 0.999$) = 0.95. A total of 121 coho salmon were held in captivity post-release from the commercial gear in six separate sub-sample groups (Table VI-27). Zero mortalities occurred during the 48-h holding period for a post-release survival estimate of $\hat{S}$ = 1.000 with a 95% lower confidence interval of CI ($S \geq 0.978$) = 0.95. All coho salmon encountered during the fish collection process for the holding study were lively and vigorous upon capture and release after 48-h, with zero fish appearing lethargic or asphyxiated.

Table VI-27. Sub-samples of coho salmon captured with the modified fish trap were held for a 48-h captive period to directly estimate release survival; water quality conditions were recorded.

Sub-sample number	Date	Mean water temperature (°C)	Fish sample size	Coho salmon survived	Coho salmon survival
1	27 Sep - 29 Sep	18.77	13	13	1.000
2	30 Sep - 2 Oct	17.74	27	27	1.000
3	3 Oct - 5 Oct	16.31	34	34	1.000
4	10 Oct - 12 Oct	15.63	13	13	1.000
5	23 Oct - 25 Oct	13.57	24	24	1.000
6	28 Oct - 30 Oct	12.75	10	10	1.000
-- ***Total*** --		15.79	121	121	1.000

Marine Mammal Encounters

During the 2019 spring and summer season study, marine mammal encounters were rare and posed minimal nuisance. It is hypothesized that low marine mammal encounter at the trap was potentially due to low abundance of spring Chinook salmon. Over 40-d, marine mammals were observed in the vicinity of the trap on five separate occasions. On two of these occasions, California sea lions were observed migrating down river, resulting in closure of the marine mammal gate for roughly 30-minute intervals until operators were certain mammals had migrated from the study region. On one occasion, a California sea lion entered the heart as a result of operator error. After surfacing once in the heart, the sea lion escaped and was not seen again. On the remaining two occasions, harbor seals were observed downstream of the trap. Neither of these two harbor seals were seen entering the heart or migrating along the lead net during the spring season study.

C. Significant Problems

No significant problems were experienced throughout the course of the 2017 study. The trap was successfully deployed, operated, refined, and tested from 26 August through 27 September 2017. Testing was delayed due to low run-size forecasts for Columbia Basin B-run steelhead and related negotiations with WDFW, ODFW, and NOAA over ESA-impacts.

Additionally, due to the low run size of steelhead in the Columbia Basin, the number of steelhead tagged throughout the study fell short of our target for the analysis. Nevertheless, these minor issues did not impact achievement of 2017 project goals or objectives.

During the spring and early-summer of 2019, a poor return of ESA-listed spring Chinook salmon, sockeye salmon, and steelhead significantly impacted fishing operations. Test fishing was delayed to 5 May at the direction of NOAA Fisheries and WDFW to minimize research impacts to the peak of the spring Chinook salmon run. With low returns and a subsequent late start date, we were unable to reach our PIT-tagging goal for Chinook salmon. Additionally, due to a poor run of sockeye salmon and steelhead in the Columbia Basin, fishing was temporarily paused at the direction of NOAA Fisheries and WDFW during the peak of the sockeye run at the end of June and halted in early July. This reduced our potential sample size for sockeye and steelhead, however, we still managed to achieve our PIT tagging goal for sockeye salmon and estimated survival with a higher level of precision than anticipated in the study proposal.

The second challenge encountered during the spring 2019 fishery was high river flows and abundant large woody debris. During the first weeks of May, significant amounts of drifting wood became affixed to the upstream side of the lead pilings, pinned by strong downstream currents. Exacerbating the problem was the lack of a tidal flood current pushing upstream, as is typical at the trap site during the summer and fall fishing seasons. Flood tides help to push debris from lead nets, partially cleaning the nets of entangled wood and detritus. With the abundance of wood and lack of flood currents, maintenance of lead nets was required consistently making trap operations challenging. It was also necessary to intercept incoming logs and retrieve lead nets throughout sampling to avoid pulses of debris. As research progressed into mid-May and peak river flows subsided, the abundance of large woody debris and suspended detritus decreased. With river conditions normalizing by late-May to that experienced during prior summer and fall investigations, trap operations and maintenance became more feasible. Based upon experiences during the spring of 2019, careful site selection and/or employment of pile driven debris booms are necessary if trap operators or resource managers desire to fish traps during spring freshet.

D. Need for Additional Work

The results of this BREP funded research project have demonstrated the feasibility of modified commercial fish traps in the lower Columbia River for selective harvest during summer and fall seasons and have provided precise and unbiased estimates of cumulative survival for fall Chinook, sockeye, coho, and summer steelhead trout to inform management of commercial fisheries and resources. Survival results suggest that fish traps can help resolve an urgent mixed-stock harvest problem in the Columbia River and beyond. Nevertheless, data gaps remain for the gear and the following studies are recommended for future investigation:

- <u>Test fish traps in new locations</u> – At present, the gear has only been tested at one site in one river system. Further research is warranted to determine the effectiveness of the gear in a diverse array of environmental and ecological conditions found within the lower Columbia River, as well as in other river systems or estuaries where conditions differ. Research is currently scheduled in 2021 for a new location within the lower Columbia

River, OR (Clifton Channel) as well as a new estuarine environment in the lower Skeena River, B.C. (Port Essington).

- Test new fish trap designs – New fish trap designs should be tested to identify potential improvements in bycatch survival, capture efficiency, and cost effectiveness. Cumulative survival results for passively captured sockeye and coho salmon from the 2019 study warrant future trap designs that fully apply this method of capture to minimize adverse impacts to bycatch. Current preliminary trap designs for Clifton Channel and Skeena River research projects call for spiller designs that collect all captured fish passively, reducing handling, air exposure, net contact, and crowding. Research of the passive spiller design is also tentatively scheduled at the Cathlamet Channel trap site for the summer and fall of 2020. If these studies are conducted, we hypothesize that reduced direct and indirect ESA mortality effects may be detected for steelhead and fall Chinook salmon relative to established 2017 mortality estimates (Tuohy et al. 2019). Consequently, sustainable commercial salmon fishing opportunities may be increased within the lower Columbia River for the benefit of wild salmon recovery and coastal fishing communities.
- Evaluate marine mammal interactions – Although marine mammal interactions were minimal during BREP research, other periods of research and test fishing have at times documented disruptive marine mammal encounters. It is possible that mammals could become attracted to fixed gears over time resulting in damage to equipment and increased fish predation. Commercial fishing gears (all of which are prone to marine mammal nuisance) should be monitored over time in various locations to investigate whether marine mammal feeding rates are equivalent in the presence or absence of commercial gear.
- Estimate release survival of bycatch from gill nets – To date, gill net release survival of limiting bycatch stocks (e.g., ESA-listed steelhead) has not been estimated through mark-recapture or net pen holding. Lacking release mortality data for these stocks, Columbia River management agencies apply assumed release mortality rates for estimation of gill net ESA-impacts (ODFW and WDFW 2018). If mortality rate assumptions by resource managers are incorrect for gill net fisheries that are approved on an annual basis, mortality of ESA-listed stocks may be higher than presently assumed. Furthermore, alternative gears that stand to benefit bycatch stocks may be at a comparative disadvantage that diminishes their perceived applicability. Gill nets must be studied as all other alternative gears have been in the lower Columbia River, and research should be conducted in a manner that is consistent and unbiased amongst gear-types.

VII. EVALUATION

A. Attainment of Project Goals and Objectives – 2017

For the 2017 study, all proposed tasks for the NA17NMF4720255 cooperative agreement were accomplished and project goals and objectives achieved (Table VII-1). From August to October of 2017, WFC and a local commercial fisherman successfully constructed, tested, and refined deployment and operation of an experimental fish trap in the lower Columbia Sub-basin (Goal #1). WFC has evaluated the effectiveness of the harvest method in capturing salmon through determination of species-specific CPUE (Goal #2), and assessed the ability of a fish trap to protect non-target species through identification of capture/release conditions, immediate survival, and post-release survival of fall Chinook salmon and steelhead trout (Goal #3). Results have been successfully compared relative to previously tested alternative and conventional gears in the lower Columbia River. Furthermore, environmental covariates that explain CPUE have been assessed to inform future fishing operations.

Table VII-1. Project timeline for the 2017-2018 NA17NMF4720255 cooperative agreement. Tasks are listed with the party responsible for the associated action. All tasks have been accomplished.

Proposed Task	Responsible Party	Date	Increment
Secure Permits/Contracts	WFC, Peterson	12/5/2016	Month 0
Modify Design	WFC, Peterson	1/1/2017	Month 0
Install Trap Hardware	WFC, Peterson	8/1/2017	Month 2
Complete 2017 Trap	WFC, Peterson	8/14/2017	Month 2
Initiate Testing	WFC, Peterson	8/15/2017	Month 2
Complete Testing	WFC, Peterson	10/15/2017	Month 3
Remove Trap Hardware	WFC, Peterson	10/15/2017	Month 4
Enter Data	WFC	10/16/2017	Month 4
Analyze Data	WFC	11/1/2017	Month 5
Submit Tissue Samples for Genotyping	WFC	12/15/2017	Month 6
NOAA Financial Report	WFC	12/31/2017	Month 6
NOAA Progress Report	WFC	1/30/2018	Month 7
Process Genetic Samples	Flathead Lake Bio. Station	2/15/2018	Month 8
Finalize Data Analysis	WFC	3/1/2018	Month 9
Publish and Submit Final Report	WFC	3/30/2020	Month 12

<u>Goal #1 - Construct, Test, and Refine Deployment and Operation of an Experimental Fish Trap</u>

On 1 August 2017, WFC and a local commercial fisherman initiated on-site construction of the experimental trap. All net modifications and marine mammal gate welding were accomplished prior to arrival in Cathlamet, WA through Christensen Net Works (Everson, WA)

and STA-weld (Redmond, WA) respectively. WFC staff and Peterson assembled the modified trap over a two-week period at the project site, finishing construction before 15 August. The trap was successfully deployed, operated, refined, and tested from 26 August through 27 September 2017. Testing was delayed due to low run-size forecasts for Columbia Basin B-run steelhead and related negotiations with WDFW, ODFW, and NOAA over ESA-impacts. Nevertheless, this delay did not impact achievement of project goals or objectives.

Minor modifications made by Peterson and WFC staff dramatically improved functionality of the gear and increased capture efficiency relative to the 2016 pilot design. WFC staff ensured all nets were flush with the river bottom before test fishing and tightened escapement points between the lead, heart, and spiller. These refinements in the deployment of the gear likely resulted in increased percentage capture of benthic oriented species, such as Chinook salmon, and greater total capture efficiency of salmonids relative to 2016 testing. Inclusion of the "fish gate" (a 5' X 25' panel of 2 ½'' knotless mesh) at the outlet of the heart also seems to have reduced escapement of fish from the heart compartment during lifting of the spiller, increasing buildup of fish within the heart prior to initiation of a succeeding soak period.

It is hypothesized that adjustments made to the deployment of the spiller compartment further contributed to increases in capture efficiency. Lifting and lowering the spiller from its four corners along 1/4'' stainless steel cable reduced friction from the previous year (in which the spiller was lifted and lowered along 3 ¼'' diameter aluminum). This reduction in friction enabled the spiller to move more easily with gravity or lift from the solar powered winch, improving the ability of the spiller to be deployed at all tides and sit flush with the river bottom to capture benthic oriented species. Additionally, raising the lifting point of the spiller to 38' above the river bottom from 30' in 2016 enabled the spiller to be raised higher, improving the effectiveness of hauls performed at or near high tide.

Reduction in the mesh size of the spiller compartment to 2 ½'' reduced the proportion of catch wedged or gilled from 2016. Less than 0.1% of all catch was wedged or gilled in the spiller compartment in 2017. Of these fish, all were jacks or residualized sub-adult salmonids. Future users of the gear should consider reductions in the mesh size of the downstream heart compartment panel, where jacks and residualized salmonids were occasionally found wedged throughout the study period. It appears that fish captured in the heart compartment tend to face into the incoming current of the flood tide at the downstream section of the heart, and during encounters with marine mammals, these small fish may attempt to swim through the mesh resulting in wedging in this particular location of the trap.

WFC constructed a marine mammal deterrent gate consisting of a series of vertical aluminum bars spaced at 10" increments. Installed at the entrance to the heart compartment of the trap, this design was intended to prevent entry of marine mammals—including harbor seals, California sea lions, and Steller sea lions—while enabling passage of salmonids for capture. Based upon 2017 data and comparison to 2016 anecdotal evidence from the pilot study, marine mammal encounters were more frequent in 2017. Inclusion of the marine mammal gate proved instrumental in reducing entry of mammals to the heart compartment of the trap relative to 2016 and minimizing potential of fish predation and damage to the gear. With only four mammal entries during 81 gate closure events, the gate demonstrated a deterrent success rate of 95.1%. Of the mammal entries during gate closure events, it is likely that entry was achieved through small gaps between the mesh lead line and the river bottom when river and tidal currents were strong.

Goal #2 - Determine Effectiveness of the Trap in Capturing Salmon Relative to Other Gears

For commercial implementation of any alternative gear type, a fishing tool must not only demonstrate potential to achieve conservation objectives but also meet the economic needs of fishers and industry. Given the historical effectiveness and popularity of commercial fish traps throughout the U.S. Pacific Northwest (Cobb 1930; Lichatowich 1999), there is little reason to believe that modern trap designs (when well placed) would be less effective than conventional gears used within Pacific Northwest salmon fisheries. Although the design of this alternative gear study provided no means to precisely and accurately compare capture efficiency of trap operations to that of the conventional gill net fishery, the performance of the experimental trap prototype suggests that the gear can once again be engineered to effectively capture salmon. Furthermore, coarse comparison with limited available evidence suggests that the trap captured at least a comparable quantity of combined hatchery-origin Chinook salmon and coho salmon per hour relative to the average Columbia River gill net vessel's combined harvest of both hatchery and wild-origin fish of those species during overlapping periods of operation (ODFW 2017a; Tuohy 2018). Nevertheless, there is a need for further research under real-world commercial fishing conditions to evaluate and compare CPUE and assess the economic feasibility of the technology (e.g., total cost, revenue, and profit). The upfront costs of a trap are presently high (roughly $120,000) and must prove surmountable and recoupable to fishers or cooperatives in order to produce anticipated long-term economic benefits (Tuohy 2018).

Comparing catch results between 2016 and 2017 revealed that minor trap design modifications can dramatically affect capture efficiency. In comparison to the trap’s 2016 performance, the modified trap in 2017 increased total salmonid CPUE by a factor of 2.95. This increase in efficiency was achieved with only 79.5% of the 15 August through 15 October 2016 run-size of Chinook, coho, and steelhead (Columbia Basin Research Lab 2019). With fish trap research in its infancy in commercial salmon fisheries, improvements in performance are likely to be largest in the near future from addressing the most pressing and obvious flaws. As testing progresses throughout the years, incremental engineering improvements will likely exhibit diminishing returns to site-specific catch. Regardless, it is evident that efficiency will only continue to increase as lessons are learned and new ideas incorporated into the design and placement of traps.

The regression analysis of CPUE from this study lends statistical evidence to inform future years of trap operation in fluvial settings. During the 2017 study, four covariates proved significant in determining CPUE for Chinook salmon, coho salmon, and steelhead trout: adult ladder fish counts at Bonneville Dam, mean tide height during each soak period, tide stage at the completion of the set, and time of day. As expected, time of the season is important for fishing, as explained by the proxy variable Bonneville adult ladder fish counts; the more fish migrating through the river during the fishing season, the more fish are likely to be captured at the trap site. The regression analysis further indicates that catch increases during periods of greater tide-height. This suggests that a trap located at a greater depth could prove more successful in capturing salmon. It also appears that CPUE is impacted by tide stage and time of day, with catch efficiency maximized at the start of the ebb (just after high-tide) during daylight hours. Nevertheless, the majority of the variation in each stock-specific model could not be explained by the selected covariates, indicating that CPUE at the study site is complicated and results primarily from factors that remain unknown.

While effective in deterring entry of marine mammals to the heart compartment of the trap, results of the CPUE regression analysis also demonstrate that the marine mammal gate, as designed in 2017, reduced catch of Chinook salmon and steelhead trout (Table VI-3; Table VI-5). This result was hypothesized prior to study, as the narrow bars of the gate make entry to the heart compartment more difficult to fish entry. Surprisingly, catch of coho salmon was statistically unaffected from closure of the deterrent device. This is perhaps due to the relatively small size of coho salmon, making closure of the gate to this species less of a perceived barrier. Despite reducing Chinook salmon and steelhead trout CPUE, inclusion of the marine mammal gate proved instrumental in reducing entry of mammals into the heart compartment of the trap relative to 2016 and minimizing potential of fish predation and damage to the gear. In future years, a better system should be developed to quantify encounters with marine mammals to determine if and how animal behavior is affected by operation of the trap. Results should be analyzed within season, between seasons, and between years of operation. Although this endeavor may prove challenging given difficulties in sighting marine mammals from above the water-column and inherent detection differences between field observers, there is a need to assess whether marine mammals are being attracted to commercial gears and the impacts they may have on migrating salmonids.

<u>Goal #3 – Identify Capture/Release Conditions and Estimate Survival of Released Fishes</u>

The 2017 study has demonstrated the viability of an experimental fish trap as a stock-selective harvest tool in lower Columbia River late-summer and fall salmon fisheries, presenting a partial solution to hatchery and bycatch problems within the Columbia Basin and other Pacific Northwest fisheries. If sufficiently regulated and operated with a conservation-minded approach, operators of the gear can successfully release the great majority of non-target salmonids unharmed. Depending on the conservation issues present within a fishery, the fish trap is yet another tool that can be successfully deployed to address bycatch and hatchery management concerns while enabling continuation of commercial fishing (Table VII-2).

Table VII-2. Lower Columbia River cumulative survival estimates from five different gear-types to McNary Dam and associated 95% confidence intervals (if available) (TAC 2008[a]; IFSP 2014[b]; WDFW 2014[c]; WDFW and ODFW Joint Staff 2018[d]; TAC 2018[e]). *Note that gill net and tangle net release survival rates for fall Chinook salmon and steelhead are only assumed and have not been studied.

Gear	Fall Chinook Survival	Steelhead Survival
Gillnet (8-8.75'')	0.520[b*]	0.552[a*]
Tangle net (3.75'')	0.764[e*]	0.764[d*]
Beach seine	0.750 (0.710 – 0.790)[c]	0.920 (0.820 – 1.000)[c]
Purse seine	0.780 (0.720 – 0.850)[c]	0.980 (0.930 – 1.000)[c]
Fish trap	0.995 (0.924 – 1.071)	0.944 (0.880 – 1.012)

Cumulative survival of Chinook salmon released from the prototype experimental trap in 2017 represents a statistically significant ($P < 0.05$) and dramatic improvement over survival estimates produced from previous studies of alternative and conventional gears (Table VII-2). Analyzing the cumulative survival effect over a 400-km upriver migration and a median duration of 13-d for fall Chinook salmon, the experimental trap outperformed all other gears used on the lower Columbia River, with cumulative relative survival estimated at 0.995 (CI ($0.924 \leq \tau\ \widehat{cumulative} \leq 1.071$) = 0.95). This result was achieved with tagging operations occurring approximately 150 km farther downriver than prior bycatch mortality studies. Furthermore, capture procedures for the control group were likely less stressful than procedures used in previous Columbia River studies, during which control group fish were trapped at the Bonneville Dam adult fish passage facility, dip netted, PIT-tagged, trucked downriver to the test fishing location (rkm 225), and transferred from a truck into the water to repeat the upriver migration for a second time (Vander Haegan et al. 2004; WDFW 2014). Consequently, survival in our study is likely biased lower relative to past studies.

For summer steelhead, cumulative survival from the prototype experimental trap over a 400-km upriver migration and median travel duration of 18-d was 0.944 (CI ($0.880 \leq \tau\ \widehat{cumulative} \leq 1.012$) = 0.95). This point estimate is a significant improvement over that of the assumed gill net survival rate (Table VII-2) but is not significantly different from point estimates for the seine from prior Columbia River survival studies. These results suggest the need for further research to better determine which gear yields greater steelhead post-release survival. It must be noted, however, that the 2017 analysis occurred over a far greater migration distance and longer post-release duration than previous alternative gear analyses. Furthermore, results from 2019 sockeye and coho salmon studies suggest that recent engineering advancements to the spiller compartment may increase steelhead release survival to roughly 100% if investigated (Tuohy et al. 2020).

B. Attainment of Project Goals and Objectives – 2019

In September 2018, a continuation of award NA17NMF4720255 was granted through the BREP to expand the study in 2019 to spring and early-summer seasons in the lower Columbia River and test further modifications to the trap design. From October 2018 through July 2019, WFC completed all trap modifications and successfully constructed, tested, and refined deployment and operation of a modified fish trap in spring and early-summer fisheries (Goal #1) (Table VII-3). WFC tested the gear’s effectiveness in capturing salmonids and shad during the spring/summer research period (Goal #2). Furthermore, the ability of the modified trap design to protect non-target species was evaluated through estimation of immediate and post-release salmonid survival (Goal #3).

Table VII-3. Project timeline for the 2018-2019 NA17NMF4720255 cooperative agreement. All project tasks have been completed.

Proposed Task	Responsible Party	Date	Increment
Modify Design	WFC, Peterson	10/1/2018	Month 0
Secure all Required Permits/Contracts	WFC, Peterson, WDFW	1/15/2019	Month 1
Install Trap	WFC, Peterson	2/21/2019	Month 2
Initiate Testing	WFC, Peterson, WDFW	3/7/2019	Month 3
Complete Testing	WFC, Peterson	7/1/2019	Month 7
Lift Trap Lead, Heart, and Spiller	WFC, Peterson	7/1/2019	Month 7
Enter/Analyze Data	WFC	7/2/2019	Month 7
Publish and Submit Final Report	WFC	12/31/2019	Month 12

Goal #1 - Construct, Test, and Refine Deployment and Operation of a Modified Pound Net Trap

During the winter and spring of 2019, WFC and a local commercial fisherman collaborated to initiate construction and testing of the modified fish trap. Modifications to the trap design were made prior to arrival at the project site. All net modifications were designed by WFC and built by Christensen Net Works (Everson, WA) between October 2018 and February 2019. Additionally, live well modifications were completed by WFC between January and March 2019 to enable passive capture through a modified commercial treatment process. WFC staff assembled the modified trap during March and April at the project site, finishing construction before the NOAA and WDFW approved start date of 5 May 2019. The trap was successfully deployed, operated, refined, and tested from 5 May through 3 July 2019.

Various modifications were made to refine deployment and operation of the trap in 2019. The most significant modification during the spring and summer study was incorporation of a passive spiller design (modified treatment) which demonstrated promise to significantly improve post-release survival of salmonid bycatch. The modified passive spiller was implemented by adding a new upstream tunnel to the existing spiller compartment. This new upstream tunnel passively funneled free-swimming fishes in the spiller to a new upstream live-well for capture and release (Figure VII-1). The retrofitted design mostly eliminated the need for the electric winch in the final moment of capture and removed all air exposure, handling, crowding, and net contact associated with the 2017 prototype process. Results from this 2019 study for sockeye salmon indicate that this new passive design has no detectable impact on bycatch release survival (Table VI-18). It must be noted that this result was achieved with a piling layout that was not originally intended to accommodate such a design. Consequently, the trap was retrofitted awkwardly and was likely functioning less efficiently than it could with an altered piling layout. Based upon results of this study which demonstrate that this new capture technique is effective at capturing fish and results in very high release survival, future users of the gear should attempt to employ a fully passive design to minimize impacts to bycatch and maximize selective fishing opportunity. Efforts are already underway by WFC (with support from the 2019 NOAA Fisheries Service BREP) to engineer a fully passive design for construction at a new site in the lower Columbia River, OR.

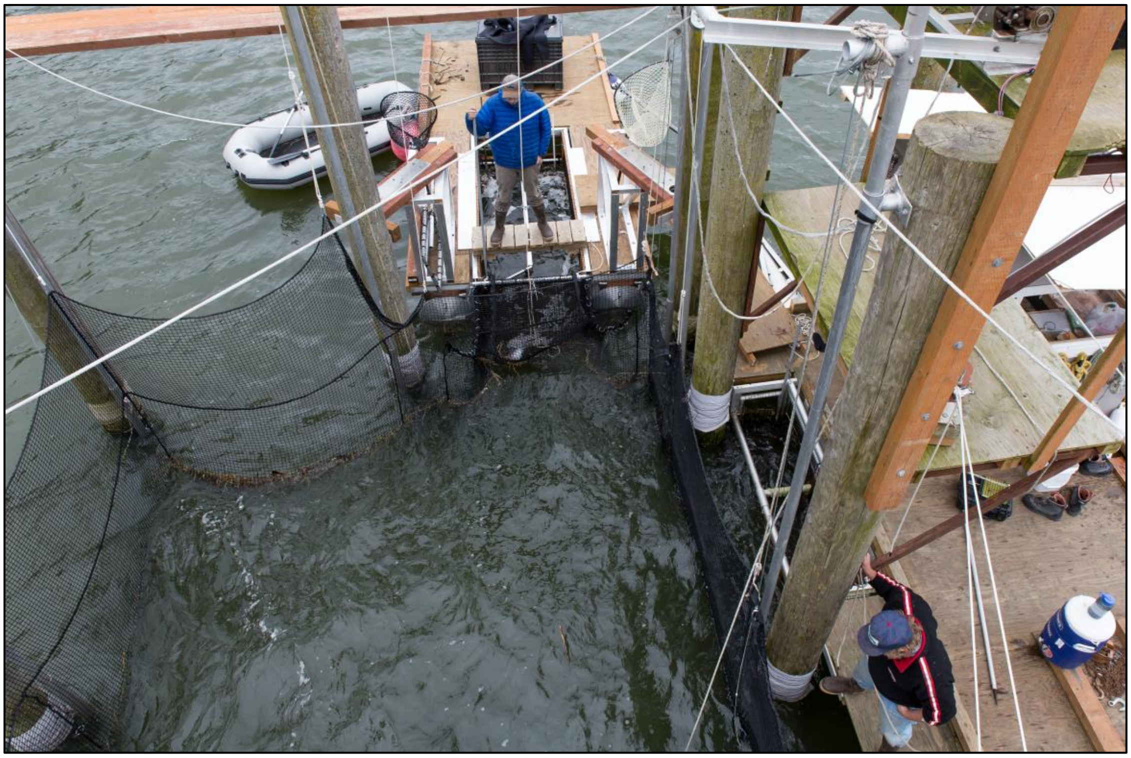

Figure VII-1. WFC staff fishing the new passive spiller design in late-May 2019.

Modifications made to the heart compartment by WFC staff likely improved immediate survival of salmonids relative to prior years of operation. Reduction in the heart compartment mesh size from 3-1/8’’ to 2-1/2’’ stretch knotless material likely reduced the probability of sockeye and Chinook jack wedging. During the 2019 spring and early-summer study, zero Chinook salmon jacks and only three small sockeye salmon (<400 mm) were wedged or gilled in the trap. Of the three sockeye salmon mortalities that resulted from wedging in the heart compartment, all occurred in a small panel of mesh that remained 3-1/8’’ where the jigger meets the heart. Future users of the gear targeting salmonids in the Columbia Basin should use 2-1/2’’ knotless mesh throughout the entirety of the heart and spiller to minimize impact to salmonids. After four years of study, it also appears that use of 3-1/8’’ mesh is appropriate for the lead, resulting in very minimal impact to all species encountered and minimal drag in the water column. Although the 2-1/2’’ spiller compartment did result in some level of mortality to juvenile outmigrant Chinook salmon (between 150 and 250 mm fork length), the overall impact was biologically insignificant considering the millions of juvenile Chinook salmon outmigrating from the system and marine smolt to adult survival rates around 3% (Quinn 2005). At present, it seems that this minimal impact to juvenile outmigrants in the spiller compartment may be unavoidable if the gear is used during the months of June and July, and changes to the mesh size are not recommended out of concern for smaller fishes (which would no longer be able to escape through the a smaller meshed spiller compartment) and larger jack and adult salmonids (which have been shown to wedge or gill on occasion in 3-1/8’’ spiller mesh). All recommended mesh sizes (hung on the square, rather than the diamond) are shown in Table VII-4 for future management of Columbia River salmon traps.

Table VII-4. Recommended mesh sizes for management of Columbia River salmon traps. All measurements represent mesh stretch in inches to mirror common measurement units used in the U.S. commercial fishing industry. Mesh should be hung on the square, rather than the diamond.

Trap Component	Recommended Mesh Size (Stretch)
Lead	3-1/8"
Jigger	3-1/8"
Heart	2-1/2"
Spiller	2-1/2"
Live-well	1-1/2"

Based upon results of the 2017 study, WFC modified the heart compartment and marine mammal gate to further reduce entry of marine mammals. The apron of the heart mesh (a section of mesh designed to stack or spread amongst the riverbed to account for inconsistencies in bathymetry) was extended to a total of 2.44 m to prevent escape of fish and passage of mammals. Additionally, a powered worm-gear split-real winch was installed on the spiller dock to increase the speed of marine mammal gate closure to less than one minute, allowing for efficient exclusion of marine mammals. These modifications showed promise in 2019, and it is recommended that all future traps in the Columbia Basin incorporate marine mammal deterrent gates and extended heart aprons to minimize entry of mammals to the heart compartment.

Modifications were made by WFC staff to enable operation of the fish trap during spring and early-summer months when flows are high and drifting woody debris is abundant. The primary modification made in 2019 to reduce problems associated with debris and flows was employment of a technique to enable efficient retrieval and deployment of the lead net (a debris boom design was considered but was not installed lacking additional upstream pilings). This technique utilized rope and pulley, with eyebolts/pulleys situated both above the highwater mark and at the riverbed for fast retrieval and deployment of the lead at all tidal stages. During the 2019 study, spring and early-summer season flows were manageable. However, debris proved challenging during the months of April and early-May (Figure VII-2). The modified deployment/retrieval technique selected for use was ineffective during the ebb tide, resulting in high accumulation of debris at times of the study and significant maintenance requirements. Although no major damage occurred to the gear, operation required significant effort during early-spring months. It is recommended that future users of the gear desiring to fish for spring Chinook from March through May consider installing angled pile driven debris booms with 3-1/8'' stretch mesh extending from the highwater to the low-water mark (it must be noted, however, that debris booms are unnecessary during summer and fall seasons when drifting woody debris is sparse). Given experiences in the spring of 2019, WFC staff unanimously agree that only pile driven booms can likely withstand flow and debris accumulation from March through May in the Columbia Basin. Users should either employ the pile driven debris boom method or be prepared for consistent and challenging maintenance throughout the early-spring season. Alternatively, users of the gear could consider natural features such as points and back eddies during the siting process which may provide protection from large woody debris during spring freshets.

Figure VII-2. WFC staff removing drifting woody debris from the lead net and the river reach upstream in early-May 2019.

Goal #2 - Determine Effectiveness of the Trap in Capturing Salmon Relative to Other Gears

During the spring and early-summer of 2019, salmon and steelhead returns to the Columbia River were extremely poor. Sockeye salmon returns were 20% of the 2009-2018 ten-year average from 5 May – 3 July; Chinook salmon returns were 52% of the 2009-2018 ten-year average during the same period (Fish Passage Center 2019). As a result of poor spring Chinook salmon return forecasts, test fishing was postponed to early-May at the request of NOAA Fisheries Service and WDFW to ensure impacts to ESA-listed species were not exceeded within the basin. Fishing was further restricted in June and July to protect ESA-listed sockeye salmon. Despite these setbacks, 1,317 non-juvenile salmonids were captured, including 896 adult sockeye salmon and 161 spring/summer Chinook salmon. Accounting for a median 4-d migration to Bonneville Dam for sockeye and 5-d migration for Chinook salmon, the trap successfully captured a mean of 2% and 0.4% of daily sockeye and Chinook salmon passage respectively at Bonneville Dam while fishing a mean of 9-h per day (Fish Passage Center 2019). These results suggest the trap was effective at capturing sockeye and Chinook salmon during the spring and early-summer research period despite a very poor return year to the basin.

Although the 2019 study demonstrated the effectiveness of the gear in capturing salmon during spring and early-summer seasons, the trap (as currently designed) proved mostly ineffective at capturing invasive American shad. Throughout the study period, only 357 American shad were captured. This result is unimpressive given nearly historic shad returns to the basin (Fish Passage Center 2019). It is hypothesized that some aspect of shad migratory behavior resulted in low catch of the species at the trap in 2019. To determine if the gear can be effective for American shad, alternative trap designs and new trap locations should be tested over multiple years. Furthermore, shad migratory behavior must be better understood to inform future trap engineering if capture and removal of the invasive species is desired.

Goal #3 – Identify Capture/Release Conditions and Estimate Survival of Released Fishes

Through two distinct research approaches, the 2019 study demonstrated the potential of a modified commercial trapping technique to achieve essentially 100% survival of released salmonids for low-impact selective harvest and ecological monitoring. Estimated relative survival ($\tau_0 * \tau_1 * \tau_2 * \tau_3$) of sockeye salmon from the modified passive trap design using a paired release-recapture study was 1.017 (CI ($0.974 \le \tau\ \widehat{cumulative} \le 1.059$) = 0.95) over a 400 km migration to McNary Dam. Utilizing an alternative 48-h net pen holding approach, cumulative survival of coho salmon was directly estimated at 1.000 (CI ($S \ge 0.978$) = 0.95). Regardless of the estimation technique employed, the modified passive capture design (which eliminated air exposure and net contact, and minimized handling and crowding) had no detectable impact on salmon release survival. Despite limitations of a single year dataset, these results suggest that the modified fish trapping technique may hold potential to nearly eliminate salmonid bycatch mortality if applied in commercial salmon fisheries (Table VII-5).

Table VII-5. Cumulative survival estimates from the modified fish trap were compared to cumulative survival estimates and associated 95% confidence intervals (if available) from prior studies. If lower Columbia River data were not available for comparison, lower Fraser River data were used (TAC 2008[a]; IFSP 2014[b]; WDFW 2014[c]; TAC 2015[d]; DFO 2017[e]; WDFW and ODFW Joint Staff 2018[f]; TAC 2018[g]; Tuohy et al. 2019[h]). Note that gill net and tangle net release survival studies for fall Chinook salmon and steelhead have not been conducted and rates are only assumed.

Gear	Chinook survival	Coho survival	Sockeye survival	Steelhead survival
Gill net	0.520[b]	0.400[e]	0.400[e]	0.552[a]
Tangle net	0.764[g]	0.764[f]	0.900[e]	0.764[f]
Beach seine	0.750 (0.710 – 0.790)[c]	0.620[d]	0.950[e]	0.920 (0.820 – 1.000)[c]
Purse seine	0.780 (0.720 – 0.850)[c]	0.710[d]	0.900[e]	0.980 (0.930 – 1.000)[c]
Fish trap	0.995 (0.924 – 1.071)[h]	1.000 (0.978 – 1.000)	1.017 (0.974 – 1.059)	0.944 (0.880 – 1.012)[h]

Relative to the performance of the prototype fish trap design used in 2017, results from the modified fish trap in 2019 represent an improvement that warrants incorporation of the passive capture technique into all future commercial salmon traps. Cumulative survival over 400 km to McNary Dam from the prototype trap design in 2017 was estimated at 0.944 (CI ($0.880 \le \tau\ \widehat{cumulative} \le 1.012$) = 0.95) for steelhead and 0.995 (CI ($0.924 \le \tau\ \widehat{cumulative} \le 1.071$) = 0.95) for fall Chinook salmon through an equivalent mark-recapture methodology (Tuohy et al. 2019). Although results from this 2019 study for sockeye and coho salmon cannot be directly compared and extrapolated to other species and periods of study, it is highly likely that the modified passive capture design would achieve improved survival results for Chinook salmon and steelhead trout if properly tested. Given sample size limitations in 2019 for spring/summer Chinook salmon and late-winter/early-summer run steelhead, additional research and incorporation of genetic assignment results are necessary to test these hypotheses.

Analyzing differences between sockeye salmon survival estimates from the two trap designs (modified treatment and prototype treatment) in 2019, the prototype trapping method demonstrated a surprisingly deleterious and significant effect on sockeye salmon survival relative to the modified passive trapping method. The cause of this poor performance relative to 2017 results for Chinook salmon and steelhead remains unknown but may be due to several factors including the scarcity of hauls performed, addition of the upstream tunnel for passive capture, annual differences in lifting mechanics, and operator error. With significantly fewer hauls performed in 2019 with the prototype method (N_{2017} = 381, N_{2019} = 32), operators had less opportunity to learn from their mistakes and adjust spiller mechanics. It was noted on multiple occasions that spills were poorly performed during the spring season study (often due to the presence of the upstream tunnel for passive capture), potentially causing physiological stress to captured fishes. Investigating the prototype treatment dataset, results were heavily skewed by four major spill events (> 10 sockeye salmon spilled and tagged) and one significant outlier in which relative release survival was only 0.093 (likely due to operator error). This result highlights the need for skilled and attentive operators if the line-and-pulley prototype technique of 2017 is employed and lends support for the modified passive capture design which dramatically reduces the likelihood of potential operator error and significantly improves release survival of fishes. Nevertheless, the sockeye salmon results for the prototype design in 2019 should perhaps be taken lightly given the small sample size available for analysis (i.e., 138 fish), the scarcity of hauls performed (i.e., 32), flaws in spiller operations, and the obsolescence of the prototype method of capture.

C. Dissemination of Project Results – 2017

This project delivered a focused education, outreach, and result dissemination strategy—as outlined in the proposal *Data Sharing Plan*—to improve stewardship of the Nation's marine resources. For all aspects of the original NA17NMF4720255 grant agreement, WFC met or exceeded goals, objectives, and dissemination requirements (Table VII-6).

Table VII-6. Major project deliverables for the 2017 BREP study. All project deliverables have been accomplished.

Deliverable	Anticipated Date
NOAA Financial Report	12/31/2017
NOAA Progress Report	1/30/2018
WFC Newsletter and Journal (Results and Summary)	4/1/2018
Brochure (Results and Summary)	5/1/2018
Video Release	6/1/2018
Final Manuscript Submission / Release of Raw Data	9/28/2018

Going beyond grantee requirements, WFC developed an online blog from the onset of trap construction—*The Fish Trap Journal*—offering a unique opportunity for resource managers and the public to follow in-season results, live-video streaming, and high-resolution photograph and short-length video posts from the project in real-time (visit http://thefishtrapjournal.org for more information). This strategy proved successful in 2017, drawing considerable attention from news media, the scientific community, resource managers, politicians, and the public. In-season results from this BREP funded study, viewed by the public primarily through *The Fish Trap Journal*, landed headlines in The Seattle Times, Drake Magazine, Associated Press, and other local papers, giving the project exposure to a much greater audience than anticipated (https://www.seattletimes.com/seattle-news/environment/fish-traps-for-columbia-river-salmon-get-another-look/). Politicians, fish commissioners, NGOs, industry, and recreational and commercial fishers responded to this news media exposure, joining WFC staff for on-site visits during the fishing season and scheduling WFC to present at various meetings and events.

In a similar fashion to *The Fish Trap Journal*, WFC released photos and results through social media platforms, including Facebook (https://www.facebook.com/wildfishconservancy/), Instagram (https://www.instagram.com/wildfishconservancy/), and Twitter (https://twitter.com/wildfishnw). With over 5,000 WFC followers through these various platforms, we have worked to achieve education and outreach goals beyond those outlined in our agreement with NOAA Fisheries Service.

From the onset of monitoring activities, WFC offered live-video streaming of all test fishing and research efforts through the online application, "Periscope," providing the upmost degree of transparency to resource managers and the public for in-season review. Implementation of electronic monitoring systems, including use of video cameras, is a priority of NOAA Fisheries Service to improve compliance monitoring and verification of self-reporting. Furthermore, electronic monitoring systems work to provide resource managers useful information on catch composition and quantity in real-time (NMFS 2011). Use of the online video-streaming application "Periscope" throughout the 2017 study demonstrated the ease in which a future trap fishery and bycatch could be monitored electronically by resource managers.

For the 2017 study, WFC released a series of short videos through youtube, Vimeo, and WFC's website to illustrate how fish traps can be utilized for commercial harvest and the benefit of the Nation's natural resources. These tasks were achieved before the proposed time schedule. Acclaimed director Shane Anderson of North Fork Studios released a film on 28 December 2017 titled *A Way Forward for Fish and Fishermen* (see https://vimeo.com/248905440). This high-resolution short film has already achieved over 14,000 views. WFC independently released another educational short-film that can be viewed through youtube and WFC's website (https://www.youtube.com/watch?v=HHGzT_AyujI).

As described in the proposed *Data Sharing Plan*, all data/metadata were documented by WFC staff and entered into a Microsoft Access database. QA/QC was performed by WFC from October through December of 2017. Data were shared with WDFW and NOAA Fisheries for reference and review from December 2017 through January 2018. All raw data/metadata from the completed 2017 study were made available through WFC's data portal (located at our website, www.wildfishconservancy.org). Data for the 2017 study may be downloaded free of charge in Microsoft Excel format through the Wild Fish Conservancy webpage by clicking on the "Projects" and "Columbia River Pound Net Project" tabs. All PIT tag information can be accessed through the PTAGIS webpage (www.ptagis.com) utilizing the code "CPN" and name "Cathlamet Pound Net." Data will remain secure and available to the public at all times through these means.

A summary of 2017 results was published in the WFC quarterly newsletter and annual journal (4/2018). A basic trifold brochure describing the successes of the project was also published and made available to colleges and universities, local communities, tribes, and fishers of the lower Columbia Basin. The brochure is available through the following link: (https://issuu.com/wildfishconservancy1989/docs/poundnetbrochurefinal) (5/2018). WFC biologist Adrian Tuohy completed his master's thesis on the 2016-2017 results through the University of Washington. The thesis can be accessed and downloaded for free through WFC's website (http://wildfishconservancy.org/tuohy-2018/at_download/file) (7/2018). Active outreach efforts were made at conferences, meetings, and events for the Steelhead Society of British Columbia (SSBC) (1/19), ODFW senior staff (12/18), the Coastal Conservation Alliance (CCA) (12/18), the Skagit Tribal Research Cooperative (12/18), the Skeena Wild Board of Trustees and B.C First Nations (11/18), the University of Washington School of Aquatic and Fishery Sciences (7/18), the Tolt River Working Group (7/2018), American Fisheries Society Conference – Oregon Chapter (2/18), the Northwest Power and Conservation Council (12/17), the Washington Fish and Wildlife Commission (10/17), WDFW senior staff (7/17), and the WA State Salmon Recovery Conference (7/17).

A manuscript summarizing findings of the 2017 BREP study was drafted and submitted to the journal of *Fisheries* for peer-review and publication by authors Adrian Tuohy, Dr. Nick Gayeski, and Dr. John Skalski in December 2018. The manuscript was accepted with minor revisions, and on 25 May 2019, the article titled "Survival of Salmonids from an Experimental Commercial Fish Trap" was published through the journal of *Fisheries* (https://afspubs.onlinelibrary.wiley.com/doi/full/10.1002/fsh.10292). The final manuscript was submitted to the NOAA Institutional Repository to be made publicly available by NOAA. The article was further made open access through the journal of *Fisheries*, enabling free access and downloading to all members of the public.

Peer-reviewed and published results from 2017 were further submitted to WDFW and the Columbia River Technical Advisory Committee (TAC) for review and approval (see Appendix B). On 20 March 2020, the U.S. v O.R. Policy Committee approved mortality estimates proposed by TAC, enabling management of future commercial trap fisheries in the Columbia River Basin.

D. Dissemination of Project Results – 2019

With continuation of award NA17NMF4720255 in 2019, WFC has exceeded goals, objectives, and dissemination requirements of the expanded grant agreement (Table VII-7).

Table VII-7. Major project deliverables for the 2019 BREP study. All project deliverables have been accomplished.

Deliverable	Anticipated Date
Online Blog Launch	2/21/2019

NOAA Progress/Financial Report	6/30/2019
WFC Newsletter and Journal (Results and Summary)	12/14/2019
Brochure (Results and Summary)	12/31/2019
Video Release	12/31/2019
Final Report Submission and Publication / Raw Data	3/30/2020

Similar to the 2017 project, an online blog was maintained throughout the study period, enabling the public to track WFC's progress with the study and preliminary results (http://thefishtrapjournal.org/). The blog was continued throughout 2018 and was expanded for the 2019 season, highlighting achievements throughout three years of study. In addition, social media platforms and live-video streaming utilized in 2017 continued to be employed to raise public awareness of the project. These strategies once again proved successful, drawing considerable attention from online media, print media, and radio broadcasting. [See the following news articles from Oregon Public Broadcasting, Oregon Business, the Longview Daily News, Wild Salmon Center, and Edible Seattle: https://www.opb.org/news/article/fish-trap-salmon-columbia-river-ban/, https://tdn.com/news/local/columbia-river-commercial-fishery-could-hinge-on-century-old-method/article_7fc5324d-c385-5404-baa3-616cf838846f.html, https://www.oregonbusiness.com/article/energy-environment/item/18638-the-fish-crisis-businesses-called-on-to-do-more-to-conserve-stocks, https://www.wildsalmoncenter.org/2019/10/30/seattle-chef-renee-erickson-eat-this-salmon/, https://edibleseattle.com/explore/features/building-a-better-fish-trap/.] Beyond these media publications and radio broadcasts, Oregon Public Broadcasting (OPB) filmed a new piece on BREP fish trap research. The televised broadcast is anticipated between April and June 2020.

As in 2017, short-videos were released to describe results of the BREP study and potential benefits of in-river selective harvest techniques for recovery of wild salmonids and rejuvenation of coastal fishing communities. Prior to the anticipated release date, a short video directed by Shane Anderson titled *A Sustainable Way Forward For Fish and Fishermen: Part Two* was released in 2019 through North Fork Studios (https://vimeo.com/310697782). The video currently has over 4,400 views and is available to the public for free streaming or download through Vimeo and youtube. An additional short film titled *The Fish Trap* was released through North Fork Studios in March 2020. This film focused on bycatch reduction achievements from 2019 and added value to trap caught seafood products with testimonials from renowned Seattle chefs serving salmon from the fish trap fishery (https://vimeo.com/397820822).

As described in the proposed *Data Sharing Plan*, all data/metadata were documented by WFC staff and entered into a Microsoft Access database. QA/QC was performed by WFC in July 2019. Data were shared on a weekly basis with WDFW and NOAA Fisheries for reference and review throughout the study period to ensure ESA-impacts were not exceeded. All raw data/metadata from the completed spring and early-summer 2019 study were made available through WFC's data portal (located at our website, www.wildfishconservancy.org). All data may be downloaded free of charge in Microsoft Excel format. PIT tag information was uploaded to the PTAGIS webpage (www.ptagis.com) in July 2019 enabling free public access. Users of PTAGIS may identify project tags utilizing the code "CPN" and name "Cathlamet Pound Net." Data will remain secure and available to the public at all times through these means.

Furthermore, all data and metadata have been submitted to the NOAA National Centers for Environmental Information (NCEI).

To summarize results of 2019 research, a short article was published in the WFC quarterly newsletter and annual journal (https://mailchi.mp/wildfishconservancy.org/another-successful-year-for-the-columbia-river-fish-trap). This summary piece was circulated to thousands of WFC's members, which include the general public and members of the scientific and resource management communities. In addition, an outreach brochure was developed for dissemination to colleges and universities, local communities, First Nations, and fishers of the lower Columbia Basin.

Various active outreach efforts were made at conferences, meetings, and events throughout 2019 and 2020 to disseminate results of the study. To date, presentations/meetings were accomplished or are currently scheduled at the following events: WDFW Ridgefield Senior Staff Meeting (1/19); B.C. Wildlife Federation Selective Fishing Forum (3/19; https://www.youtube.com/watch?v=MLaNNgbeS34); WDFW Olympia Senior Staff Meeting (5/19); the World Salmon Forum (8/19); the Skeena River First Nation's Technical Committee Meeting (9/19); Fisheries and Oceans Canada (DFO) (9/19); Marine Stewardship Council (11/2019); Coastal Conservation Association (CCA) Washington (12/2019); Monterey Bay Aquarium Seafood Watch (12/2019); and the lower Columbia River Emerging Commercial Fishery Advisory Board (2/2020). In addition to these events, WFC invited various visitors on site for tours of the gear in 2019. Visitors included lower Columbia River fishermen, fish buyers, resource managers from WDFW, ODFW, and NOAA Fisheries, the Columbia River Technical Advisory Committee (TAC), Canadian First Nation scientists and fishers, WA and OR fish commissioners, WA and OR state representatives, regional journalists, and students and teachers of Cathlamet High School. WFC remains in consistent contact with WDFW and members of the Columbia River Emerging Fishery Advisory Board, providing data and recommendations for a transition to alternative gears in the lower Columbia River.

Similar to the dissemination strategy in 2017, a manuscript focusing on survival of sockeye and coho salmon from the modified fish trap design in 2019 was submitted to the *North American Journal of Fisheries Management* for peer-review in February 2020. Open access publication of the manuscript is anticipated before July 2020. Additionally, a summary of 2017-2019 research was published in *The Osprey* (a journal published by the Steelhead Committee) in February 2020 to raise awareness of fish trap research within the recreational fishing community. Results from 2019 were further submitted to WDFW and the Columbia River TAC to set official mortality estimates for future management of the modified passive fish trap gear in the Columbia River Basin.

E. Applications and Potential Benefits

Partial retooling of commercial gill netting fleets to lower-impact alternative gear-types such as fish traps could provide substantial benefit to the Pacific Northwest salmon fishing industry (Gayeski et al. 2018b). Presently, commercial gill netting opportunities are dramatically constrained due in part to high release mortality rates and bycatch impacts to ESA-listed salmonids (Vander Haegen et al. 2004; Martin 2008). By transitioning to alternative fishing gears with reduced ESA bycatch impacts, commercial fishers may fully utilize fisheries allocations and increase profits. Given results of this alternative gear study and anticipated implementation benefits, WDFW has initiated a formal process to potentially legalize fish traps at a broader scale for commercial use in the lower Columbia River (Tuohy and Jorgenson 2020). If legalized, this emerging fishery will be managed based upon bycatch mortality data from this BREP study, which have been formally reviewed by WDFW and the Columbia River TAC (Tuohy and Jorgenson 2020). Although the process to legalize the alternative gear fishery remains incomplete at present, BREP research efforts and recent management actions have made a transition to fish traps and mark-selective fisheries possible in the lower Columbia River for the benefit of wild salmon recovery and the commercial fishing industry.

While enabling fishers to fish for longer and more consistently, use of alternative gears with substantially reduced bycatch impacts could better enable the salmon fishery to become certified sustainable in the marketplace, returning a greater price per pound (Gayeski et al. 2018b). Sustainable market certifiers brand seafood products in the marketplace that meet specific sustainability criteria. This branding can result in product differentiation to consumers and increased prices received by fishers and processors (Cooper 2004; Kaiser and Edwards-Jones 2006; Gayeski et al. 2018b). Concurrently, value-added practices (including bleeding and icing fish on site, and direct marketing of a higher quality live-captured product to restaurants and other buyers) could help retooled fisheries increase profitability (Sea Grant 2018). Transitioning to alternative gears and utilizing value-added practices in certified-sustainable fisheries could improve economic prospects within the industry, increasing fishing opportunity and prices received for harvested products (Gayeski et al. 2018b).

For threatened and endangered wild salmonids in the Pacific Northwest, reduction of hatchery and bycatch impacts could prove essential to their survival and recovery (Lichatowich et al. 2017). The percentage of hatchery-origin spawners (pHOS) continues to exceed hatchery management targets, with many spawning populations in the region experiencing pHOS greater than 50% (reducing the fitness and survival of subsequent generations) (Chilcote et al. 2011; Hatchery Science Review Group 2014; WDFW 2018). Release mortality from gill nets remains significant (and unknown for some stocks), prompting management to allow harvest of both hatchery and wild-origin salmon stocks indiscriminately in many Pacific Northwest fisheries (Buchanan et al. 2002; IFSP 2014). Considering these impacts and the accelerating effects of global climate change, the need for selective harvest is urgent to improve targeting of hatchery-origin fishes and escapement of wild salmonids (Lichatowich et al. 2017; Gayeksi et al. 2018a).

Although transition from the ongoing fisheries management paradigm of production hatcheries and conventional harvest will prove challenging, change may be necessary to prevent further wild salmonid declines, degradation of genetic and life-history diversity, and curtailment of fishing opportunities (Schindler et al. 2010; Lichatowich et al. 2017; Gayeski et al. 2018a). Partial solutions are at hand (e.g., selective commercial gears) to help remedy harvest and hatchery problems in the region. Despite the short-term discomfort that may be caused by changes in harvest strategy, long-term benefits from a well-orchestrated policy and management shift toward the use of selective gears such as fish traps could improve the economic outcome for fishers and fisheries of the Pacific Northwest (Gayeski et al. 2018a). Use of traps could also reduce the challenges associated with commercial fisheries observation and enforcement and provide a means for low-impact ecological monitoring. Although further research is needed in other locations, seasons, and years, it is possible that the return to a historical fishery in the

Pacific Northwest could prove to be a win-win situation for fishers, ESA-listed salmonid stocks, management, and the environment.

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APPENDICES

A. Bayesian Absolute Survival Analysis

N.J. Gayeski - WFC

Introduction

Tuohy et al. (2019) published an analysis of the survival of fall Chinook salmon and steelhead captured, tagged, and released from an experimental fish trap on the lower Columbia River. As explained in that paper, in order to retain comparability of results to recent experimental evaluations of other potentially selective fishing gears conducted in the lower Columbia River, survivals of "treatment" fish were compared to survivals of "control" fish (see Tuohy et al. (2019) for a description of the treatment and controls). In this study, survival was measured as the ratio of the number of "control" or "treatment" fish tagged and released from the trap and estimated to have passed Bonneville Dam to the total number tagged and released at the trap using a Cormack-Jolly-Seber mark-recapture design, or as the ratio of the number estimated to have passed one of the lower Columbia River mainstem dams to the number similarly estimated to have passed the preceding dam. The survival of treatment fish was then calculated as the ratio of treatment to control survival at each of the three lower mainstem dams (Bonneville, The Dalles, and McNary).

A primary reason for confining the survival estimates to relative (treatment/control) survival concerned the fact that there are several tributaries between the site of the trap (167 km downstream of Bonneville Dam) and Bonneville Dam to which an unknown number of fall Chinook salmon and steelhead captured at the trap may have been bound. Consequently, estimating absolute survival of either treatment or control samples as the ratio of the total number tagged and released at the trap that were estimated to have passed Bonneville Dam to the total numbers tagged and released at the trap would likely significantly under-estimate true survival, as any tagged fish not bound for Bonneville Dam that may have survived to enter a tributary below Bonneville Dam that lacked a PIT-tag detector would have been counted as a mortality, thus distorting the true effect of having encountered the trap and been subjected to one of the two handling procedures (control or treatment).

While the results reported in Tuohy et al. (2019) are strong and compelling in regard to the ability of a fish trap to achieve very high post-release survival of treatments relative to controls, it would be of further benefit to fisheries managers to have credible estimates of the absolute survival of treatment and control fish. As explained in Tuohy et al. (2019), non-lethal tissue samples for DNA analysis were obtained from more than 2,000 fall Chinook salmon (treatment and control, wild- and hatchery-origin (adipose-clipped)) captured, PIT-tagged, and released from the project site. A subset of 496 of these were successfully genotyped using a suite of Columbia River Basin-specific single nucleotide polymorphism (SNP) markers and the individual sample assigned to below-Bonneville and above-Bonneville locations. The results of the DNA analysis permit an estimate to be made of the absolute survivals of Chinook salmon subjected to one or the other of the two handling/tagging procedures from release at the project site to Bonneville Dam and propagated to obtain estimates of absolute survivals to The Dalles and McNary dams.

Methods

The approach to the survival estimation consists of two sequential components. First, the genetic assignment data are used to estimate the probability distribution of the number of control and treatment Chinook salmon tagged and released at the trap that were bound for spawning locations upstream of Bonneville Dam. Second, survivals of control and treatment Chinook salmon to Bonneville Dam, The Dalles, and McNary dams were estimated from the PIT tag detection data at each of the three dams using a modification of the Jolly-Seber mark-recapture method that I define as the "Jolly-Seber Lincoln-Peterson" (JSLP) method described below.

Estimation of the Numbers of Control and Treatment Bound for Bonneville Dam

The genetic assignment data from the 496 genotyped samples were used to parameterize a Beta distribution that was then used as an informative prior for a Bayesian estimation of the unknown parameter of a Beta-Binomial distribution, the number of control or treatment Chinook salmon bound for Bonneville Dam (Equation 1):

(1) P(M.0|N.0, A, B) ~ BBN(N.0, A, B) , where
M.0 is the number of control or treatment Chinook tagged and released from the trap that are bound for spawning locations upstream of Bonneville Dam and are the unknowns to be estimated, and where the dots (periods, '.') stand for either control samples or treatment samples. N.0 is the total number of control or treatment Chinook tagged and released from the trap, A is the number of "prior" successes, defined as the number of genetic samples assigned to spawning locations upstream of Bonneville Dam, and B is the number of "failures" defined as the number of samples assigned to spawning locations downstream of Bonneville Dam. The M.0's are the unknown quantities to be estimated; the N.0's, A, and B are known quantities. In other words, we ask "if the prior number of successes and failures are A and B, respectively, what is the probability that M.0 of the N.0 fish tagged and released at the trap are bound for spawning locations upstream of Bonneville Dam?"

As reported in Tuohy et al. (2019), a total of 496 tissues samples were randomly selected from the 2,000+ total number of Chinook salmon (both control and treatment) tagged and released at the trap, of which 397 were assigned to populations spawning upstream of Bonneville Dam and 99 to populations spawning downstream of Bonneville Dam. A contingency test showed that the proportions of control and treatment samples assigned to each of the two categories were identical (0.80 and 0.20). Accordingly, we pooled the total assignment data to form a common informative Beta prior (Beta(397, 99)). The total number of control Chinook salmon samples released from the trap (Nc0) was 969; the total number of treatment samples was 1,085. Thus, the two beta binomials to be estimated were:

(1c): P(Mc0| 969, 397, 99) ~ BBN(969, 397, 99) (controls)
(1t): P(Mt0|1085, 397, 99) ~ BBN(1085, 397, 99) (treatment).

Estimation of the Survivals of Control and Treatment Samples using the JSLP Model

To estimate survival of control (c) and treatment (t) fish from the trap to Bonneville Dam, we need to estimate the number of the Mc0 and Mt0 fish bound for locations upstream of Bonneville (estimated from the Beta-Binomial) that survived from release at the trap to Bonneville Dam, given PIT tag detections of tagged c and t fish at Bonneville and detection sites upstream of Bonneville, primarily the Dalles Dam.

Consider the following three spatially sequential locations and associated times, 1 - 3. At location 1 N1 individually recognizable fish are observed and therefore known to be alive. An unknown number Ns of these survive to location 2, at which time a random resighting process observes some, but not necessarily all, of the survivors. Subsequently, at location 3, an independent and random resighting process observes some, but not necessarily all, of the individuals that survive to that subsequent location and time (all of which must have been alive during the resighting process at location 2).

This yields three distinct observed sighting history patterns. These patterns are mutually exclusive and exhaustive of the observed outcomes for survivors, but not of the unobserved survivors. Label these the three patterns

n(++): the number resighted at both locations 2 and 3;

n(+0): the number resighted at location 2 but not subsequently;

n(0+): the number resighted at location 3 but not at location 2.

(In the case at hand, location 2 is Bonneville Dam and location 3 is The Dalles Dam.)

These counts can be aggregated as the n(.+) individuals that were resighted after the location 2 regardless of sightings at location 2, and the n(+.) individuals that were resighted at location 2 regardless of subsequent resighting:

n(+.) = n(++) + n(+0);

n(.+) = n(++) + n(0+).

These quantities can now be employed to define a Lincoln-Peterson design for inference on the Ns survivors. For clarity call n(.+) M for the number “released” into the “population” of Ns individuals, call n(+.) n for the recapture sample and call n(++) m for the number of the M individuals carrying the “mark” in the recapture sample n. Then, the hypergeometric distribution (model) can be used as the likelihood function (Equation 2):

(2) P(m|Ns,M,n) ~ HG(Ns, M, n).

In this case, M and n are the known design parameters, m is the known observation, and Ns is the unknown parameter to be estimated.

The estimation procedure just described can be iterated to estimate the numbers surviving to location 3, The Dalles Dam (using resighting data from locations 2 – 4), and to location 4

(McNary Dam (using resighting data from locations 3 – 5, where location 5 includes PIT tag detection locations in the Snake River Basin and the Columbia River upstream of McNary Dam).

Call the numbers of control fish estimated to have been bound for spawning locations upstream of Bonneville Mc0, and the corresponding number of treatment fish Mt0, and call the number estimated to have survived to Bonneville Dam, Ncs and Nts, respectively. Survival from release of c and t fish at the trap to Bonneville Dam was then determined simply as the ratios Ncs/Mc0 and Nts/Mt0 (and similarly for survivals to The Dalles and McNary dams).

A Bayesian model in Stan ® was used to estimate all unknown quantities of interest. Four chains of 10,000 samples each were run using the default burn-in length of 5,000 samples per chain. This resulted in a total of 20,000 samples of the joint posterior distribution. Convergence was determined by evaluating the R-hat statistic and trace charts of the posterior samples of each parameter. All parameters achieved an R-hat of 1.0 and no trace chart showed evidence of either a failure to examine the full parameter space or failure to converge smoothly and quickly to the central 50 percent of the posterior distribution.

The survival parameters were estimated as derived parameters from the posterior distributions of the M.0s and the N.s's for locations 2 to 4. Derived parameters for the difference in survivals between treatment (St) and control fish (Sc)—defined as St-minus-Sc—were estimated from each of the three location-specific survival rate estimates in addition to the ratios St/Sc.

Results

The primary unknown quantities of interest are Mc0 and Mt0, the number of control and treatment fish, respectively, tagged and released at the trap that were bound for spawning locations upstream of Bonneville Dam. These were well-estimated. Mc0 had a mean(standard deviation) of 775(17.3) Mt0 had a mean(standard deviation) of 868(19.3) (Table A-1).

Table A-1. Posterior means, standard deviations, coefficients of variation, minimum and maximum values of the posterior probability distributions of primary quantities of interest.

	PropC&T	Mc0	Nc1	Nc2	Nc3	Mt0	Nt1	Nt2	Nt3
Mean	0.800	775	531	323	235	868	582	375	262
Std Dev	0.0178	17.3	1.1	0.8	1.4	19.3	1.0	0.9	1.8
CV	0.022	0.022	0.002	0.002	0.006	0.022	0.002	0.002	0.007
Min	0.720	698	530	322	234	785	581	374	260
Max	0.862	836	538	330	248	935	590	381	278

The posterior distributions of Mc0 and Mt0 followed the shape of the informative Beta prior, which had a mean(standard deviation) of 0.8(0.18) (Table A-1, Figure A-1).

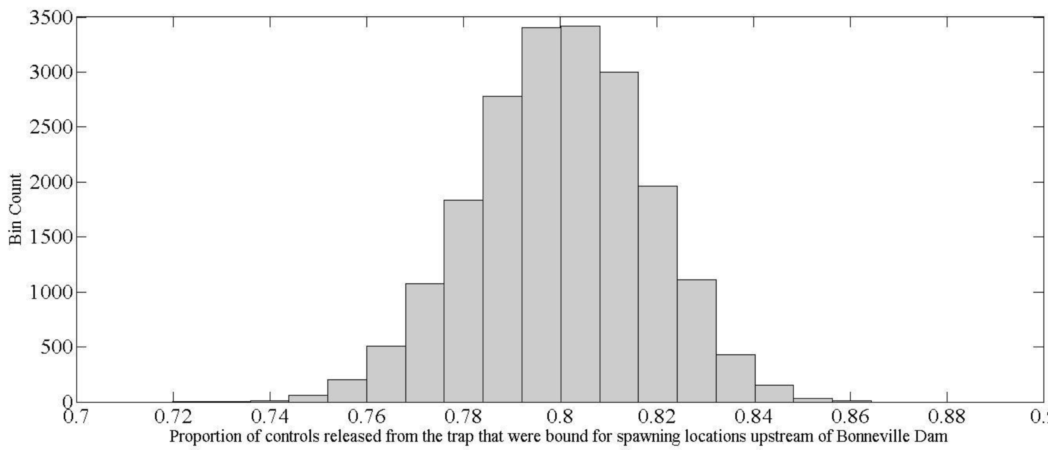

Figure A-1. Prior distribution of the probability that a control fish tagged and released from the trap is bound for spawning locations upstream of Bonneville Dam. The prior distribution of the probability a treatment fish tagged and released from the trap is bound for spawning locations upstream is Bonneville Dam is essentially identical to that for control fish.

From the posterior distributions of Mc0 and Mt0 it was possible to estimate the distribution of absolute survival rates of control and treatment fish from tagging and release at the trap to Bonneville Dam using the posterior distribution of N1's (the number surviving from tagging and release at the trap to Bonneville Dam) estimated from the first stage of the Jolly-Seber-Lincoln-Peterson method by calculating posterior distribution of the ratios of Sc1 = Mc0/N1c and St1 = Mt0/Nt, where N1c is the number surviving to Bonnveille Dam and similarly for N1t. Survival rates of control and treatment fish were similarly estimated from the posterior distributions of the numbers estimated to have survived to The Dalles and McNary Dams (e.g., Sc2 = Nc2/Nc1 and Sc3 =Nc3/Nc2 (Table A-2).

Table A-2. Posterior means, standard deviations, coefficients of variation, minimum and maximum values of the posterior probability distributions of derived parameters of interest. DS = treatment survival-minus-control survival. RS = (treatment survival)/(control survival).

	Sc1	Sc2	Sc3	St1	St2	St3	DS1	DS2	DS3	RS1	RS2	RS3
Mean	0.69	0.61	0.73	0.67	0.64	0.70	-0.01	0.04	-0.03	0.98	1.06	0.96
Std Dev	0.015	0.002	0.005	0.015	0.002	0.005	0.021	0.003	0.007	0.031	0.004	0.009
CV	0.023	0.003	0.006	0.022	0.003	0.007	-1.483	0.073	-0.221	0.032	0.004	0.010
Min	0.63	0.60	0.71	0.63	0.63	0.68	-0.110	0.022	-0.086	0.852	1.035	0.890
Max	0.75	0.62	0.77	0.75	0.66	0.75	0.056	0.052	0.012	1.084	1.086	1.016

Absolute survival of control fish from the trap to Bonneville Dam, from Bonneville Dam to The Dalles Dam, and from the Dalles Dam to McNary Dam were 0.69(0.015), 0.61(0.002), and 0.73(0.005), respectively. Absolute survival of treatment fish was 0.67(0.015), 0.64(0.002), and 0.70(0.005), respectively (Table A-2).

Finally, derived parameters were calculated for the difference between treatment and control survivals to each dam as treatment survival-minus-control survival (DS1 – 3) and for the ratio of treatment to control survival (St/Sc, RS1 – 3) (Table A-2). As for the analysis of Tuohy et al. (2019), the point estimates of the mean and standard deviations of the ratios were well estimated and essentially identical to the results presented herein. Based on the posterior mean and standard deviation, control fish survived from the trap to Bonneville and from The Dalles to McNary dams at slightly greater rates than treatment fish (RS1: 0.98(0.031); RS3: 0.96(0.009). The reverse was the case for survival from Bonneville Dam to the Dalles Dam (RS2: 1.06(0.004). Mean cumulative survival from the trap to McNary Dam of treatment relative to control was 0.997 (0.98*1.06*0.96).

In the case of RS2, the posterior probability mass lies entirely to the right of one, and 99% of the posterior probability mass of RS3 lies to the left of one (Table A-2). As a result, the mean and standard deviation of RS2 and RS3 provide a meaningful amount of information as to the true value of the relative survival of treatment fish. This is less so in the case of RS1, the posterior cumulative distribution of RS1 (treatment survival/control survival from the trap to Bonneville Dam, Figure A-2).

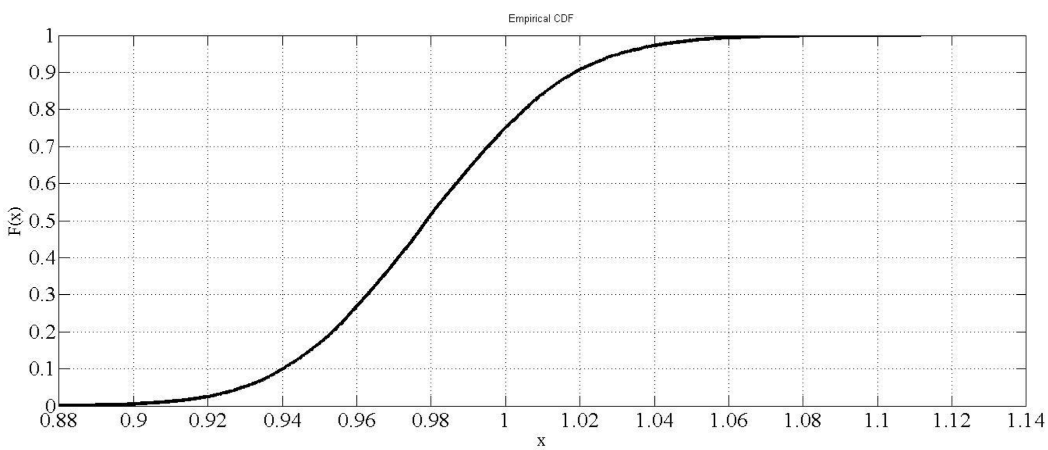

Figure A-2. Posterior Cumulative Probability Distribution of treatment relative to control survival (RS1 = St1/Sc1) from the Cathlamet trap to Bonneville Dam.

In this case, there is a probability of nearly 0.25 that treatment fish survived slightly better than control fish (RS1 > 1).

<u>Discussion</u>

By employing the genetic assignment data from a subsample consisting of 24% of the total number of control and treatment Chinook tagged and released from the Cathlamet trap in a

Bayesian analysis framework, we were able to achieve robust estimates of the absolute rates of survival of control and treatment fish between each of four detection points in the lower Columbia River Basin (the trap, Bonneville, The Dalles, and McNary dams). This information shed additional light on how treatment fish fared compared to control fish after physical capture, tagging, and release at the trap.

Of greatest importance, our estimates of absolute survival rates reveal differences in the likely impact of harvest activities in the Columbia River mainstem upstream of the Cathlamet Channel 167 kilometers (104 miles) downstream of Bonneville Dam in which the trap was situated. During the 2017 study period (26 August to 27 September 2017), Chinook released from the trap that were bound for spawning locations upstream of Bonneville Dam were subject to commercial fisheries of varying intensity and duration. From release at the trap to Bonneville Dam, Chinook were subject to the Zone 4-5 non-tribal commercial gill net fishery. Between Bonneville Dam and McNary Dam, Chinook were subject to the tribal Zone 6 commercial gill net fishery, the heaviest fishing occurring between Bonneville Dam and The Dalles Dam.

Our results reflect the relative magnitude and intensity of commercial fisheries that occurred between the trap and Bonneville Dam, Bonneville Dam and The Dalles Dam, and The Dalles Dam and McNary Dam. The mean survival rates of control and treatment fish between the trap and Bonneville (Sc1 and St1) were 0.69 and 0.67, respectively. Mean rates between Bonnveille Dam and The Dalles Dam (Sc2 and St2) were 0.61 and 0.64, respectively. Mean rates between The Dalles Dam and McNary Dam were 0.73 and 0.70, respectively (Table A-2). Cumulatively, from the trap to McNary Dam mean absolute survival rates were identical between control and treatment fish: 0.30 (control: 0.69*0.61*0.73; treatment: 0.67*0.64*0.70).

All of these survival estimates are very robust as a result of the narrow distribution of the informative Beta prior distribution used to estimate the number of control and treatment fish released from the trap that were bound for spawning locations upstream of Bonneville Dam (PropT&C, Table A-1).

B. Alternative PD7 Relative Survival Analysis

B. Cox and T. Sippell - WDFW

Background

In 2017, Wild Fish Conservancy (WFC) conducted a research study to evaluate post-release survival of fall Chinook and summer steelhead captured by a pound net located in the Columbia River near Cathlamet, WA (Tuohy et al. 2019). Two fishing methods were employed at the pound net, fish were either passively released or brailed by a lift into a sorting box. This analysis estimates survival of PIT tagged fall Chinook and summer steelhead released from the pound net relative to previously PIT tagged fish detected at the PD-7 array. Both the passive release and brailing treatments were compared to fish detected PD-7.

Methods

Data

PIT tag detections for both PD-7 and the pound net were downloaded from PTAGIS and genetic assignment data for Chinook were provided by WFC. Capture histories were generated for each tag code with a detection at a mainstem dam indicated with a 1 and no detection indicated with a 0.

Steelhead

Steelhead retention was prohibited in Columbia River sport fisheries in August 2017, but allowed in September. Only adipose-clipped steelhead were allowed to be retained in Columbia River sport fisheries. Steelhead detections at PD-7 were filtered for adipose-clipped steelhead ($n = 11$), to ensure that control fish would be vulnerable to the same fisheries as adipose-clipped steelhead released from the pound net. All adipose fin-clipped steelhead detected at PD-7 in August and September 2017 were marked as juveniles in either Upper Columbia or Snake River tributaries, thus we assume they would pass all mainstem dams up to and beyond McNary Dam if alive (i.e., if alive, fish would remain in the study area). All clipped steelhead from the pound net ($n = 649$) were included in the data set, as parent-based tagging (PBT) and genetic stock identification (GSI) assignments indicated nearly all fish captured (>98%) originated in Snake River and Upper Columbia populations that would also likely pass McNary Dam. Of the 649 steelhead captured by the pound net, 315 were passively released and 334 were brailed.

Chinook

To meet the assumption that, if alive, fish would migrate through the Columbia River hydrosystem to McNary Dam, only Chinook with known origins in upper Columbia or Snake River tributaries were included in both treatment and control data sets. At PD-7, there were $n = 23$ detections of fish PIT tagged as juveniles in tributaries upstream from McNary Dam. Because several populations of fall Chinook that return to tributaries between Bonneville and McNary dam would assign to the UCOLSF (Upper Columbia Summer/Fall) GSI group, only Chinook that assigned to the SRFALL (Snake River Fall) GSI group or to hatcheries upstream of McNary Dam by parental based tagging (PBT) were included from the pound net ($n = 73$). Of the 73 PBT and SRFALL Chinook captured by the pound net, 40 were passively released and 33 were brailed.

Model

A Cormack-Jolly-Seber (CJS) model was fit to individual capture histories for steelhead and Chinook detected at PD-7 and released at the pound net. The CJS model was formulated as a state-space model, with observations of individuals i at mainstem dams d modeled as a Bernoulli random variable:

$$y_{id} \sim Bernoulli(\mu_{2_{id}})$$

The probability of an individual being observed at dam d was modeled as:

$$\mu_{2_{id}} = p_d \times z_{id},$$

where p_d is the probability of detection at dam d and z_{id} is a binary latent state indicating if the fish was alive(1) or dead(0) at dam d. The latent state of individuals at each dam was also modeled as a Bernoulli random variable:

$$z_{id} \sim Bernoulli(\mu_{1_{id}}),$$

with the probability of an individual being alive at dam d, given that it was still in the study area (i.e., migrating through the mainstem Columbia River), modeled as:

$$\mu_{1_{id}} = \phi_{gr-1} \times z_{id-1}$$

where ϕ_{gr-1} is apparent survival of group g through the previous reach r and z_{id-1} is the latent state of the fish at the previous dam.

A logistic linear model was used to represent differences in apparent survival among the PD-7 and pound net groups, and differential survival in river reaches between the dams:

$$logit(\phi_{gr}) = \beta_g + \gamma_r$$

The two pound net treatments (β_g) were modeled as offsets from the PD-7 group and γ_r represented fixed effects in the river reaches between the mainstem dams. To estimate apparent survival in the interval between John Day Dam and McNary Dam, a catch-all 6^{th} recapture occasion was included for detections at any upper Columbia or Snake River sites above McNary Dam because the final p and ϕ would otherwise be confounded in a fully time-varying model. Vague priors, $Normal(\mu = 0, \sigma = 10)$, were selected for group and time effects on the logit-scale for all β_g and γ_d parameters, with the exception of γ_4 for Chinook. This parameter demonstrated weak identifiability in preliminary model runs, thus the prior was adjusted to have slightly a lower standard deviation ($\sigma = 5$), which was still relatively vague on the probability scale but produced a more unimodal posterior. Independent uniform beta priors were placed over recapture probabilities at each dam: $p_d \sim Beta(1,1)$. Relative survival of the pound net treatment groups g (i.e., passive or brailed) in each river reach r was derived as:

$$Relative\ survival_{g_r} = \frac{\phi_{g_r}}{\phi_{PD-7_r}}$$

Cumulative survival from the pound net to McNary Dam was estimated as the product of the relative survival estimates for each treatment group.

The model was fitted with both Bayesian and maximum-likelihood methods. Using MCMC in JAGS (Just Another Gibbs Sampler), a minimum of 4 chains were initialized with 3,000 adaptation steps and 75,000 burn-in iterations were discarded. Chains were thinned at a rate of 1/50 and 14,000 posterior samples were drawn. MCMC chains were examined for convergence by visually inspecting trace plots and using the Gelman-Rubin diagnostic. Autocorrelation in the chains was examined visually with ACF plots, and indicated little autocorrelation in sampled parameters. Estimates from the Bayesian model were compared to maximum-likelihood estimates from the same model built using Program MARK for consistency.

Results

Median relative survival for the passively released pound net treatment was >1 for both species in each interval from the pound net to McNary Dam, because passively released fish had higher apparent survival than the PD-7 control (Figure B-1, Figure B-3, Table B-1). Relative survival for steelhead in the brailed treatment group varied from 96.7 – 99.6 % in the four intervals from the pound net to McNary Dam and relative survival varied from 97.4 – 100% from the trap to McNary Dam for brailed Chinook (Figure B-3, Table B-2, Table B-3). The posterior median cumulative survival to McNary Dam of both Chinook and steelhead were also >1 for the passively released pound net group (Table B-4). Median cumulative survival was estimated to be 93.5% and 94.7% for Chinook and steelhead respectively for the brailed treatment group (Table B-4).

Conclusions

Although the estimates of relative survival and cumulative relative survival were uncertain given the sample sizes of the three groups, these data are most likely to meet the assumption that fish from each group will pass through the mainstem dams with equal probability. Given this assumption is met, the point estimates are unbiased. WDFW supports adopting the median relative survival estimates from the pound net to Bonneville Dam or the cumulative survival from the pound net to McNary Dam. For passively released Chinook and steelhead, the recommended release mortality rate is 0%. For Chinook brailed at the pound net, the recommended release mortality rate is 3.0% from the trap to Bonneville Dam or 6.5% cumulative mortality to McNary. For steelhead, the recommended release mortality rate is 3.0% from the trap to Bonneville Dam or 5.3% cumulative mortality to McNary Dam. Should new data become available from future pound net research, this analysis should be revisited to incorporate future information. The framework of this analysis could be easily adapted to evaluate post-release survival for fish sampled at the Bonneville Dam Adult Fish Facility (AFF) by treating passively detected fish at Bonneville Dam as the control group relative to fish tagged at the AFF.

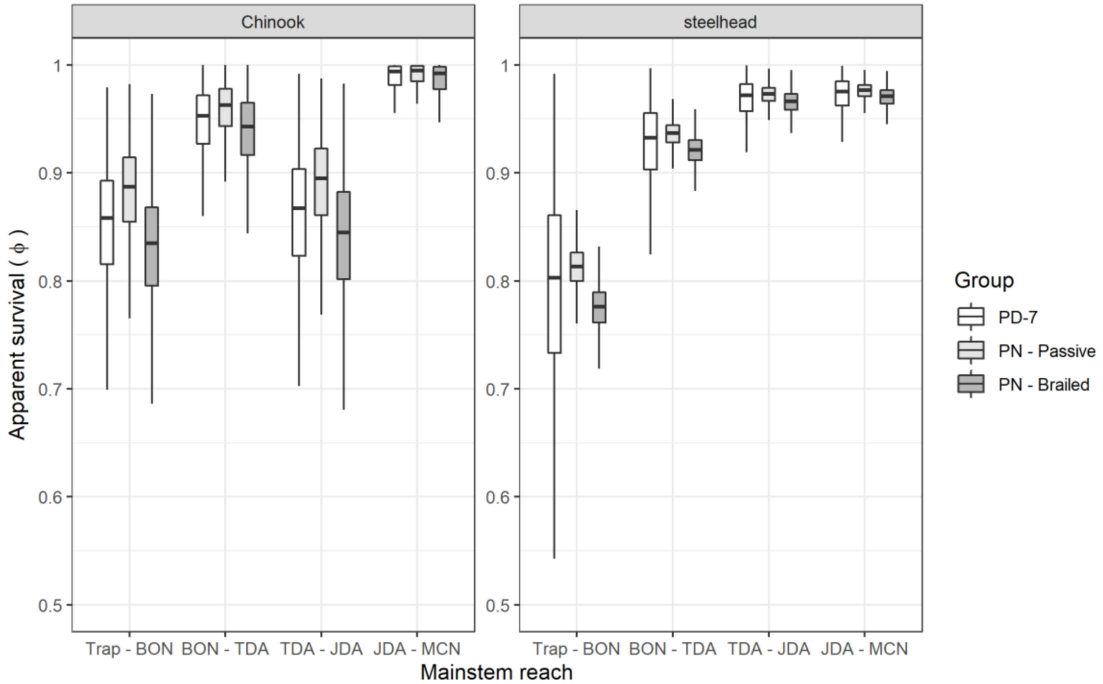

Figure B-1. Apparent survival (ϕ) for the PD-7 control and two pound net treatment groups in each mainstem reach from the pound net to McNary Dam.

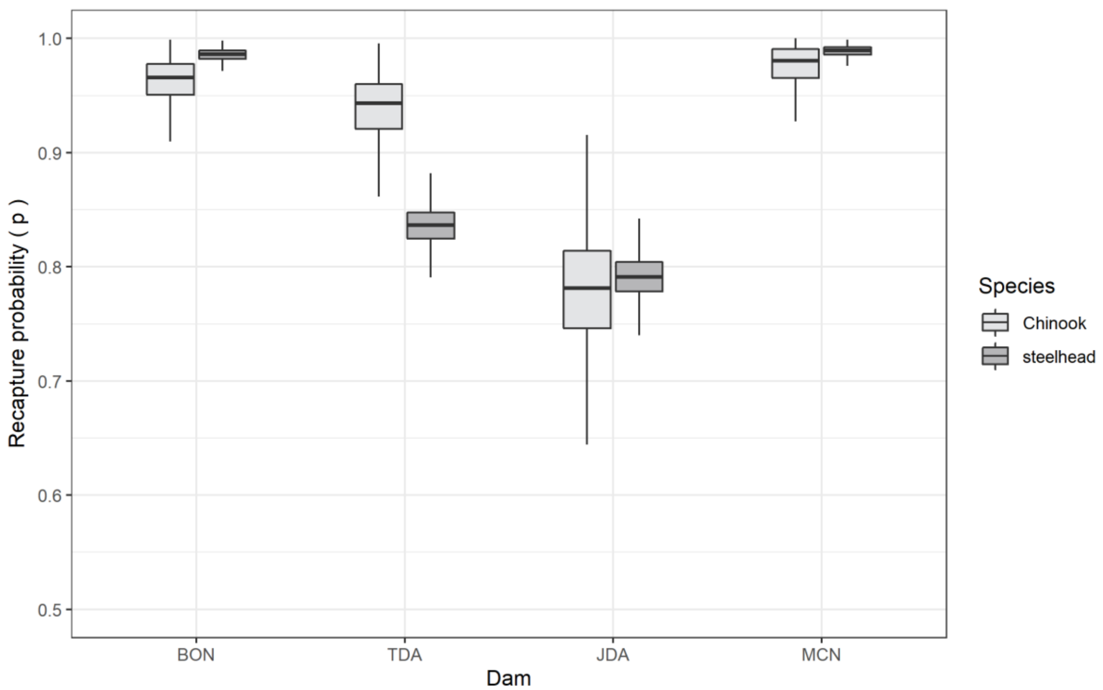

Figure B-2. Recapture probability (p) for Chinook and steelhead at each mainstem dam from Bonneville to McNary.

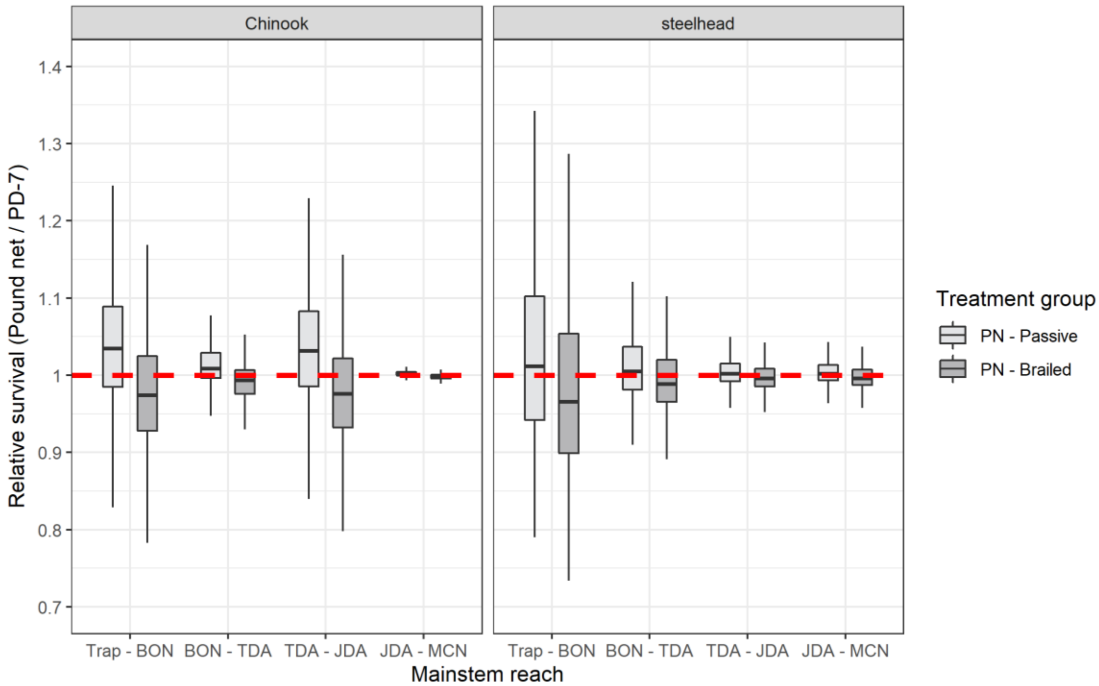

Figure B-3. Relative survival for the pound net treatment groups in each mainstem reach from the pound net to McNary Dam.

Table B-1. Posterior median apparent survival (ϕ) estimates with 95% quantile intervals for Chinook and steelhead.

Species	Reach	Treatment	Median	lc95	uc95
Chinook	Trap - BON	PD-7	0.86	0.72	0.94
		PN - Passive	0.89	0.78	0.95
		PN - Brailed	0.83	0.71	0.92
	BON - TDA	PD-7	0.95	0.86	1.00
		PN - Passive	0.96	0.89	1.00
		PN - Brailed	0.94	0.85	1.00
	TDA - JDA	PD-7	0.87	0.72	0.95
		PN - Passive	0.89	0.78	0.96
		PN - Brailed	0.84	0.70	0.93
	JDA - MCN	PD-7	0.99	0.93	1.00
		PN - Passive	0.99	0.95	1.00
		PN - Brailed	0.99	0.92	1.00
steelhead	Trap - BON	PD-7	0.80	0.59	0.94
		PN - Passive	0.81	0.77	0.85
		PN - Brailed	0.78	0.73	0.81
	BON - TDA	PD-7	0.93	0.82	0.98
		PN - Passive	0.94	0.91	0.96
		PN - Brailed	0.92	0.89	0.95
	TDA - JDA	PD-7	0.97	0.91	0.99
		PN - Passive	0.97	0.95	0.99
		PN - Brailed	0.97	0.94	0.98
	JDA - MCN	PD-7	0.98	0.92	0.99
		PN - Passive	0.98	0.96	0.99
		PN - Brailed	0.97	0.95	0.99

Table B-2. Median relative survival for Chinook treatment groups with lower quantile intervals ranging from 0.5 to 0.95 probability (table continues on next page).

Species	Treatment	Reach	Median	Lower limit	Upper limit	Prob.
Chinook	Passive	Trap - BON	1.03	0.99	1.09	0.50
				0.97	1.11	0.60
				0.96	1.12	0.70
				0.94	1.15	0.80
				0.91	1.19	0.90
				0.89	1.23	0.95
Chinook	Passive	BON - TDA	1.01	1.00	1.03	0.50
				0.99	1.03	0.60
				0.99	1.04	0.70
				0.98	1.05	0.80
				0.97	1.07	0.90
				0.95	1.09	0.95
Chinook	Passive	TDA - JDA	1.03	0.99	1.08	0.50
				0.97	1.10	0.60
				0.96	1.12	0.70
				0.94	1.14	0.80
				0.92	1.18	0.90
				0.89	1.22	0.95
Chinook	Passive	JDA - MCN	1.00	1.00	1.00	0.50
				1.00	1.01	0.60
				1.00	1.01	0.70
				1.00	1.01	0.80
				0.99	1.02	0.90
				0.98	1.03	0.95
Chinook	Brailed	Trap - BON	0.97	0.93	1.02	0.50
				0.92	1.04	0.60
				0.90	1.05	0.70
				0.89	1.08	0.80
				0.86	1.11	0.90
				0.83	1.15	0.95
Chinook	Brailed	BON - TDA	0.99	0.98	1.01	0.50
				0.97	1.01	0.60
				0.96	1.02	0.70
				0.95	1.03	0.80
				0.94	1.04	0.90
				0.92	1.06	0.95
Chinook	Brailed	TDA - JDA	0.98	0.93	1.02	0.50
				0.92	1.03	0.60

Species	Treatment	Reach	Median	Lower limit	Upper limit	Prob.
				0.91	1.05	0.70
				0.89	1.07	0.80
				0.86	1.11	0.90
				0.83	1.14	0.95
Chinook	Brailed	JDA - MCN	1.00	1.00	1.00	0.50
				0.99	1.00	0.60
				0.99	1.00	0.70
				0.99	1.00	0.80
				0.98	1.01	0.90
				0.97	1.02	0.95

Table B-3. Median relative survival for steelhead treatment groups with lower quantile intervals ranging from 0.5 to 0.95 probability (table continues on next page).

Species	Treatment	Reach	Median	Lower limit	Upper limit	Prob.
steelhead	Passive	Trap - BON	1.02	0.94	1.11	0.50
				0.93	1.14	0.60
				0.91	1.17	0.70
				0.90	1.22	0.80
				0.87	1.30	0.90
				0.86	1.38	0.95
steelhead	Passive	BON - TDA	1.01	0.98	1.04	0.50
				0.98	1.05	0.60
				0.97	1.06	0.70
				0.96	1.07	0.80
				0.96	1.10	0.90
				0.95	1.13	0.95
steelhead	Passive	TDA - JDA	1.00	0.99	1.02	0.50
				0.99	1.02	0.60
				0.99	1.02	0.70
				0.98	1.03	0.80
				0.98	1.05	0.90
				0.98	1.06	0.95
steelhead	Passive	JDA - MCN		0.99	1.01	0.50
				0.99	1.02	0.60
				0.99	1.02	0.70
				0.99	1.03	0.80
				0.98	1.04	0.90
				0.98	1.05	0.95
steelhead	Brailed	Trap - BON	0.97	0.90	1.06	0.50
				0.89	1.09	0.60
				0.87	1.12	0.70
				0.86	1.16	0.80
				0.83	1.24	0.90
				0.82	1.32	0.95
steelhead	Brailed	BON - TDA	0.99	0.97	1.02	0.50
				0.96	1.03	0.60
				0.95	1.04	0.70
				0.95	1.06	0.80
				0.94	1.08	0.90
				0.93	1.11	0.95
steelhead	Brailed	TDA - JDA	1.00	0.99	1.01	0.50
				0.98	1.01	0.60

Species	Treatment	Reach	Median	Lower limit	Upper limit	Prob.
				0.98	1.02	0.70
				0.98	1.02	0.80
				0.97	1.04	0.90
				0.97	1.05	0.95
steelhead	Brailed	JDA - MCN		0.99	1.01	0.50
				0.99	1.01	0.60
				0.98	1.02	0.70
				0.98	1.02	0.80
				0.98	1.03	0.90
				0.97	1.04	0.95

Table B-4. Cumulative survival estimates (Trap - MCN) for pound net treatment groups with lower quantile intervals ranging from 0.5 to 0.95 probability.

Species	Treatment	Median cum. survival	Lower limit	Upper limit	Prob
Chinook	Passive	1.089	0.963	1.233	0.50
			0.932	1.271	0.60
			0.898	1.325	0.70
			0.855	1.393	0.80
			0.799	1.496	0.90
			0.752	1.599	0.95
	Brailed	0.935	0.832	1.061	0.50
			0.808	1.094	0.60
			0.779	1.137	0.70
			0.747	1.192	0.80
			0.696	1.289	0.90
			0.648	1.380	0.95
steelhead	Passive	1.024	0.911	1.188	0.50
			0.889	1.239	0.60
			0.865	1.304	0.70
			0.840	1.394	0.80
			0.808	1.551	0.90
			0.783	1.727	0.95
	Brailed	0.947	0.842	1.099	0.50
			0.822	1.146	0.60
			0.800	1.206	0.70
			0.777	1.287	0.80
			0.747	1.441	0.90
			0.724	1.597	0.95

C. Project Publications

Peer-Reviewed Papers

Tuohy, A.M. 2018. Post-release survival of Chinook salmon and steelhead trout from an experimental commercial fish trap in the lower Columbia River, WA. Master's Thesis. University of Washington. Seattle, WA. http://wildfishconservancy.org/tuohy-2018/at_download/file

Tuohy, A.M., Skalski, J.R., and N.J. Gayeski. 2019. Survival of salmonids from an experimental commercial fish trap. Fisheries, 44(6). https://doi.org/10.1002/fsh.10292.

Tuohy, A.M. 2020. Commercial fish traps for bycatch mortality reduction in salmon fisheries. The Osprey, 95: 6-9. http://ospreysteelhead.org/archives.htm

Tuohy, A.M., Skalski, J.R., and A. Jorgenson. 2020. Modified commercial fish trap to help eliminate salmonid bycatch mortality. Submitted to the North American Journal of Fisheries Management.

Short-Films

Anderson, S. 2018. A sustainable way forward for fish and fishermen: part one. North Fork Studios. Olympia, WA. https://vimeo.com/248905440

Anderson, S. 2019. A sustainable way forward for fish and fishermen: part two. North Fork Studios. Olympia, WA. https://vimeo.com/310697782

Anderson, S., and J.A. Clark. 2020. The fish trap. North Fork Studios. Olympia, WA. https://vimeo.com/397820822

D. Project Photographs

Figure D-1. Researching historical trap blueprints to design the fish trap.

Figure D-2. WFC designing the trap configuration and piling layout based upon historical research.

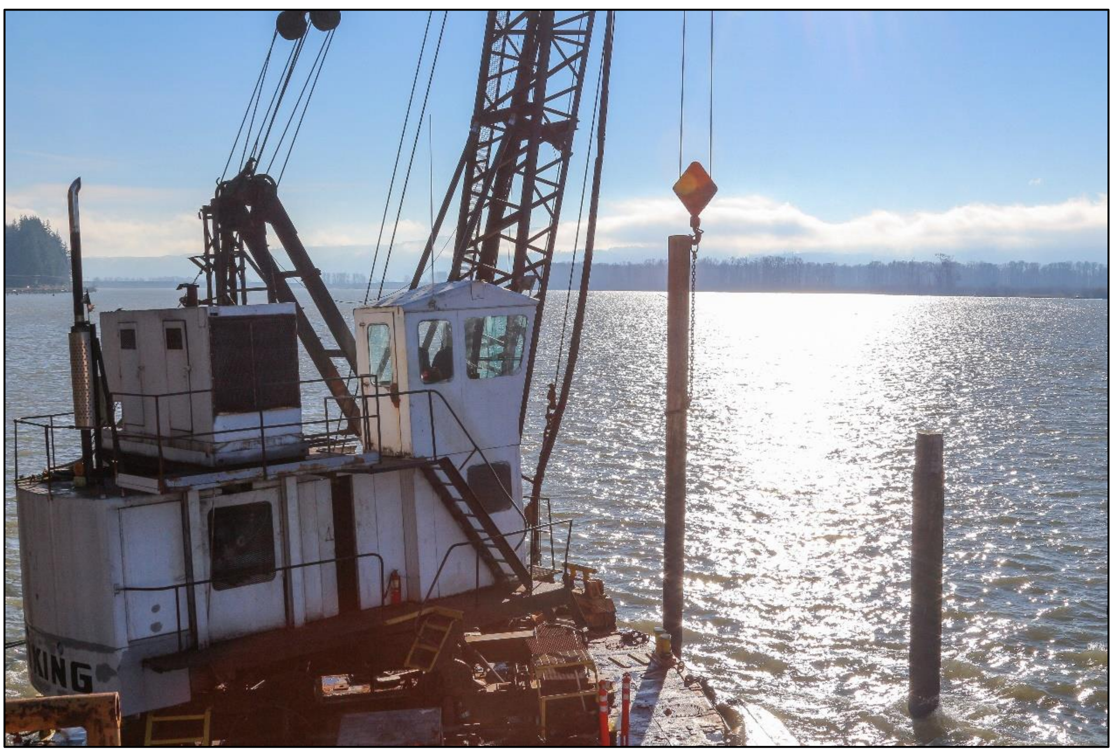

Figure D-3. Pile driving in December 2015.

Figure D-4. Prefabricating components of the fish trap with STA-Weld (Redmond, WA).

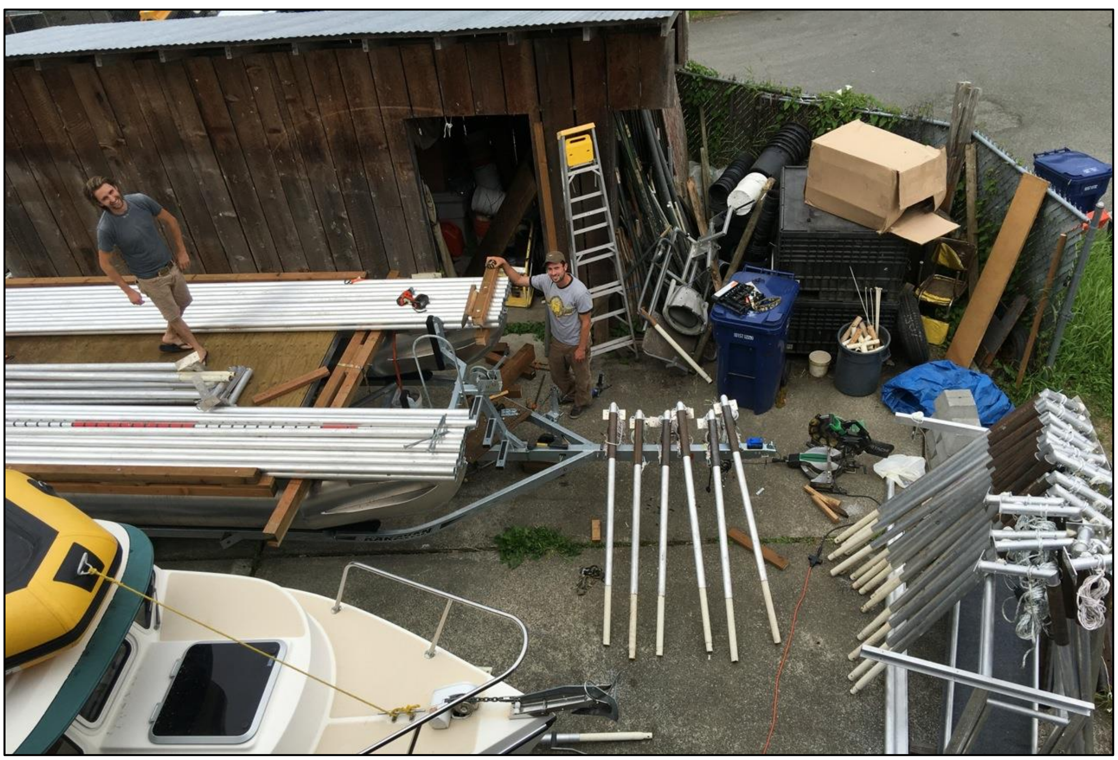

Figure D-5. Assembling the live well dock and other trap components in 2017.

Figure D-6. Constructing the pound net trap in August 2017.

Figure D-7. Hanging the lead web on the fish trap in August 2017.

Figure D-8. Constructing the spiller compartment in August 2017.

Figure D-9. Modifying and orienting the spiller compartment in August 2017.

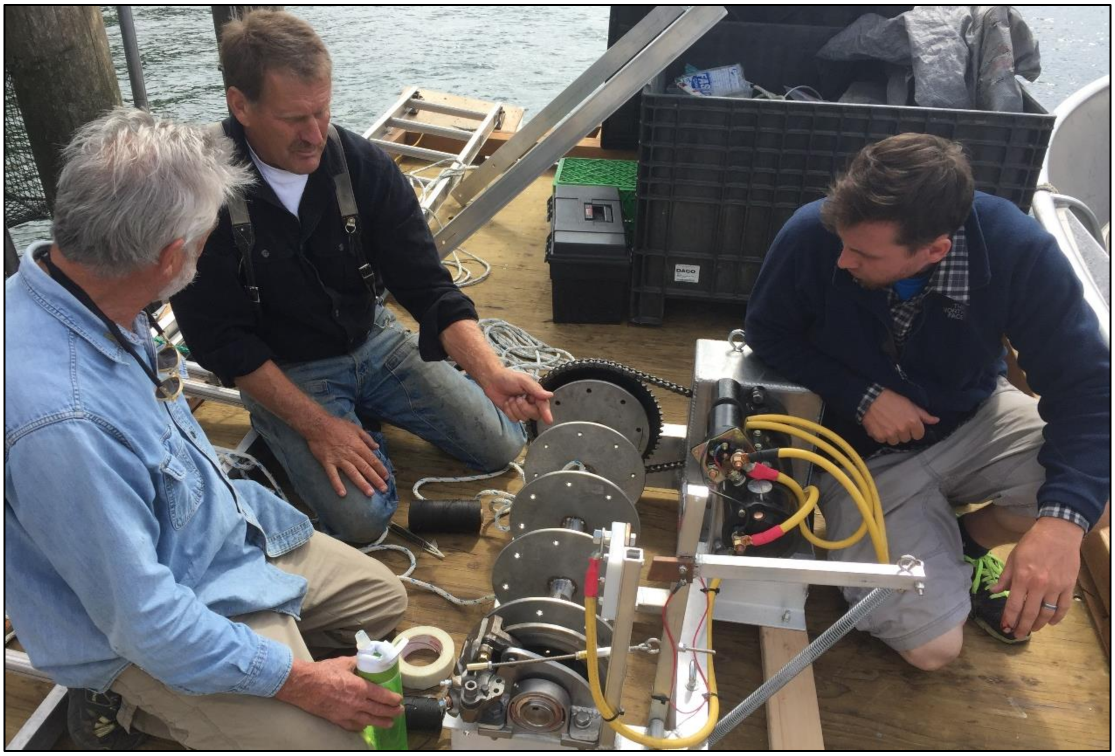

Figure D-10. Installing the solar powered electric winch with commercial fisher Blair Peterson (center) in August 2017.

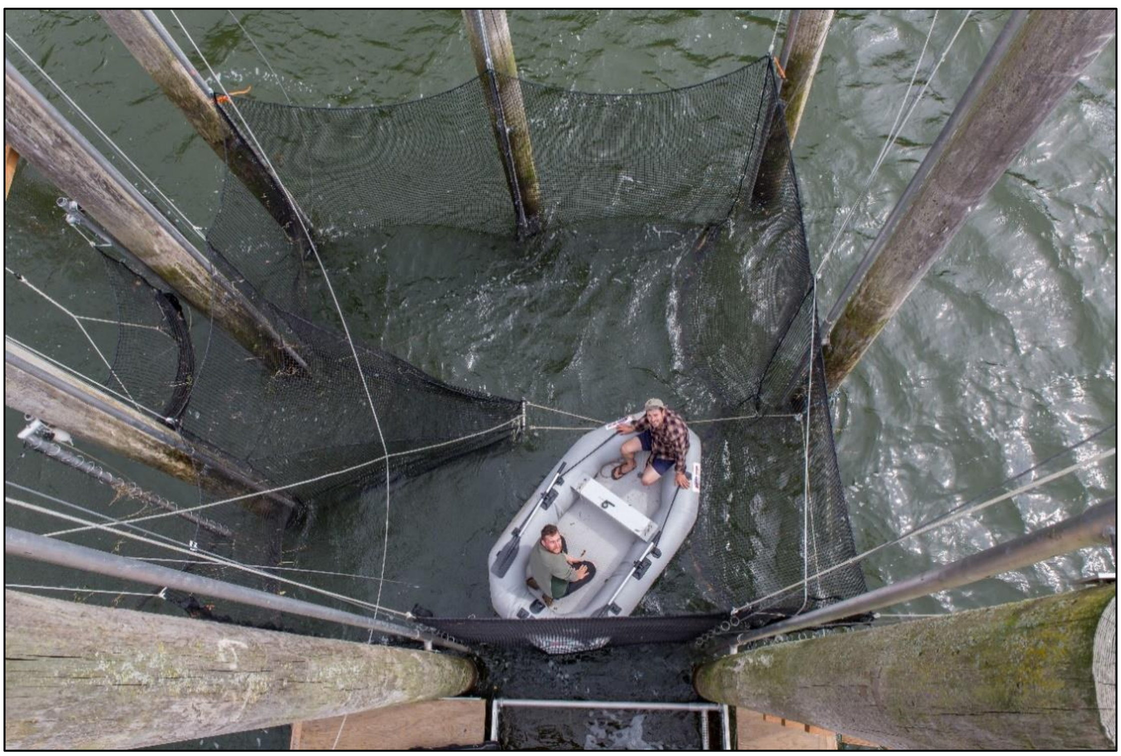

Figure D-11. Installing spiller tunnel extension and retrieval lines.

Figure D-12. The perforated live-well compartment positioned adjacent to the spiller. This compartment enabled river flows to continuously oxygenate the water for recovering fish. The live well release door can be viewed near the top of the photo.

Figure D-13. Upstream side of the completed pound net trap lead viewed from shore.

Figure D-14. Field camp for the 2017 study.

Figure D-15. Completed pound net trap viewed from above in 2017.

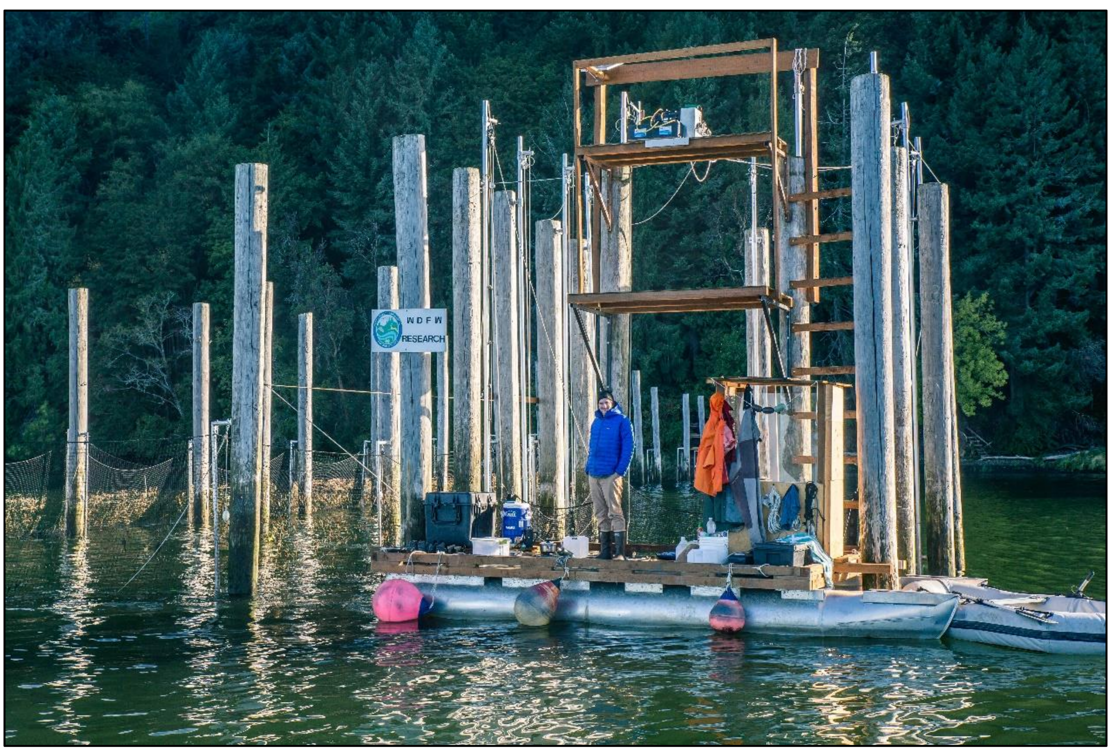

Figure D-16. Live-well dock, spiller, and winch platform viewed from the side in 2017.

Figure D-17. WFC field staff lift the spiller compartment with a solar powered winch in 2017.

Figure D-18. WFC field staff prepare to spill a haul of fish through the spiller door in 2017.

Figure D-19. WFC field staff PIT-tag an adult Chinook salmon from the live-well.

Figure D-20. A wild fall Chinook, tagged, fin-clipped, and ready for release upstream.

Figure D-21. University intern Blake Joplin records PIT tag data through P4 software on the live-well dock in 2017.

Figure D-22. Data entry in between sets from the data booth (positioned on the live-well dock).

Figure D-23. Lead commercial fisher Blair Peterson mending mesh in the heart compartment.

Figure D-24. Constructing the modified live well dock for passive capture in February 2019.

Figure D-25. The heart compartment apron is mended and extended in Cathlamet, WA by WFC staff in March 2019 to prevent entry of marine mammals.

Figure D-26. Commercial fisher Billie Delaney hanging the shore lead in April 2019.

Figure D-27. Completed fish trap viewed from above in 2019.

Figure D-28. WFC staff fishing the passive spiller trap design in May 2019.

Figure D-29. Sockeye salmon captured through the passive spiller trap design in June 2019.

Figure D-30. American shad captured through the passive spiller trap design in June 2019.

Figure D-31. The new upstream live-well dock (featured on the right) which enabled the passive spiller method in 2019, and the old live-well dock and modified data booth (left) where the winch-and-spill treatment operated.

Figure D-32. Spring Chinook captured through the modified passive spiller treatment in May 2019.

Figure D-33. Commercial fisher Billie Delaney releases a coho salmon from the 2019 holding study.

Figure D-34. WFC staff at the completion of the 2019 BREP study.

E. Data Sharing

All data may be downloaded free of charge through the Wild Fish Conservancy webpage (www.wildfishconservancy.org) by clicking on the "Projects" and "Columbia River Pound Net Project" tabs. All PIT tag information can be accessed through the PTAGIS webpage (www.ptagis.com) using the code "CPN" and name "Cathlamet Pound Net."