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DEVELOPING AN ALTERNATIVE MODEL FOR SUSTAINABLE COMMERCIAL SALMON FISHERIES OF THE LOWER COLUMBIA RIVER SUB-BASIN

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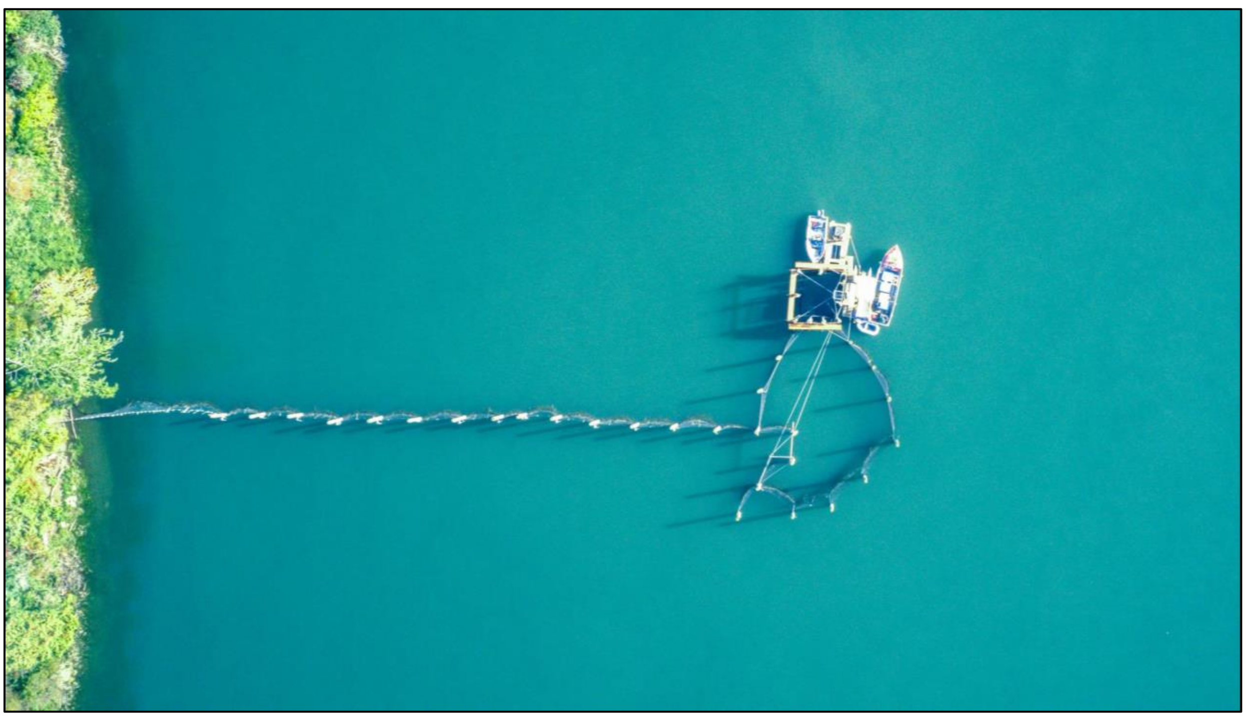

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II. ABSTRACT

Bycatch impacts to Endangered Species Act (ESA)-listed Pacific salmonids (*Oncorhynchus spp.*) dramatically constrain commercial fishing opportunities in salmon fisheries of the Columbia River and elsewhere in the U.S. Pacific Northwest. To investigate the viability of an alternative fisheries model to increase sustainable fishing opportunities for underutilized hatchery-origin salmon in the lower Columbia River, a commercial salmon trap (or, 'pound net') fishery was implemented on a test-basis between August and November 2018-2020 in the Cathlamet Channel, WA. In contrast with the conventional gill net fishery, the test fishery employed a passive, live-capture fishing gear to minimize bycatch mortality of ESA-listed wild salmonids. Use of the salmon trap enabled selective harvesting of hatchery-origin salmon and successful release of bycatch. Furthermore, value-added practices and direct marketing strategies were employed to develop a reputation of quality and sustainability for trap-caught salmon products in the marketplace for the benefit of future fishery participants. Results from 2018-2020 demonstrated that the trap fishery effectively harvested commercially viable quantities of hatchery-origin Chinook Salmon (*O. tshawytscha*) and Coho Salmon (*O. kisutch*) with minimal mortality effect to wild salmonid bycatch. Over the course of 2018-2020 fall season test fisheries, a total of 4,818 hatchery-origin Chinook Salmon and Coho Salmon were selectively harvested, with revenue exceeding estimates of annual costs. A total of 4,357 unmarked (assumed wild-origin) adult salmonids were successfully released between 2018-2020 with zero adult immediate mortalities. Post-release survival of wild Coho Salmon bycatch from modified passive capture and release processes was estimated to be 0.969 (CI ($0.961 \leq \widehat{cumulative} \leq 0.971$) = 0.95) over three consecutive years of net pen holding studies. These results, paired with marketing-project findings, suggest that modified salmon traps could prove effective in minimizing wild salmonid bycatch mortality and improving the profitability of regional salmon fisheries. Given the results of fish trap research and test fishing, the Washington Department of Fish and Wildlife (WDFW) is now moving forward with a formal process to legalize fish traps for mark-selective commercial harvest within the lower Columbia River.

III. EXECUTIVE SUMMARY

Bycatch impacts to Endangered Species Act (ESA)-listed Pacific salmonids (*Oncorhynchus spp.*) dramatically constrain commercial gill netting opportunities in salmon fisheries of the Columbia River and elsewhere, contributing toward declines in income, increased unemployment, and heightened poverty rates in coastal fishing communities. Responding to Washington Fish & Wildlife Commission policy directives to develop and implement alternative fishing practices to conventional gill netting, the nonprofit Wild Fish Conservancy (WFC) and local commercial fishers collaborated to develop a passive, live-capture salmon trap to increase sustainable harvest opportunities for hatchery-origin salmon while minimizing mortality to wild-origin salmonids in the lower Columbia River. With the salmon trap gear demonstrating success in 2017, the Washington Department of Fish and Wildlife (WDFW) authorized commercial test fisheries to further investigate stock-composition, bycatch mortality, and potential economic viability of salmon trap fisheries between 2018-2020. These test fisheries were designed to inform WDFW's decision to potentially legalize and implement a selective alternative gear fishery for hatchery-origin salmon through an Emerging Commercial Fishery designation (RCW 77.65.400).

Between August and November 2018-2020, commercial test fisheries occurred with an experimental salmon trap in the Cathlamet Channel, lower Columbia River, WA. In each fall season of test fishing, WFC partnered with local commercial fishers, fish buyers, processors, chefs, and WDFW to operate, monitor, study, and evaluate the performance of the commercial salmon trap fishery. During the study, catch-composition, bycatch encounters, immediate bycatch survival, and post-release survival of Coho Salmon (*O. kisutch*) were studied. Hatchery-origin salmon were selectively harvested by the fishers, with the catch live-bled and placed in slush ice immediately upon removal from the trap to add value to the catch. All harvested fishes were processed locally in Cathlamet, WA and marketed across the U.S. and Canada, with small deliveries made to high-end restaurants in Seattle, WA.

Results from 2018-2020 demonstrated that the trap fishery effectively harvested commercially viable quantities of hatchery-origin Chinook Salmon (*O. tshawytscha*) and Coho Salmon, with average seasonal revenue exceeding estimated annual costs over the peak of the fishery in August and September. Over the course of 2018-2020 fall season test fisheries, a total of 4,818 hatchery-origin Chinook Salmon and Coho Salmon were selectively harvested. Although Chinook Salmon accounted for the majority of revenue generated in 2018, the trap fishery functioned most effectively for harvest of hatchery Coho Salmon in each year of study. On average, daily revenue during the peak of the fishery in August and September was approximately $1,097. In total, the commercial trap fishery generated an average of $24,442 in revenue each year while accepting the gill net market price (a pricing standard for commercial test fisheries). Accounting for the annual costs of gear deployment, operation, and maintenance, wages for all hours of labor necessary to run a fish trap were estimated at $19.29/h in the absence of any form of added-value.

Although annual profits and living wages were demonstrated from these test fisheries while accepting gill net market prices, added-value practices, direct marketing, and outreach efforts indicated that fishers could eventually secure substantial price increases and far greater wages from use of mark-selective salmon traps. Industry experts ranging from fishers to buyers, processors, and chefs noted that trap harvested salmon were of exceptional quality, with little to no bruising, scale-loss, net damage, gaping of the meat, or damage to egg skeins. These industry experts suggested that trap fishers could likely secure troll fishery ex-vessel value (roughly double conventional gill net market prices during this study). Through direct marketing to high-end restaurants, chefs quoted potential price increases roughly 4-5 times greater than conventional gill net market prices. Given that the salmon trap fishery further provides opportunities for sustainable market certification and other branding advantages, this marketing experiment suggests that future salmon trap fishers should have access to high-end markets with considerable added value.

During the commercial test fishing and marketing project, WFC and partners continued to monitor and study immediate and post-release bycatch survival. Over three years of commercial test fishing, a total of 4,357 unmarked (assumed wild-origin) adult salmonids were successfully released with zero adult salmonid immediate mortalities. Post-release survival of Coho Salmon from a modified passive capture and release technique was investigated through net pen holding studies that occurred between 2019-2020. The Cathlamet Channel net pen holding studies were supplemented by data collected in 2021 at a new fish trap site designed for passive capture and release of bycatch at a location nearby in the lower Columbia River. These three consecutive years of post-release survival study for Coho Salmon resulted in a post-release survival estimate of 0.969 (CI ($0.961 \leq \widehat{cumulative} \leq 0.971$) = 0.95). Given that the holding studies were conducted in an uncontrolled setting, this post-release survival estimate represents the joint likelihood of Coho Salmon survival from the effects of the gear, long-term confinement in the net pen environment, lethal water quality conditions during net pen holding, research handling processes, and the natural environmental baseline. Therefore, survival estimates for Coho Salmon from this study are conservative, and if the survival effect from the gear could be isolated from other confounding factors, it is very likely that it would exceed that of survival estimates detailed within this report.

Based upon the biological and economic results of this project, it appears that modified salmon traps could prove effective as an alternative gear to help minimize bycatch mortality of various salmonid stocks, increase harvest opportunities for hatchery-origin fishes, and improve the profitability of Columbia River salmon fisheries. Given the results of fish trap research and test fishing, WDFW is now moving forward with a formal process to legalize salmon traps for selective commercial harvest of hatchery-origin salmon within the lower Columbia River for the first time since 1935 through an Emerging Commercial Fishery Designation (RCW 77.65.400). Although grant funding or other subsidies may be necessary to help fishers transition from gill netting and overcome existing barriers to participating in the Emerging Commercial Fishery (e.g., upfront capital costs, existing investments in gill netting, allocation uncertainty), it appears that an established salmon trap fishery could prove economically viable to fishing communities while benefiting the recovery of ESA-listed wild salmonids in the Columbia River Basin.

IV. PURPOSE

A. Description of the Problem

Thirteen wild Pacific salmonid (*Oncorhynchus spp.*) evolutionarily significant units (ESUs) are currently listed under the U.S. Endangered Species Act (ESA) in the Columbia River Basin as a result of harvest, habitat loss, dams, hatcheries, and climate change (Lichatowich 1999; Northwest Fisheries Science Center (NFSC) 2015; Crozier 2016). Hatchery production of salmon continues to be used for mitigation purposes in the region, theoretically increasing short-term harvest (Naish et al. 2007). Nevertheless, the practice often threatens ESA-listed wild salmonid populations genetically and ecologically (Naish et al. 2007; Chilcote et al. 2011; Gayeski et al. 2018a). Furthermore, hatchery production encourages continued mixed-stock fishing, often with non-selective commercial gears (e.g. gill nets) that cause mortality of ESA-listed bycatch (Wright 1993; Flagg et al. 1995). This fisheries management paradigm of hatchery production and conventional mixed-stock harvest has failed to recover wild salmonids (Lichatowich et al. 2017; Gayeski et al. 2018a). Consequently, many commercial, recreational, and tribal salmon fisheries are increasingly constrained by ESA impact concerns (Martin 2008; ODFW and WDFW 2019).

Recognizing the need for harvest and hatchery reforms to promote salmonid recovery, fish commissioners directed the Washington Department of Fish and Wildlife (WDFW) and Oregon Department of Fish and Wildlife (ODFW) to develop and implement alternative commercial gear to enable selective harvest of hatchery-origin salmon and reduce bycatch impacts to ESA-listed wild salmonids (WFWC 2009, 2013; ODFW 2013). Alternative gears—including beach seines, modified purse seines, and tangle nets—were tested between 2001 and 2016 in the lower Columbia River to estimate bycatch mortality rates and bycatch encounters for comparison to that of the conventional gill net (Vander Haegen et al. 2004; WDFW 2014; Takata and Johnson 2018). Gill nets were studied for bycatch mortality effects to spring Chinook Salmon (*O. tshawytscha*) (Vander Haegen et al. 2004), however, no data were collected to enable estimation of gill net mortality impacts to other critical bycatch stocks in primary commercial fisheries (NMFS 2018). Due in-part to apparent bycatch impact limitations of studied alternative gears, amongst other factors, state policy directives to develop and implement alternative gears while phasing out gill nets in the mainstem Columbia River did not materialize (WDFW 2018).

Given perceived limitations of tested alternative gears, the fish trap (or, 'pound net') was proposed as yet another alternative gear for investigation (Tuohy et al. 2019). The fish trap was an historically effective gear, popular in both indigenous and commercial salmon fisheries of the U.S. Pacific Northwest (Cobb 1930; Lichatowich 1999). The gear functions by taking advantage of a salmon's natural instinct to migrate against the current. Returning adult salmon migrating upriver are passively funneled from shore by the trap's 'lead' through a maze of walls and compartments, that by design, are increasingly difficult to escape. Captured fishes are eventually funneled into a final chamber from which trap operators can easily sort and access the free-swimming catch. Although the fishing practice allows for selective harvest and live-release of bycatch, the fishing method was banned in Washington State in 1934 and Oregon in 1948 due to an excess of fishing effort and 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).

In 2016, the nonprofit organization Wild Fish Conservancy (WFC) and a local commercial fisher constructed the first operational pile trap in over 80 years in the lower Columbia River's Cathlamet Channel (Wahkiakum County, Washington; river kilometer (rkm) 67) to identify a low-impact tool for fisheries monitoring, reduce bycatch impacts in commercial fisheries, and improve selective harvesting of hatchery-origin salmon (Tuohy 2018; Tuohy et al. 2019). The experimental fish trap was modeled after designs historically used in the lower Columbia River and was modified to minimize physical and physiological damage to salmonid bycatch. The gear functioned to passively corral returning adult fishes from the lead and heart walls to the pot compartment (~6 m wide x 6 m long x 6 m deep), from which the free-swimming catch could be brailed (or, 'spilled') en-masse or individually dip-netted into a live well for data collection and passive release. In contrast with gill netting, these methods eliminated entanglement of adult salmonids and dramatically reduced air exposure and handling effects known to contribute to bycatch mortality (Donaldson et al. 2014; Raby et al. 2015; Teffer et al. 2017).

To evaluate the effects of the alternative gear to bycatch, post-release survival from the prototype trap was estimated through a paired release-recapture study in 2017 using Passive Integrated Transponder (PIT) tags (Burnham et al. 1987; Tuohy et al. 2019). Results demonstrated that the trap effectively captured hatchery-origin Chinook Salmon and Coho Salmon (*O. kisutch*) while improving salmonid bycatch survival rates relative to other commercial fishing gear-types. Survival of trapped and spilled fish compared to passively released dip-netted controls over a 400-km migration to McNary Dam was estimated at 0.944 ($\widehat{SE}$ = 0.046) and 0.995 ($\widehat{SE}$ = 0.078) for Steelhead (*O. mykiss)* and Chinook Salmon, respectively (Tuohy et al. 2019). In a separate analysis conducted by WDFW, survival of dip-netted, passively released controls relative to fishes tagged as juveniles and passively redetected in the lower Columbia River was "greater than 1.000 for both species [Chinook Salmon and Steelhead] in each interval from the pound net to McNary Dam" (Cox and Sippel 2020, pg. 4). This suggested that the passive control sourcing method employed at the trap (which accounted for 48% of the tagged and released sample) had no detectable impact to the survival of captured and tagged fishes.

Given promising results of post-release survival studies, WDFW authorized further evaluation of the gear and commercial viability through commercial test fisheries over the fall fishing seasons of 2018-2020 (WDFW 2021). These test fisheries were designed to inform a rule-making process (RCW 77.65.400 - Emerging Commercial Fishery) to potentially implement the fish trap as a legal gear for selective commercial harvest of salmon for the first time in Washington State since 1935. Furthermore, test fisheries allowed for proof-of-concept study of engineering modifications to the gear. Modifications to the salmon trap gear were designed to advance passive capture and release processes for bycatch that had demonstrated potential to achieve essentially 100% post-release survival for Chinook Salmon and Steelhead in 2017 (Cox and Sippel 2020).

B. Objectives

To build the foundation for a successful alternative gear fishery in the lower Columbia River Sub-basin for the recovery of ESA-listed salmonids and rejuvenation of working waterfront communities, WFC and partners conducted a unique fisheries research, development, promotion, and marketing project during fall season salmon fisheries of 2018-2020. The project had the following objectives:

1) Evaluate a Commercial Trap Fishery: Identify successes and failures of bringing hatchery salmon resources to market for the first time with a new commercial fishing technology.

2) Perform Research: Monitor catch-composition, immediate bycatch mortality, and post-release bycatch mortality; identify and test engineering modifications to improve gear efficiency and sustainability to meet conservation and management goals.

3) Develop and Implement Value-Added/Direct Marketing Practices: Form a steering group to ensure use of best practices in harvesting, icing, processing, and marketing to maximize customer base and pricing for sustainably harvested fish.

4) Initiate Sustainable Market Certification Processes: Initiate the certification process for fish trap fisheries with Monterey Bay Aquarium's Seafood Watch (MBASW) to increase product profile, customer base, and future fish value in the marketplace.

5) Plan for the Future: Develop proposed gear regulations, identify potential trap sites, stream-line the permitting process, raise awareness of alternative harvest tools, and identify stakeholder mitigation options and appropriate economic incentives to facilitate an alternative gear transition in the lower Columbia River through an Emerging Commercial Fishery designation.

Through the completion of these research and marketing experiments, WFC and partners have increased the availability of information necessary for WDFW to potentially implement fish traps as a legal alternative fishing gear in lower Columbia River commercial fisheries. Ultimately, the goal of this project was to inform the implementation process for alternative gears to increase sustainable harvest opportunities for hatchery-origin salmon while addressing both harvest and hatchery factors known to limit recovery of ESA-listed wild salmonids.

V. APPROACH

A. Description of the Work Performed

Establishing the Commercial Test Fishery and S-K Working Group

At the discretion of WDFW and the US v OR Technical Advisory Committee (TAC), commercial test fisheries were instituted consistent with WA state rules regarding test fishing (RCW 77.12.451) in August 2018-2020 in order to evaluate the performance of the fish trap gear in a commercial selective harvest setting. In a WDFW authorized test fishery, Department staff are legally allowed to retain harvestable fish and sell them to help offset costs of conducting a test fishery (RCW 77.12.177), which include administering contracts, monitoring gear performance and ecological impacts, and contracting a qualified commercial fisher. Agreements between WDFW, WFC, lead commercial fisher Jon Blair Peterson, and fish buyer/processor C&H Fish Company were made in 2018-2020 to enable fall season commercial test fishing in the lower Columbia River. A working group was formed consisting of representatives from WFC, WDFW, the local commercial fishing community, C&H Fish Company, and J&B Sales to inform the commercial harvesting plan. For associated research activities, Dr. John Skalski (University of Washington) provided input and review.

Study Area

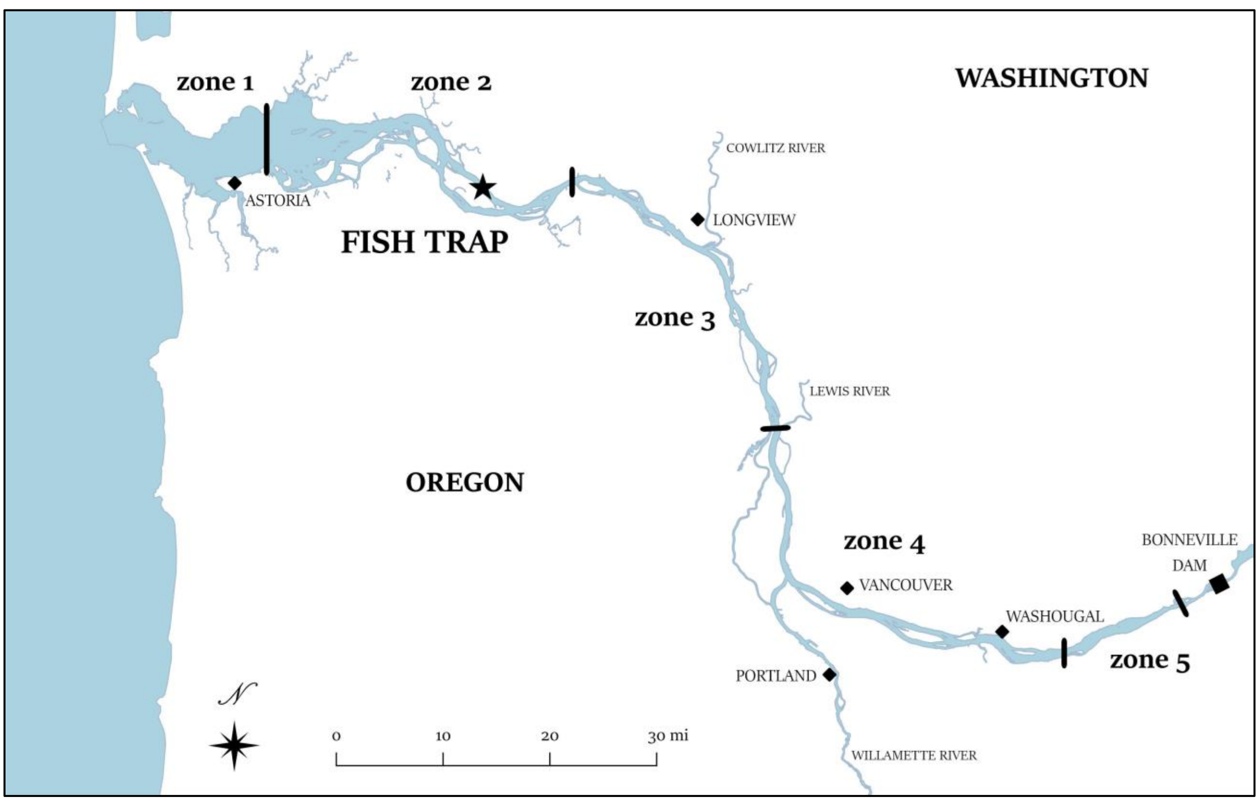

Figure V-1. Lower Columbia fishing zones and the location of the test fishery in WA State.

The location of the 2018-2020 salmon trap fishery was at rkm 67 on the lower Columbia River in the Cathlamet Channel of Wahkiakum County, Washington State (Figure V-1). The fishery occurred in Zone 2 where salmon traps were once commonplace before the Washington State ban on fixed gear in 1934 (WA State Session Laws 1935). 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. Daily tidal flux during the study ranged from 1.5 m to 2.8 m.

Gear Design and Modifications

By design, fish traps remain fixed in position by piling or anchor and passively 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 (Figure V-2) (Cobb 1921). Captured salmonids instinctively move against the current into progressively smaller compartments of a fish trap ('heart,' 'pot/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 passive release with little to no air exposure and handling. Salmonids remain free-swimming within a fish trap and selected mesh dimensions minimize or prevent entanglement altogether (Tuohy et al. 2019).

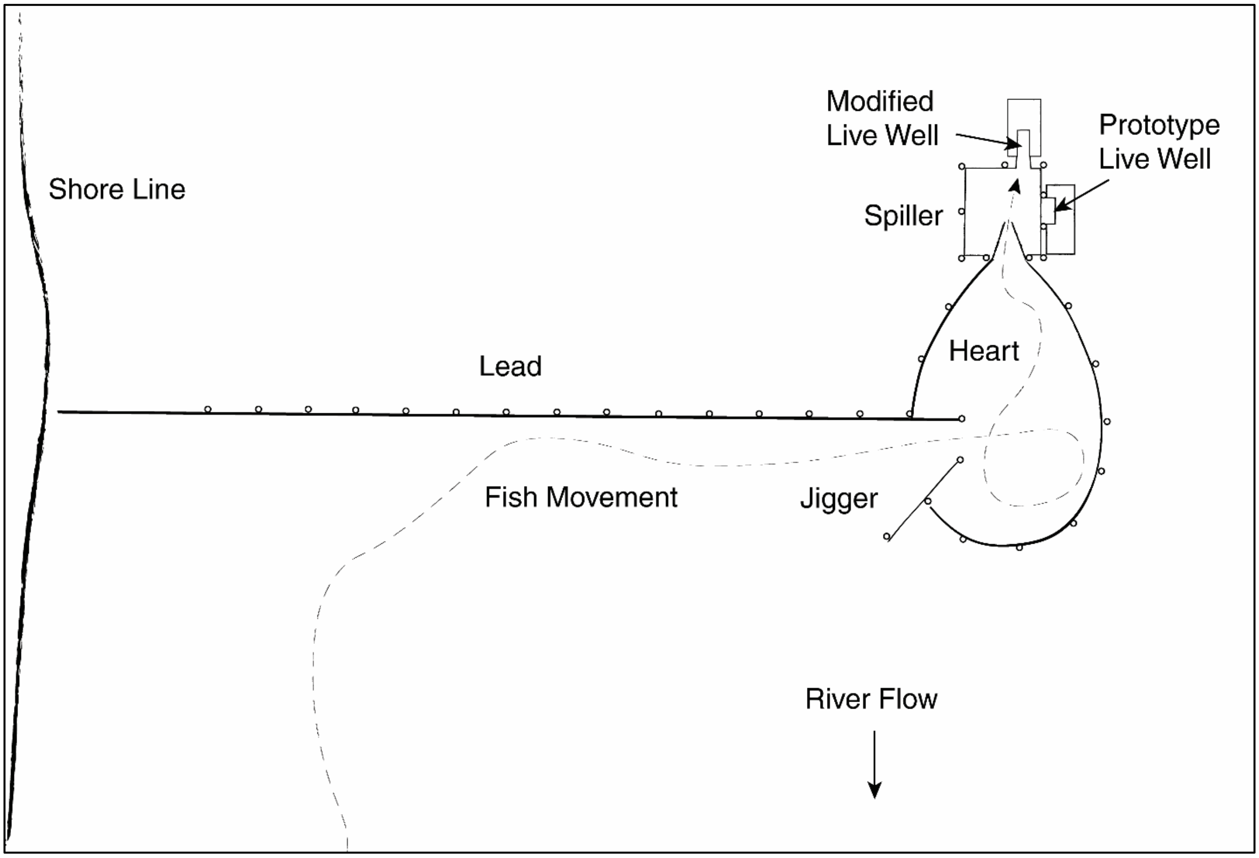

Figure V-2. The fish trap consisted of a lead, jigger, heart, tunnel, spiller, and one live well. In 2019-2020, the spiller was modified to enable passive capture and release from the final compartment through the addition of a second upriver live well.

Identical to prior fish trap investigations between 2016-2017 (Tuohy 2018), the Cathlamet Channel fish trap consisted of a lead (~90 m), jigger (~10 m), heart (23-m length; 20-m maximum width), tunnel, and spiller (6 × 6 × 6 m) (Figure V-2). Black nylon mesh with a stretch of 7.94 cm was used for the lead and jigger (Christensen Net Works, Everson, Washington). The heart, spiller, and tunnel were constructed of 6.35-cm knotless-nylon mesh. Mesh sizes were carefully selected by study investigators to minimize entanglement of fish and drag within the water column. All compartment nets were secured to untreated pilings (generally positioned 5 m apart) from the bottom of the riverbed to roughly 1 m above the high-water mark. As in the 2017 study, an aluminum marine mammal deterrent gate was installed at the entrance to the heart, enabling operators to open or close trap to prevent entry of large mammals to the heart and spiller (Tuohy et al. 2019).

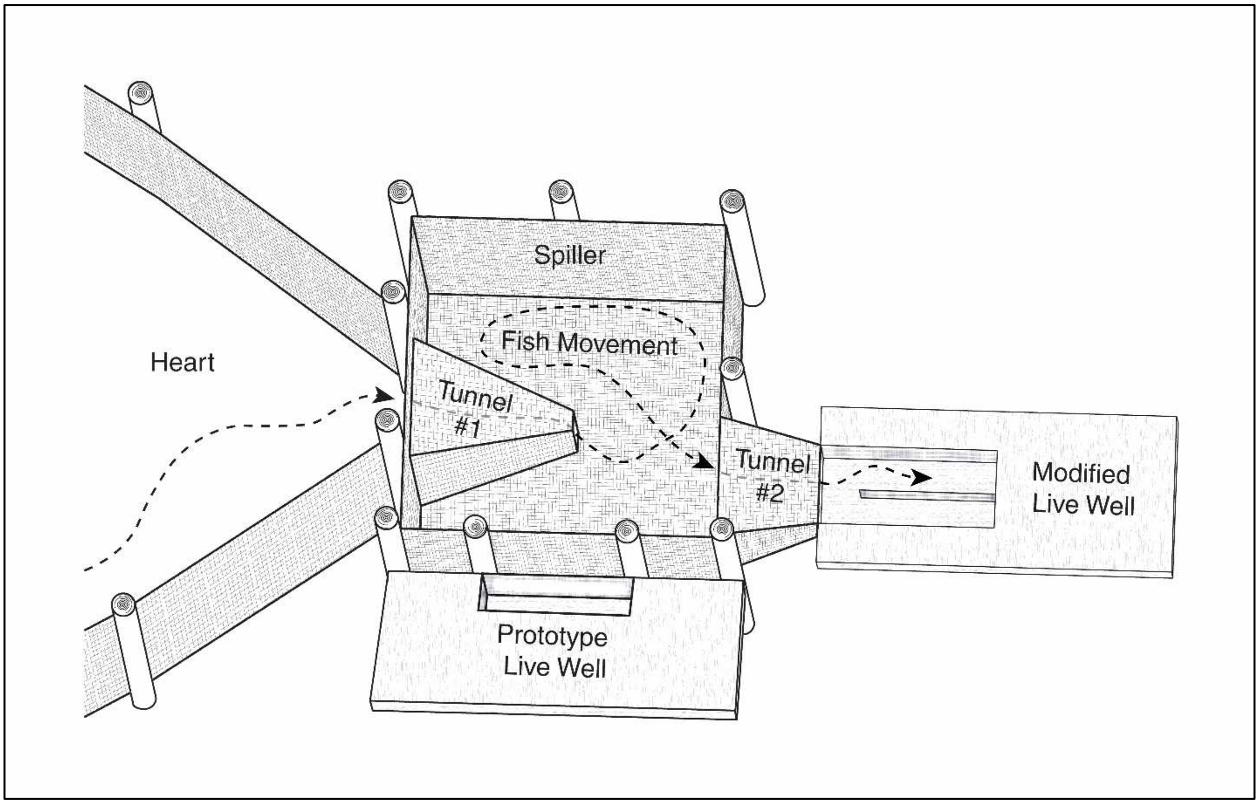

Figure V-3. Diagram of the 2019-2020 modified passive treatment design. The addition of upstream tunnel #2 passively funneled free-swimming fishes in the spiller to a new upstream live-well for capture and release. This design eliminated the need for the electric winch and reduced air exposure, handling, crowding, and net contact associated with the 2016-2018 prototype process.

To improve post-release survival of captured fishes from the gear, the spiller compartment and final capture processes were modified in 2019. In contrast with the 2016-2018 prototype trap design (Tuohy et al. 2019: Figure V-4a), a line and pulley electric winch system (henceforth, the “prototype treatment”) was no longer necessary for hauling the mesh bottom of the spiller/tunnel complex to the shallows for sorting of the catch (a procedure that may cause physiological stress or minor physical damage to captured fishes). A modified passive capture design (henceforth, the "modified passive treatment") was implemented in 2019 by adding a new upstream tunnel to the existing spiller compartment (Figure V-3; Figure V-4b). 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 capture door to passively entrap migrating fishes in one chamber while enabling the vacant chamber to occupy (Figure V-3; Figure V-4b).

Within the modified 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 2016-2018 prototype spilling process. Ultimately, the intent of these engineering modifications was to nearly eliminate post-release mortality effects to bycatch, much like Cox and Sippel (2020) had demonstrated for dip-netted and passively released Chinook Salmon and Steelhead from the fish trap in 2017. Despite the ability of the modified passive capture method to capture and release fishes without handling, it must be noted that handling of all fishes remained necessary for test fishery data collection and research purposes.

Figure V-4. The prototype spilling technique (left) used line-and-pulley and an electric winch to brail groups of captured fish to a live well for sorting. The modified passive design (right) employed an upstream tunnel from the spiller compartment to allow individual fish to migrate at their own volition from the spiller to an attached upstream live well for sorting and passive release with zero air exposure, handling, and brailing.

Test Fishery Operations and Monitoring

Research and commercial test fishing were conducted between August and November during peak migration periods for fall Chinook Salmon and Coho Salmon in the lower Columbia River (Johnson, Chapman, and Schoning 1948; Healey 1991; Sandercock 1991). Hatchery-origin Chinook Salmon and Coho Salmon were commercially targeted for harvest within the test fishery and conventional lower Columbia River commercial fishery. Specific populations of wild-origin Steelhead, Chinook Salmon, Coho Salmon, Chum Salmon (*O. keta*), and Sockeye Salmon (*O. nerka*) are ESA-listed and constitute common bycatch stocks that dramatically constrain commercial fisheries of the region (Martin 2008; NFSC 2015).

To begin a fishing event, trap operators deployed the spiller to the river bottom and opened all tunnel doors, enabling the capture of free-swimming fishes from the spiller compartment using one of two separate techniques: (1) the 2019-2020 modified passive treatment, or (2) the 2016-2018 prototype spilling treatment. Investigators from WDFW and WFC documented the beginning set time, tidal stage (ebb, flood, slack), water temperature (°C; Extech), presence of marine mammals, and the method of capture (modified treatment or prototype treatment). Tunnel doors remained open to fish passage until a pause or cessation of fishing was desired. During trap operations, the marine mammal deterrent gate was periodically closed due to the proximity of Steller Sea Lions (*Eumetopias jubatus*) and California Sea Lions (*Zalophus californianus*) to the project site.

Trap operators visually observed the spiller and upstream live well to determine fish entrance and occupancy through the modified treatment process. Once a live well chamber was occupied by one or more fish, fishers and biologists trapped the catch through closure of the capture door and enumerated, measured (FL), and identified all specimens by species and origin (adipose fin clipped or unclipped, suggesting hatchery or natural origin, respectively) (Figure V-5a). Adult salmonids could also be captured en-masse via the prototype treatment method to a separate live well chamber for sorting and data collection (Figure V-5b).

Figure V-5. Fish captured individually through the passive capture design (left) and a spill of fish captured en masse through the prototype spilling technique (right).

During test fishery operations, hatchery-origin Chinook Salmon and Coho Salmon could be harvested with WDFW present on site for 100% commercial observation and sampling. Hatchery-origin salmon selected for harvest were dip-netted from the live well, live-bled, and immediately placed in an on-site tote filled with slush ice (Figures V-5 - V-7). At a pause in fishing activity, WDFW sorted the catch by species and flesh quality to determine harvested weight by stock (Figure V-8). Investigators then enumerated the catch, measured each fish to FL (mm), scanned for Coded Wire Tags (CWT) and Passive Integrated Transponder (PIT) Tags, gathered genetic tissue and scale samples, and placed the catch in a fresh ice tote for delivery to the local processing plant (Figure V-9) (C&H Fish Company; Cathlamet, WA). During the project, processed fish were sold throughout the U.S. and Canada, with small quantities shipped to high-end restaurants of Seattle, WA to build a reputation for trap-caught seafood products (Figure V-10).

All wild salmonids and other non-retained fishes encountered with the gear (e.g., Steelhead, jacks, and other non-target species) were scanned for PIT tags with a Biomark HPR Lite reader (Biomark, Boise, Idaho). If existing PIT tags were detected, codes were recorded. Non-lethal 2 mm caudal fin genetic tissue samples were secured from Chinook Salmon and Steelhead encountered. After which, all bycatch or non-retained fishes were released from the live well with minimal handling and air exposure and additional sets performed. Fish showing no signs of life at capture or release were considered an immediate mortality. These test fishery data collection methods by WFC and WDFW[1] enabled documentation of total catch, catch composition, bycatch, immediate survival, and catch-per-unit-effort (CPUE).

Figure V-6. Commercial fisher Billie Delaney (left) selectively dip-nets hatchery-origin salmon from the live well for transfer across the deck to the live-bleeding station (right).

[1] Test fishery catch data (catch totals and composition data) were collected by WDFW and WFC staff. Test fishery data are public data sourced from WDFW (2019, 2020, 2021): https://wdfw.wa.gov/fishing/commercial/columbia-river-test. WDFW may consider test fishery data as preliminary.

Figure V-7. Fishers Peterson (left) and Clark (right) live-bleed the catch into slush ice.

Figure V-8. Commercial sampling is conducted by WDFW for selectively harvested hatchery-origin salmon. Staff weigh the catch, enumerate by stock, scan for tags, measure to FL, and collect genetic and scale samples.

Figure V-9. Lead commercial fisher Jon Blair Peterson packs the hatchery-origin catch into ice (left) for delivery to C&H Fish Company in Cathlamet, WA (right).

Figure V-10. James Beard award winning Seattle restaurant owner and chef Renee Erickson of Sea Creatures prepares trap-caught Coho Salmon at her acclaimed restaurant Willmott's Ghost in October 2019.

Post-Release Bycatch Survival Study

Since 2017, post-release bycatch survival from the fish trap gear had been investigated for Chinook Salmon, Sockeye Salmon, and Steelhead trout through a paired release-recapture approach using PIT tags (Tuohy et al. 2019; Tuohy et al. 2020; Cox and Sippel 2020; Fryer et al. 2021). To fill a data gap for Coho Salmon and supplement the findings of the paired release-recapture studies for fish traps, net pen holding survival studies were conducted by WFC with the proof-of-concept passive trapping method throughout the fall of 2019 and 2020 at the original Cathlamet Channel site in the lower Columbia River (Wahkiakum County, Washington; rkm 67). A third research season of net pen holding was conducted for the passive trapping method at a new site in the lower Columbia River developed in Clifton Channel (Clatsop County, Oregon; rkm 55) in the fall of 2021 (Figure V-11). This new fish trap represented the first of its kind to function entirely for passive capture and release on both tides, and marked the first pile trap in Oregon in over 73 years. Although 2021 net pen holding research was funded by NOAA's Bycatch Reduction Engineering Program (BREP), net pen holding study results are included within this report as the work represents an extension of the 2019-2020 Coho Salmon post-release survival studies for the modified passive trapping method.

Figure V-11. A modified passive fish trap was deployed in the lower Columbia River, OR. This trap was the first of its kind to enable passive capture and release of all encountered fishes. Photo by Jamie Glasgow, Wild Fish Conservancy.

The net pen holding studies conducted between 2019 and 2021 were similar in design to those conducted by Buchanan et al. (2002) and Takata and Johnson (2018), in which Coho Salmon were captured with commercial gear and released into captivity to directly observe mortalities over a set period of time. This methodology of estimating post-release survival was selected for three primary reasons: 1) Coho Salmon mostly spawn in tributaries of the lower Columbia River below mainstem dam PIT-tag arrays; 2) technologies to detect PIT-tags or radio tags below Bonneville Dam are insufficient to meet model assumptions for paired release-recapture (WDFW 2014); and 3) previous alternative gear studies specific to Coho Salmon in the lower Columbia River have mostly relied upon a net pen holding methodology to estimate post-release survival (Takata and Johnson 2018).

Mirroring the timeframe of study in the lower Columbia River for tangle nets when commercial Coho Salmon fisheries commonly occur (Takata and Johnson 2018), net pen holding studies were conducted at the completion of commercial test fishing weeks that occurred from late-September through October 2019-2020. These studies observed Coho Salmon survival from the passive trapping process over short-term (48 h) and intermediate (96 h) post-release periods in water temperatures ranging from 12.75°C to 18.77°C—conditions comparable to Takata and Johnson (2018). At the recommendation of management agency representatives, the study period in 2021 was shifted earlier than any prior Coho Salmon net pen holding study conducted in the lower Columbia River to evaluate long-term (144 h) post-release survival of the species in adverse water quality conditions in early September. It must be noted that study investigators expressed concern regarding the duration and timing of the unpaired holding study in 2021 due to anticipation of confounding mortality effects from prolonged confinement in lethal water quality conditions exceeding 20°C (EPA 2003; Donaldson et al. 2011; EPA 2021).

On research days in each year of study, trap operators deployed the pot of the gear to the river bottom and opened the tunnel doors to initiate the soak period. Observers noted the set time, tidal stage, tide height (m), water temperature (ºC), and presence of marine mammals. With the soak period initiated, the pot and upstream live well of the modified fish trap was monitored to determine fish entrance and occupancy. Once a live well chamber was occupied by one or more fishes, operators passively trapped the catch through closure of the capture door. If fishes could not be captured passively, they were dip netted from the pot and the capture method noted (specifically at the Cathlamet Channel site, as all live fish were successfully captured passively in 2021 with the improved Clifton Channel gear design). Fishes captured through any means were enumerated, measured (FL), noted for capture/release conditions (WDFW 1-5 scale; WDFW 2019), and identified by species and adipose fin mark status. Fish showing no signs of life at capture or release from any compartment of the trap—as observed from the live well dock and daily underwater snorkel/dive surveys of all deployed trap panels—were considered an immediate mortality. Non-lethal 1 mm caudal fin genetic samples were secured from all Chinook Salmon and Steelhead encountered. Furthermore, all salmonids were scanned for PIT-tags with a Biomark HPR Lite reader and tag data recorded through P4 software (PTAGIS 2019). After all data were collected, live salmonids were released to resume the upriver migration, unless criteria were met for inclusion in 2021 Chinook Salmon and Steelhead mark-recapture studies or 2019-2021 Coho Salmon net pen holding studies.

During collection of net pen holding sub-samples, adult Coho Salmon (> 47 cm FL) captured with the modified trap were restrained by hand and transferred individually with a rubberized dip net to a designated temporary holding chamber of the live well until a sample of approximately 10 to 44 fish was retained. With the desired sample size achieved after a 4-12 h collection period, investigators sealed outlets to all pot tunnels. Coho Salmon were once again restrained by hand, enumerated, identified by origin (adipose fin clipped or unclipped), measured to fork length (FL), noted for capture condition ("lively", "lethargic", or "no signs of life"; Takata and Johnson (2018)), and transferred from the live well by hand or dip-net to the sealed pot compartment (now functioning as a net pen holding chamber with dimensions similar to Takata and Johnson (2018)). Once the last fish was released into the net pen, investigators initiated short-term (>0 - 48 h), intermediate (48 - 96 h), and long-term (96 - 144 h) observation periods and noted the date, time, water temperature (°C; Extech), and presence of marine mammals. As in previous studies (Takata and Johnson 2018), Coho Salmon that exhibited significant predator-induced injuries or previous damage from gill nets were excluded from the holding study.

Post-release survival of Coho Salmon was estimated by holding and observing six sub-sample groups of fish (mean = 20, min = 13, max = 34) for a 48 h period in 2019, three sub-sample groups (mean = 35, min = 29, max = 38) for a 96 h period in 2020, and five sub-sample groups (mean = 40, min = 38, max = 44) for a 144 h period in 2021. To determine fish mortalities during the holding periods, samples were checked at least once daily at regular intervals from above and below the water surface (via snorkel/free-dive or underwater video survey). At the end of the holding period, all Coho Salmon in the pen were enumerated, measured (FL), scanned for PIT tags, identified for species type and origin (hatchery/wild), noted for condition ("lively", "lethargic", or "no signs of life"), and released to resume the upriver migration.

Figure V-12. Commercial fisher Billie Delaney releases Coho Salmon at the completion of the 48 h holding study in 2019.

At the conclusion of each research season, sub-sample data in each defined post-release period—short-term (>0 - 48 h), intermediate (48 - 96 h), and long-term (96 - 144 h)—were pooled for analysis. Post-release survival in each period was directly estimated by a binomial proportion (p = # survived/# total) with associated binomial variance. Cumulative survival was calculated as the product of immediate, short-term, intermediate, and long-term survival ($S_0 * S_1 * S_2 * S_3$). As in prior lower Columbia River holding studies (Takata and Johnson 2018), potentially confounding mortality effects from factors such as confinement, environmental stressors, natural mortality, and research processes (e.g., fish handling and dip-netting to restrain fish during data collection) were not controlled.

To estimate parameters of the joint likelihood model, including standard errors and 95% profile likelihood confidence intervals, data were uploaded to Program USER (Skalski and Millspaugh 2006; http://www.cbr.washi ngton.edu/analy sis/apps/user), which provides a convenient means of constructing multinomial and product multinomial likelihoods and numerically solving for maximum likelihood estimates and associated standard errors. In the case of no observed mortality, a lower one-tailed interval estimate of survival was calculated using the method in Skalski (1981).

Stock-Specific Exploitation

The proportion of the total run-size captured (either harvested or released) for a specific fish stock was calculated based upon 2018-2020 harvest and release totals and the total estimated return of a stock to the Columbia River (WDFW and ODFW Joint Staff 2019, 2020, 2021). Annual exploitation results were then adjusted for the total number of hours fished in each bi-weekly fishing period between late-August and November in 2018-2020. This analysis was conducted to determine the effectiveness of the gear in capturing targeted salmon stocks and bycatch between years and bi-weekly fishing periods.

Total Harvest and CPUE Comparison

In the fall of 2019, commercial tangle net operations in Zones 1-3 of the lower Columbia River overlapped with the salmon trap test fishery in Zone 2 (Figure V-1). This provided the best opportunity to date to compare the capture effectiveness of the fish trap to a conventional gear deemed commercially viable by management and commercial fishers of the Columbia River. On eight days of overlapping operation in time and location within the lower river, harvest of hatchery-origin Coho Salmon and Chinook Salmon was compared between the fish trap gear and the mean tangle net fisher. In addition, CPUE was calculated (CPUE = catch/h) and compared between gears. For this analysis, deliveries were used as a proxy for the number of active tangle net vessels and the length of the fishery opener was used to determine total hours of daily fishing effort (ODFW 2019).

Revenue Estimation and Value-Added Projections

Total revenue generated from the salmon trap test fishery was calculated based upon the total weight (lbs.) of bright Chinook Salmon, tule Chinook Salmon, and Coho Salmon harvested at the trap and the market price received for each stock per-pound in the lower Columbia River (Revenue = Price * Quantity). Since this was the first-time trap-caught fish were brought to market and no reputation had been previously established to differentiate trap-harvested fish in the marketplace, the test fishery accepted the Columbia River gill net market price in 2018-2020. It must be further noted that test fishery rules and processes (that provide fixed contracts to fishers and require sale of harvested products at “fair market price” to a buyer of the fisher’s choice) generally do not encourage fish buyers to pay state agencies more than the established gill net market price.

Despite the fact that the commercial test fishery mostly accepted gill net market prices as a result of standard test fishery rules and incentives, processors and buyers of the product noted that the quality of the trap-caught product was extremely high from the means of capture and use of value-added practices. These industry experts suggested that bright Chinook Salmon and Coho Salmon captured from traps could eventually achieve or exceed troll fishery market prices. As a result, added-value revenue projections have been made for the fishery with Washington Coast troll market prices serving as the maximum price for all stock-specific revenue estimates (PFMC 2019, 2020, 2021). Quoted 2021 fish prices from C&H Fish Company were also utilized for a short-term conservative estimate of added-value prices in the analysis.

Cost Estimation

Capital costs and the economic costs of production within the salmon trap fishery were identified by researchers and commercial fishers familiar with the gear. Annual production costs to the average fisher were estimated (excluding research and administration costs for the test fishery) and split amongst fixed costs (FC) (costs that are unchanged by the level of output) and variable costs (VC) (those that vary with output). From these cost estimates, average total cost (total cost divided by the output level), average fixed cost (total fixed cost divided by the output level), and marginal cost (the increase in cost from one extra day of harvest and delivery) were determined.

The value of labor in commercial fisheries is rarely predetermined by a fisher and his or her crew, making economic analysis and profit maximization challenging. Commercial fishers generally conduct their work, pay for material costs, and pay themselves or their crew with whatever remains. As a result, annual fixed and variable labor requirements were determined by fishers and researchers experienced with the gear. Average revenue over three years of test fishing was determined to assess the daily rate and hourly wage for each labor input in the absence and presence of potential added value prices (using quoted added-value prices from C&H Fish Company).

B. Project Management

Dr. Nick Gayeski (PhD), WFC Principle Investigator

Dr. Gayeski (Redmond, WA) co-managed the S-K study and provided project oversight.

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

Mr. Tuohy (Seattle, WA) co-managed the study and participated in all working group discussions. He co-led permitting, trap engineering, construction, field staff management, test fishing operations, field data collection, and data management. He conducted statistical analyses and contributed toward the dissemination of all research findings. He co-authored the S-K report and a manuscript accepted by 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 and participated in all working group discussions. He co-led trap engineering, construction, field staff management, test fishing operations, field data collection, and data management. He contributed toward the statistical analysis and co-authored the S-K report and manuscript accepted by 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.

Lisa Harlan (B.S.), WDFW Project Manager

Ms. Harlan (Ridgefield, WA) managed the WDFW salmon trap test fishery and participated in all working group discussions. She led WDFW field staff management, test fishery observation, test fishery data collection, and data management.

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 all working group discussions from 2016-2020. He is an active member of the Emerging Commercial Fishery Advisory Board.

Mike Clark, Commercial Fisher and Fish Processor

Mr. Clark (Cathlamet, WA) assisted with trap operations from 2018-2020 and participated in all working group discussions with WDFW and WFC regarding the advancement of the gear to a commercial harvest setting. He is the owner of C&H Fish Company and was the primary fish buyer and processor for the S-K project. Clark is an active member of the Emerging Commercial Fishery Advisory Board.

Billie Delaney, Commercial Fisher

Ms. Delaney (Astoria, OR) contributed to trap construction, operations, and project development from 2017-2019. She is a lead collaborator with WFC for 2020-2021 BREP fish trap research in the lower Columbia River, OR.

VI. FINDINGS

A. Actual Accomplishments and Findings – Project Results

Fishing Effort and Annual Salmonid Returns

Annual and Seasonal Salmon Fishing Effort

Salmon trap operations differed between years based upon forecasted salmon returns, allocated research impacts, and budget constraints. In 2018, the salmon trap was fished for 226.2 h over 32 d between 25 August and 31 October. Over the course of the project, the trap was operated for a mean of 7.1 h per day (min = 0.9 h; max = 14.3 h; SD = 2.5 h) (Figure VI-1). Little fishing effort was dedicated to the second half of September 2018 in order to investigate the potential of the fishery in the month of October for Coho Salmon.

In 2019, the salmon trap was fished for 446.4 h over 46 d between 19 August and 28 October. The gear was fished more intensively and consistently in 2019, operating for a mean of 9.7 h per day (min = 4.0 h; max = 16.7 h; SD = 2.67 h) (Figure VI-1).

In 2020, the trap was operated for 185.9 h over 25 d between 28 August and 16 October. Over this period, the trap was fished for a mean of 7.4 per day (min = 3.0 h; max = 10.6 h; SD = 1.6 h). Fishing was cancelled for a week-long period in mid-September due to heavy wildfire smoke and hazardous air quality in the region; this reduced fishing effort over the peak of the Coho Salmon run in the middle of September.

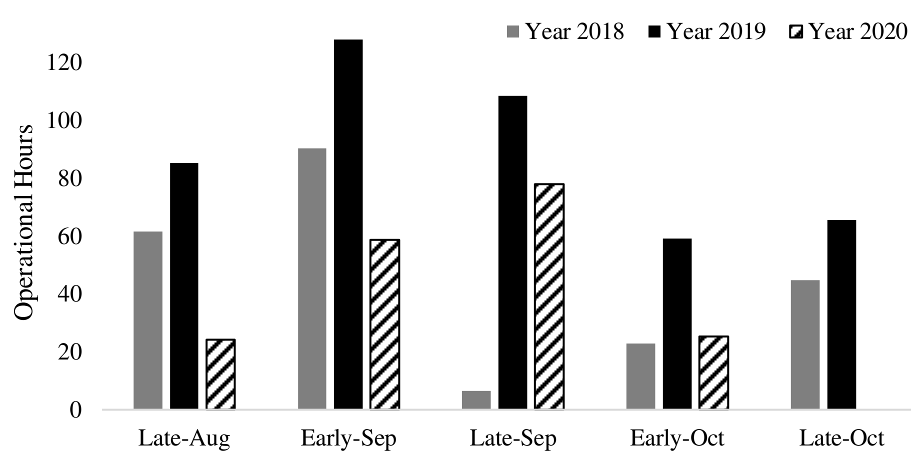

Figure VI-1. Operational hours in 2018-2020 by seasonal bi-weekly testing period.

Annual Salmonid Returns to the Columbia River

Total salmonid returns to the Columbia River during the fall 2018 season were very poor relative to historical returns and the most recent 10-year average. The total 2018 fall Chinook Salmon return to the Columbia River was 293,424 adult fish (WDFW and ODFW 2019). This return represented 39% of the recent 10-year average (2008-2017). The Coho Salmon run was below expectations with only 138,380 adult fish returning to the basin (78,910 early stock fish; 59,470 late stock fish). Returns of upriver summer Steelhead were only 33% of the recent 10-year (2008-2017) average return, with only 100,483 fish passing Bonneville Dam between April and October. The run was comprised of 6,483 Skamania stock, 69,338 A-Index stock, and 24,662 B-Index stock. Of the total upriver Steelhead return, natural-origin Steelhead totaled only 26,702 fish (WDFW and ODFW 2019).

The 2019 fall season salmonid return was greater than 2018, but poor relative to historical returns and the 10-year average. The total 2019 fall Chinook Salmon return to the Columbia River was estimated at 375,769 adult fish (WDFW and ODFW 2020). This return represented only 51% of the recent 10-year average (2009-2018), but an improvement over 2018. The 2019 Coho Salmon run was also greater than 2018 with an estimated total of 212,333 adult fish returning to the basin (144,933 early stock fish; 67,400 late stock fish). Similar to 2018, returns of upriver summer Steelhead remained very poor, with only 75,600 fish passing Bonneville Dam between April and October (45% of the recent 10-year (2009-2018) average return) (WDFW and ODFW 2020). The run was comprised of 3,134 Skamania stock, 66,174 A-Index, and 6,292 B-Index stock. Of the total upriver Steelhead return over Bonneville Dam, natural-origin Steelhead totaled an estimated 32,721 fish (WDFW and ODFW 2020).

Returns in the fall of 2020 improved relative to prior seasons, but still remained poor. The fall Chinook Salmon return to the Columbia River was estimated at 574,800 adult fish (WDFW and ODFW 2021). This return represented 78% of the recent 10-year average (2010-2019) and an improvement over 2019. The 2020 Coho Salmon run was also greater than 2019 with an estimated total of 338,800 adult fish returning to the basin (223,200 early stock fish; 115,500 late stock fish). Similar to all prior years of study, returns of upriver summer Steelhead remained very poor, with 111,692 fish passing Bonneville Dam between April and October (49% of the recent 10-year (2010-2019) average return) (WDFW and ODFW 2021). The run was comprised of 4,101 Skamania stock, 75,392 A-Index, and 32,199 B-Index stock. Of the total upriver Steelhead return over Bonneville Dam, natural-origin Steelhead totaled an estimated 35,464 fish (WDFW and ODFW 2021).

Biological Results

Total Catch and Stock Composition[2]

Year: 2018

Total catch and stock composition varied between years of test fishing. Over the course of the 2018 study, a total of 3,697 salmonids were captured with 95.3% of total catch occurring in the 20 d period between August and September (Table VI-1; Table VI-2). Total catch was composed of 48.1% Chinook Salmon (1,777 total; 39.2% ad-clipped; 15.1% jack salmon), 43.1% Coho Salmon (1,593 total; 58.4% ad-clipped; 39.0% jack salmon), 8.8% Steelhead (325 total; 79.3% ad-clipped; 44.9% B-run (> 78cm)), and < 0.1% Chum Salmon (2 total; 0.00% ad-clipped) (Figure VI-2). In addition to salmonid catch, White Sturgeon (*Acipenser transmontanus*) (4 total), Largescale Sucker (*Catostomus macrocheilus*), Peamouth (*Mylocheilus caurinus*), Largemouth Bass (*Micropterus salmoides*), Northern Pikeminnow (*Ptychocheilus oregonensis*), and Pumpkinseed (*Lepomis gibbosus*) were occasionally encountered.

Table VI-1. Total salmon harvested and released at the fish trap between Aug. and Nov. 2018.

SALMON ENCOUNTERED - 2018

Species		**Adults**			**Jacks**			**Total**
		Marked	Unmarked	Unknown	Marked	Unmarked	Unknown	
Coho	Harvested	497	0	0	12	0	0	509
	Released	10	461	4	406	199	4	1,084
Chinook	Harvested	600	0	0	48	0	0	648
	Released	3	903	2	45	176	0	1,129
Chum	Released	0	2	0	0	0	0	2
Total		1,110	1,366	6	511	375	4	3,372

Table VI-2. Total Steelhead released at the fish trap between Aug. and Nov. 2018.

STEELHEAD ENCOUNTERED -2018

Species		**Adults**			**Total**
		Marked	Unmarked	Unknown	
A-Run (<78 cm)	Released	125	42	0	167
B-Run (>78 cm)	Released	113	23	0	136
Unknown Size	Released	18	2	2	22
Total		256	67	2	325

[2] Test fishery catch data (catch totals and composition data) were collected by WDFW and WFC staff. Test fishery data are public data sourced from WDFW (2019, 2020, 2021): https://wdfw.wa.gov/fishing/commercial/columbia-river-test. WDFW may consider test fishery data as preliminary. Catch totals in each year include fishes encountered during WFC research operations that occurred before and after commercial test fishing.

Year: 2019

Despite greater returns of Chinook Salmon in 2019 and increased test fishing effort (Figure VI-1), fewer Chinook Salmon were captured with the gear. However, the trap captured many Coho Salmon in 2019, reflecting the relative increase in the return over the prior year of operation. Over the course of the 2019 study, a total of 4,961 adult and jack salmonids were captured (Table VI-3; Table VI-4). Total catch was composed of 81.1% Coho Salmon (4,024 total; 62.9% ad-clipped; 12.5% jack salmon), 12.0% Chinook Salmon (597 total; 51.8% ad-clipped; 25.5% jack salmon), 6.3% Steelhead (314 total; 67.5% ad-clipped; 15.3% B-run (> 78cm)), 0.1% Chum Salmon (5 total; 0.0% ad-clipped), 0.04% Pink Salmon (*O. gorbuscha*) (2 total; 0.0% ad-clipped), 0.22% resident/residualized [< 50 cm] Rainbow Trout (11 total; 60.0% ad-clipped), 0.14% resident [< 30 cm] Cutthroat Trout (*O. clarkii*) (7 total; 0.0% ad-clipped), and 0.02% *Oncorhynchus spp.* (1 total) (Figure VI-2). In addition to salmonid catch, we captured 67 Largescale Sucker, 32 Northern Pikeminnow, 13 Starry Flounder (*Platichthys stellatus*), 10 Peamouth, 2 White Sturgeon, 2 Pacific Lamprey (*Entosphenus tridentatus*), 1 Largemouth Bass, and 1 Common Carp (*Cyprinus carpio*).

Table VI-3. Total salmon harvested and released at the fish trap between Aug. and Nov. 2019.

SALMON ENCOUNTERED - 2019

Species		Adults			Jacks			Total
		Marked	Unmarked	Unknown	Marked	Unmarked	Unknown	
Coho	Harvested	1828	0	0	2	0	0	1830
	Released	379	1300	14	313	185	3	2194
Chinook	Harvested	176	0	0	10	0	0	186
	Released	59	197	3	62	89	1	411
Chum	Released	0	4	1	0	0	0	5
Pink	Released	0	2	0	0	0	0	2
Total		2,447	1,503	18	387	274	4	4,628

Table VI-4. Total Steelhead released at the fish trap between Aug. and Nov. 2019.

STEELHEAD ENCOUNTERED - 2019

Species		Adults			Total
		Marked	Unmarked	Unknown	
A-Run (<78 cm)	Released	178	88	0	266
B-Run (>78 cm)	Released	34	14	0	48
Unknown Size	Released	0	0	0	0
Total		212	102	0	314

Year: 2020

Over the course of the 2020 test fishery, a total of 5,467 salmonids were captured (Tables VI-5 and VI-6). Total catch was composed of 72.3% Coho Salmon (3,953 total; 69.5% ad-clipped; 47.5% jack salmon), 17.6% Chinook Salmon (960 total; 50.3% ad-clipped; 19.5% jack salmon), and 10.1% Steelhead (554 total; 67.1% ad-clipped; 36.8% B-run (> 78cm)) (Figure VI-2). In addition to salmonid catch, White Sturgeon (1 total), Largescale Sucker, Peamouth, Largemouth Bass, Northern Pikeminnow, Starry Flounder, and Pumpkinseed were occasionally encountered throughout the study period.

Table VI-5. Total salmon harvested and released at the fish trap between Aug. and Nov. 2020.

SALMON ENCOUNTERED

Species		**Adults**			**Jacks**			**Total**
		Marked	Unmarked	Unknown	Marked	Unmarked	Unknown	
Coho	Harvested	1,268	0	0	0	0	0	1,268
	Released	37	770	0	1,444	434	0	2,685
Chinook	Harvested	377	0	0	0	0	0	377
	Released	29	367	0	77	110	0	583
Chum	Released	0	0	0	0	0	0	0
Pink	Released	0	0	0	0	0	0	0
Total		1,711	1,137	0	1,521	544	0	4,913

Table VI-6. Total Steelhead released at the fish trap between Aug. and Nov. 2020.

STEELHEAD ENCOUNTERED

Species		**Adults**			**Total**
		Marked	Unmarked	Unknown	
A-Run (<78 cm)	Released	210	140	0	350
B-Run (>78 cm)	Released	162	42	0	204
Unknown Size	Released	0	0	0	0
Total		372	182	0	554

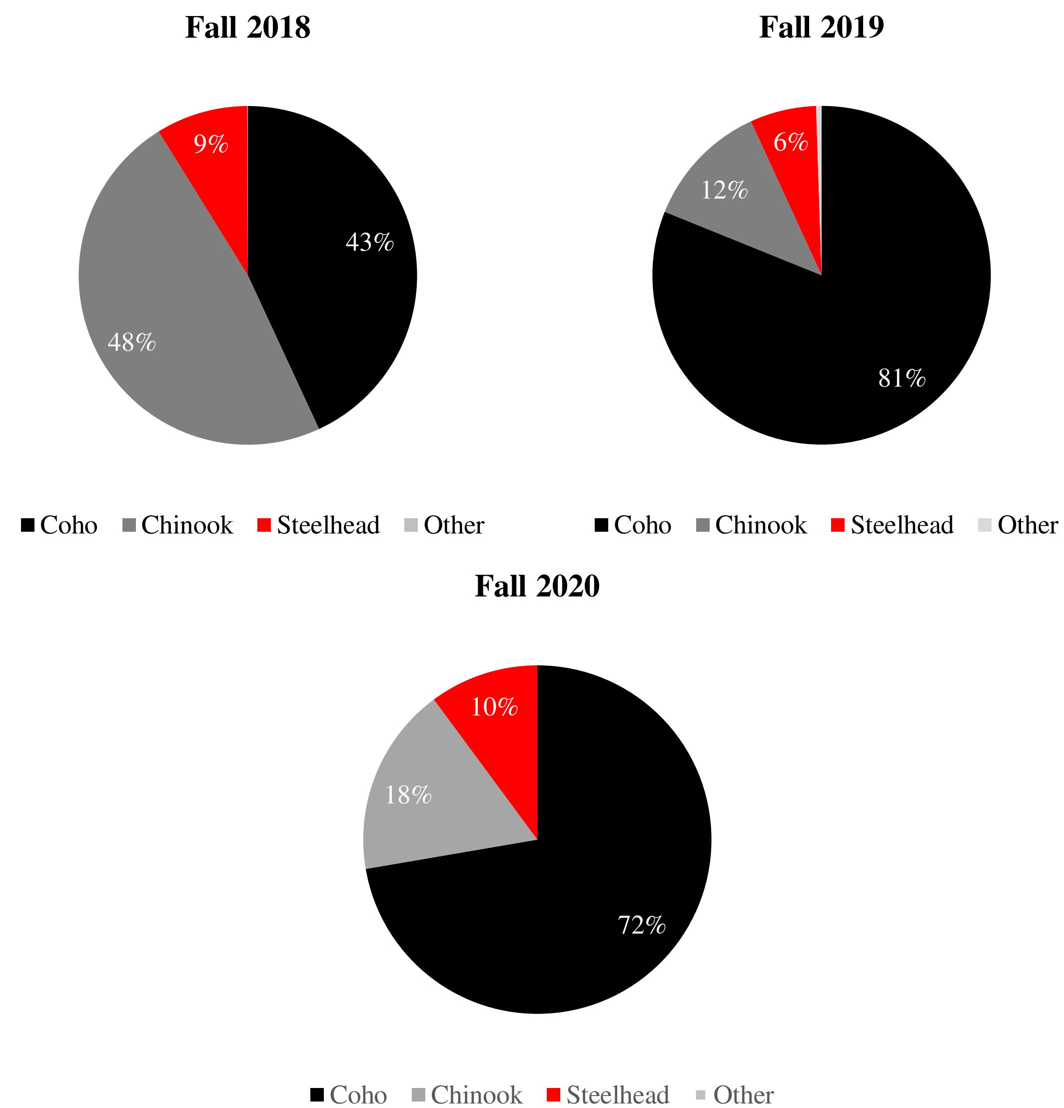

Figure VI-2. Composition of catch by species in 2018-2020 salmon trap fisheries.

Stock-Specific Exploitation

Adjusted for the number of hours operated in each bi-weekly period (Figure VI-1), the species-specific proportion of the total return encountered differed between 2018-2020 fisheries. Although the trap consistently functioned most effectively for capture of the Coho Salmon run in each year of operation, 2019 catch of the Chinook Salmon return was dramatically less than that of 2018 and 2020. Furthermore, catch of the Steelhead return was dramatically greater in 2020 relative to 2018-2019. Figures VI-3-VI-5 show annual and seasonal differences in the proportion of the total run size encountered for each species, adjusted for the total number of hours fished. Overall, 2019 operations were less effective at capturing the salmonid return than 2018 and 2020 operations during most seasonal periods. This highlights the site-specific nature of the gear and the sensitivity of catch efficiency to annual and seasonal differences in fish migration patterns.

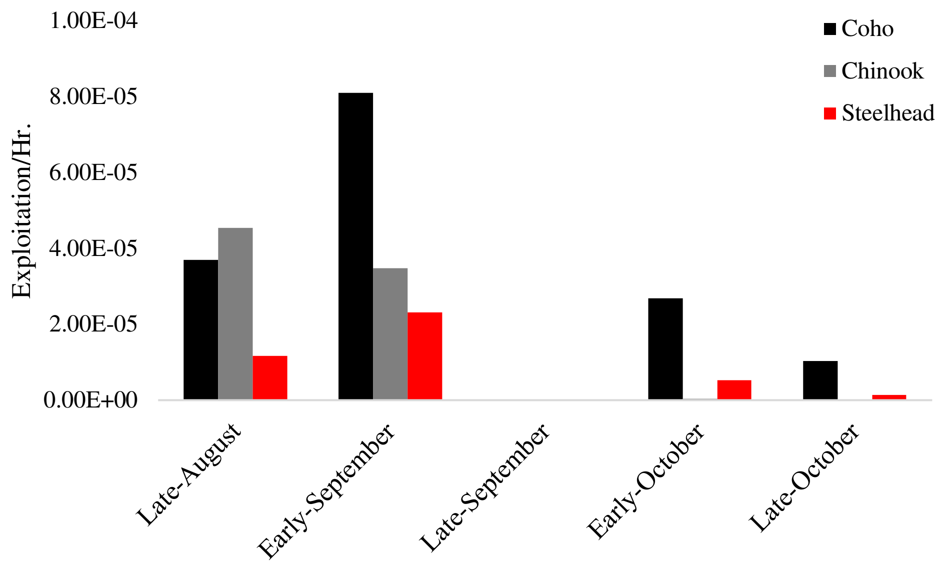

Figure VI-3. Species specific hourly exploitation rate of the 2018 salmonid return to the Columbia Basin by seasonal bi-weekly period. Note that no fishing occurred in the late-September fishing period.

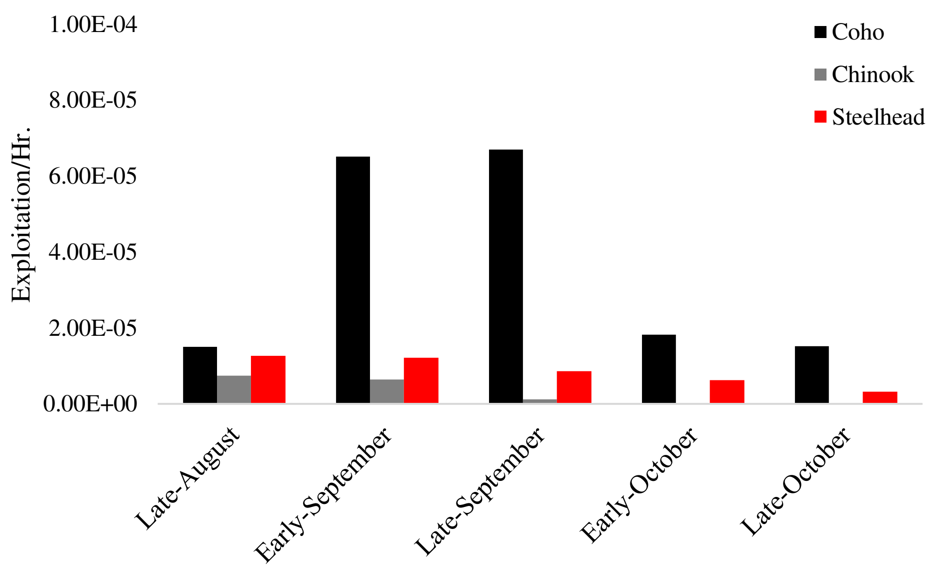

Figure VI-4. Species specific hourly exploitation rate of the 2019 salmonid return to the Columbia Basin by bi-weekly period.

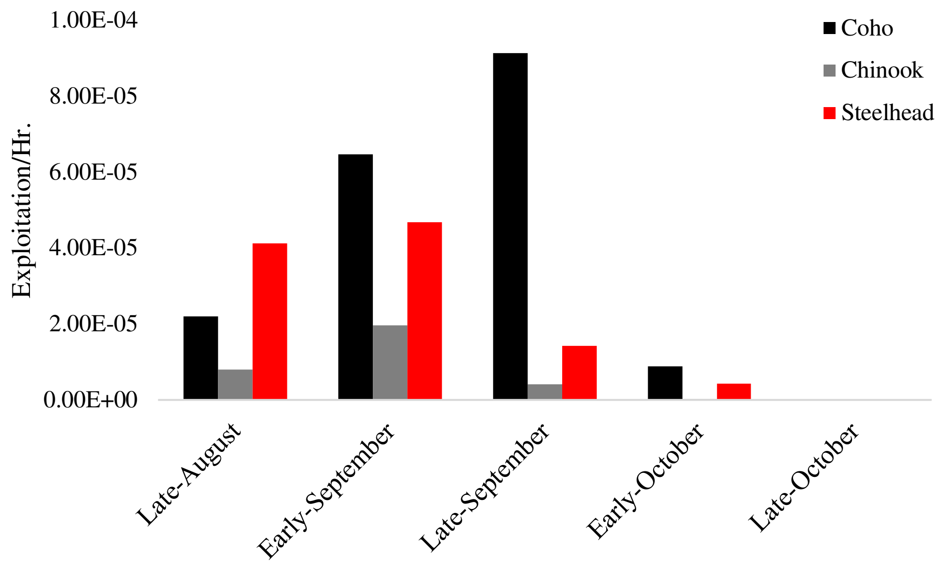

Figure VI-5. Species specific hourly exploitation rate of the 2020 salmonid return to the Columbia Basin by bi-weekly period. Note that no fishing occurred in late-October.

CPUE and Run-Timing

Salmonid run-timing at the trap site was similar between years of operation despite differences in stock-specific CPUE (species-specific catch of adults and jacks per operational hour). In 2018, Chinook Salmon were the most abundant species from late-August through early-September. Daily CPUE of Chinook Salmon peaked at 25.0/h on 30 August, and then again at 19.7/h on 9 September (mean = 6.7, SD = 6.9) (Figure VI-6). Coho Salmon were most abundant in mid-September, with daily CPUE peaking at 21.3/h on 13 September (mean = 6.6, SD = 5.8). Steelhead encounters were greatest in mid-September, with daily CPUE peaking at 4.9/h on 11 September (mean = 1.3, SD = 1.3).

In 2019, Coho Salmon were the most abundant species encountered from September through October, with daily CPUE peaking at 34.7/h on 10 September (mean = 8.9, SD = 7.6) (Figure VI-7). Relative to 2018, Chinook Salmon encounters were uncommon. CPUE of Chinook Salmon peaked at 6.9/h on 4 September (mean = 1.3, SD = 1.7). Steelhead were encountered most frequently in late-August and early-September, with daily CPUE peaking at 3.1/h on 29 August (mean = 0.7, SD = 0.6).

In 2020, Coho Salmon were the most abundant species encountered from September through October, with daily CPUE peaking at 68.1/h on 19 September (mean = 20.9, SD = 18.2) (Figure VI-8). Chinook Salmon were most abundant in late-August and early-September, with Chinook Salmon CPUE peaking at 15.8/h on 3 September (mean = 5.9, SD = 5.3). Similar to other years, Steelhead were encountered most frequently in late-August and early-September, with daily CPUE peaking at 7.0/h on 31 August (mean = 3.0, SD = 2.3). Steelhead encounters were uncommon in late-September and October.

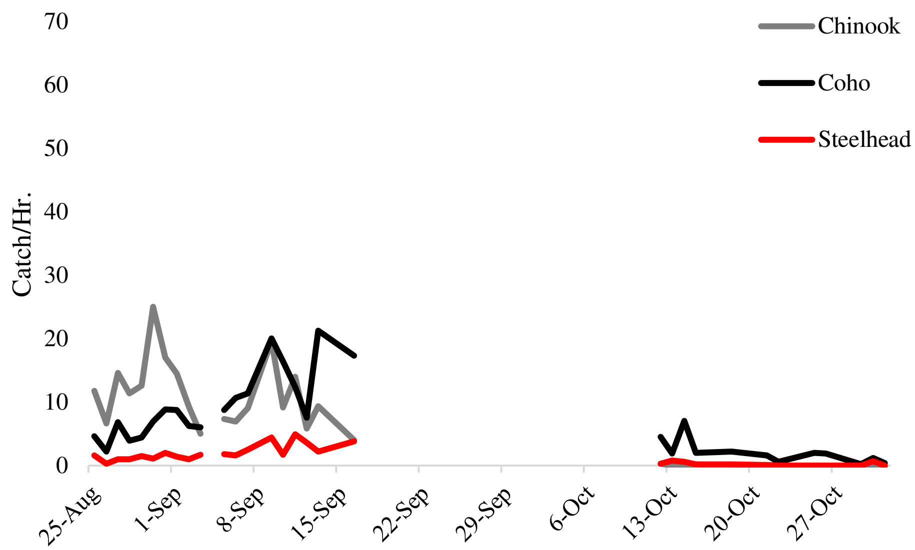

Figure VI-6. Salmon trap fishery catch per hour for Chinook, Coho, and Steelhead in 2018.

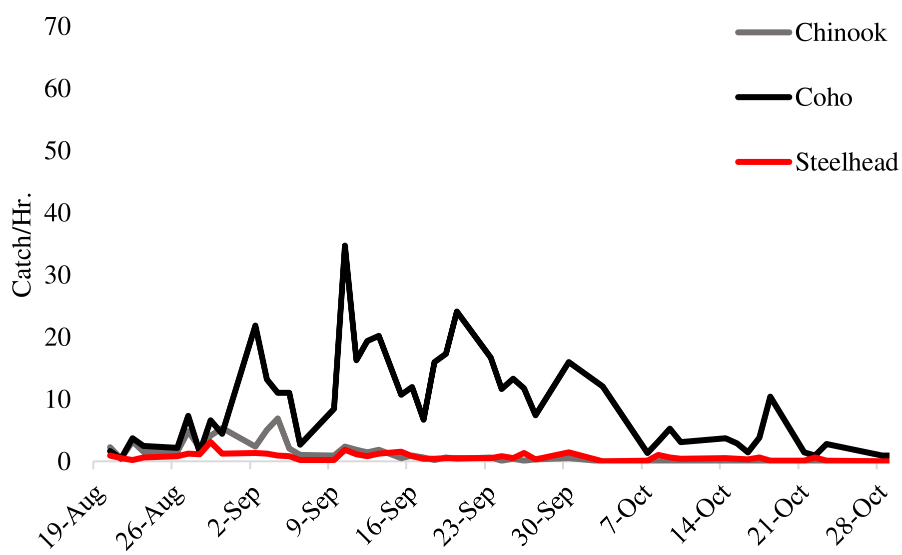

Figure VI-7. Salmon trap fishery catch per hour for Chinook, Coho, and Steelhead in 2019.

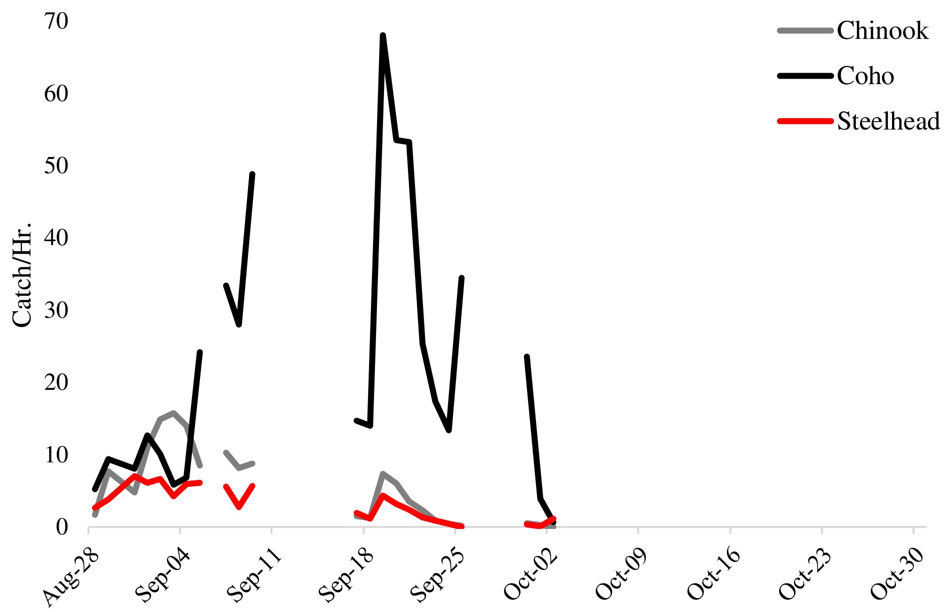

Figure VI-8. Salmon trap fishery catch per hour for Chinook, Coho, and Steelhead in 2020.

Immediate Survival

Throughout 2018-2020 late-summer and fall test fishery operations, there were zero immediate adult salmonid mortalities. From these results, the immediate adult mortality rate for all salmonid species was zero (immediate survival = 1.00) (Table VI-7; Table VI-8; Table VI-9). However, there were 11 total Coho Salmon jack mortalities (<30 cm) and 2 resident/residualized Rainbow Trout (<30 cm) mortalities as a result of wedging in the heart / jigger where the mesh size had not been reduced to 2-1/2''. Furthermore, there were 43 Largescale Sucker, 35 Pikeminnow, 17 Peamouth, and 10 Starry Flounder immediate mortalities from wedging or gilling in the 3-1/8'' knotted lead and jigger mesh.

Table VI-7. Immediate adult salmonid mortalities during the 2018 test fishery.

Species	Adults Captured	Adult Mortalities	Immediate Mortality	Immediate Survival
Coho	972	0	0.00	1.00
Chinook	1508	0	0.00	1.00
Steelhead (>50 cm)	325	0	0.00	1.00
Chum	2	0	0.00	1.00
Total	2,807	0	0.00	1.00

Table VI-8. Immediate adult salmonid mortalities during the 2019 test fishery.

Species	Adults Captured	Adult Mortalities	Immediate Mortality	Immediate Survival
Coho	3,521	0	0.00	1.00
Chinook	435	0	0.00	1.00
Steelhead (>50 cm)	314	0	0.00	1.00
O. Mykiss (<50 cm)	11	0	0.00	1.00
Cutthroat	7	0	0.00	1.00
Chum	5	0	0.00	1.00
Pink	2	0	0.00	1.00
Unknown Salmonid	1	0	0.00	1.00
Total	4,296	0	0.00	1.00

Table VI-9. Immediate adult salmonid mortalities during the 2020 test fishery. Note that additional research operations resulted in capture and release of an additional 134 Coho Salmon.

Species	Adults Captured	Adult Mortalities	Immediate Mortality	Immediate Survival
Coho	2,075	0	0.00	1.00
Chinook	773	0	0.00	1.00
Steelhead (>50 cm)	554	0	0.00	1.00
Total	3,402	0	0.00	1.00

Coho Salmon Post-Release Survival Results

Year: 2019

A short-term 48 h Coho Salmon holding study was conducted between 27 September and 30 October 2019. During the research period, water temperatures ranged from 19.2ºC to 12.1ºC (mean = 15.79ºC) (Table A-1). Encountering 3,521 adult Coho Salmon at the trap site in 2019, there were zero adult Coho Salmon immediate mortalities resulting in an immediate survival rate of $\hat{S}_0 = 1.000$ with a 95% lower confidence interval of CI ($S_0 \geq 0.999$) = 0.95 (Table VI-10). A total of 121 Coho Salmon were held in captivity post-release from the commercial gear in six separate sub-sample groups (Table A-1). Zero mortalities occurred during the 48 h holding period for a short-term post-release survival estimate of $\hat{S}_1 = 1.000$ (CI ($S_1 \geq 0.978$) = 0.95) (Table VI-10). All Coho Salmon encountered during the fish collection process for the 2019 holding study were lively and vigorous upon capture and release after 48 h, with zero fish appearing lethargic.

Year: 2020

Between 25 September and 15 October 2020, an intermediate 96 h net pen holding study was conducted. During the research period, water temperatures ranged from 19.3ºC to 16.7ºC (mean = 18.08ºC) (Table A-1). Encountering 2,209 adult Coho Salmon at the trap site in 2020 (note that this total includes fish captured during the test fishery and operations for research), there were zero adult immediate mortalities resulting in an immediate survival rate of $\hat{S}_0 = 1.000$ with a 95% lower confidence interval of CI ($S \geq 0.999$) = 0.95 (Table VI-10). A total of 105 Coho Salmon were held in captivity post-release from the commercial gear in three separate sub-sample groups (Table A-1). No mortalities occurred within the 48 h short-term holding period, nor did any mortalities occur during the 96 h intermediate holding period for post-release survival estimates of $\hat{S}_1 = 1.000$ (CI ($S_1 \geq 0.975$) = 0.95) and $\hat{S}_2 = 1.000$ (CI ($S_2 \geq 0.975$) = 0.95), respectively for short-term and intermediate holding periods (Table VI-10). All Coho Salmon encountered during the fish collection process for the 2020 holding study were lively and vigorous upon capture and release after 96 h, with zero fish appearing lethargic. However, the snout and caudal fins of all fish appeared moderately abraded upon release after 96 h of confinement in the net pen environment.

Table VI-10. Immediate and post-release survival of Coho Salmon was estimated between 2019 and 2021 with associated 95% profile likelihood confidence intervals.

Year	Survival estimate and 95% profile likelihood confidence interval				
	Immediate (0 h)	**Short-term (>0-48 h)**	**Intermediate (48-96 h)**	**Long-term (96-144 h)**	**Cumulative (0-144 h)**
2019	1.000 (0.999-1.000)	1.000 (0.978-1.000)	--	--	--
2020	1.000 (0.999-1.000)	1.000 (0.975-1.000)	1.000 (0.975-1.000)	--	--
2021	0.999 (0.997-0.9998)	0.995 (0.978-0.9997)	0.995 (0.978-0.9997)	0.974 (0.946-0.991)	0.964 (0.947-0.968)
Combined (2019-2021)	0.9997 (0.9992-0.99996)	0.998 (0.990-0.9999)	0.997 (0.986-0.9998)	0.974 (0.946-0.991)	0.969 (0.961-0.971)

Year: 2021

In 2021, a long-term 144 h net pen holding study was conducted earlier in the fall fishing season than prior years, with fish collection dates occurring between 3 September and 29 September. Throughout the research period, water temperatures ranged from 20.9ºC to 17.4ºC (mean = 19.22ºC) (Table A-1). Encountering 1,790 adult Coho Salmon at the trap site in 2021, there were two adult immediate mortalities from predator-induced injury, resulting in an immediate survival rate of $\hat{S}_0 = 0.999$ with a 95% confidence interval of CI ($0.997 \leq \widehat{immediate} \leq 0.9998$) = 0.95 (Table VI-10). A total of 200 Coho Salmon were held in captivity post-release from the commercial gear for a 48 h short-term duration in five separate sub-sample groups (Table A-1). One mortality occurred during the 48 h holding period for a short-term post-release survival estimate of $\hat{S}_1 = 0.995$ (CI ($0.978 \leq \widehat{short-term} \leq 0.9997$) = 0.95) (Table VI-10).

With one mortality occurring during the short-term 48 h holding period, a total of 199 Coho Salmon were held in captivity for the 96 h intermediate holding period in five separate sub-sample groups (Table A-1). Similar to the short-term holding period, one mortality occurred between 48 h and 96 h of confinement for an intermediate 96 h post-release survival estimate of $\hat{S}_2$ = 0.995 (CI ($0.978 \leq \widehat{intermediate} \leq 0.9997$) = 0.95) (Table VI-10).

Given the two total mortalities that occurred within the short-term and intermediate holding periods and removing two fish from the long-term sample due to pinniped predation within the holding pen, a total of 196 Coho Salmon were held in captivity for the 144 h long-term holding period in five separate sub-sample groups (Table A-1). Between 96 h and 144 h of confinement, five mortalities occurred. From these results, long-term post-release survival was estimated at $\hat{S}_3$ = 0.974 (CI ($0.946 \leq \widehat{long - term} \leq 0.991$) = 0.95). Cumulative survival in 2021 was estimated to be 0.964 (CI ($0.947 \leq \widehat{cumulative} \leq 0.968$) = 0.95) (Table VI-10).

Similar to prior years of study, all Coho Salmon encountered during the fish collection process for the holding study were lively and vigorous upon capture with no signs of physical injury related to the commercial gear. Those that survived the 144 h holding period to release also appeared lively and vigorous despite considerable abrasion to the snout and caudal fins from prolonged confinement in the net pen environment. Cause of death for the mortalities within this study could not be determined from autopsy, but likely were the result of the pooled effect of natural mortality, confinement in the net pen environment during lethal water temperature conditions (> 20°C) (Table A-1), and potential stressors from passive capture and research processes.

Marine Mammal Encounters

Marine mammal encounters have potential to damage fishing gear, delay commercial operations, and cause fish predation. During the 2018 fall season study, encounters with marine mammals varied. For the first 10 d of trap operations, there were no marine mammal encounters within the near vicinity of the project site. The first significant marine mammal encounter occurred on 4 September when a Stellar Sea Lion entered the heart of the trap. It was determined via snorkel and dive survey that scouring of substrate at the base of the heart piles was enabling entry of marine mammals below the heart netting. Since the net could not be extended in the midst of the 2018 season, marine mammals occasionally entered the heart of the trap on 8 separate days throughout the remainder of September. In October, heart entry points were addressed, and no further encounters occurred.

In 2019, there were no sea lions within the vicinity of the project site for the first 23 d of trap operations. The first significant encounter occurred on 12 September. Failure of the marine mammal deterrent gate during the first encounter event temporarily halted trap operations for a 2-h duration, after which, the mammal migrated upriver and fishing operations resumed without incident. The deterrent gate was repaired on 13 September and proved effective in deterring both Stellar Sea Lions and California Sea Lions for the remainder of fall season operations. Sea lions were observed outside of the heart and lead on occasion over 5 d between 12 and 18 September. After this mid-September operational week, only one additional sea lion was observed in the Cathlamet Channel near the project site on 10 October, presumably migrating downriver from Bonneville Dam.

In 2019, Harbor Seals were first observed in the Cathlamet Channel on 29 August. The species did not encounter the gear until 3 September when a seal was observed briefly entering and exiting the heart compartment. As in prior years of trap operation, the marine mammal deterrent gate proved mostly ineffective in preventing occasional entry of smaller-bodied harbor seals to the heart. After 19 September, two seals appeared daily within the vicinity of the project site and were observed entering and exiting the heart of the trap during operations. Unlike sea lions, Harbor Seals pose no threat to the fish trap gear. However, seals likely secure food resources with aid from commercial fishing gears such as the fish trap. Whether mammals would fail to feed in the absence of the fish trap remains unknown.

In 2020, there were no major sea lion encounters at the fish trap for the first half of the season through mid-September. One Harbor Seal was briefly documented at the trap on the 11th day of operation (9 September 2020). The seal encounter did not disrupt operations, damage gear, or result in any observed fish predation.

Once 2020 operations resumed after the wildfire smoke event in mid-September, there were two encounters with sea lions in which the mammals entered the heart of the trap due to operator error. In both of these situations, the heart panel was opened and the mammals departed in less than 5 minutes without any observed fish predation; after which, fishing resumed with the marine mammal gate deployed. Sea lions were also occasionally observed within the middle of the channel during this late-September fishing period, at a distance of 100 m or greater from the fish trap. Harbor Seals more frequently encountered the gear in late-September as well; nevertheless, no damage occurred to the gear, nor was any fish predation observed.

Economic Results

Selective Harvest and Revenue

Commercial test fishery operations occurred over 32 d during the late-summer and fall fishery in 2018. A total of 1,157 hatchery-origin salmon were selectively harvested, of which 44% were Coho Salmon (509 total; mean weight = 7.4 lbs.) and 56% were Chinook Salmon (648 total; mean weight = 11.3 lbs.). A total of 11,089 lbs. of salmon were harvested, consisting of 3,769 lbs. of Coho Salmon (100% Good Meat Color (GMC)) and 7,320 lbs. of Chinook Salmon (69% GMC) (Table VI-11). At the request of the processor, hatchery-origin jack salmon were frequently released due to their poor commercial value.

In 2019, commercial test fishing occurred over 36 d during the late-summer and fall fishery. A total of 2,016 hatchery-origin salmon were selectively harvested, of which 91% were Coho Salmon (1,830 total; mean weight = 5.8 lbs.) and 9% were Chinook Salmon (186 total; mean weight = 10.7 lbs.). A total of 12,652 lbs. of salmon were harvested, consisting of 10,666 lbs. of Coho Salmon (97.4% GMC) and 1,986 lbs. of Chinook Salmon (44% GMC) (Table VI-11). At the request of the processor, hatchery-origin jack salmon were frequently released due to their poor commercial value. Furthermore, ad-clipped adult Coho (379 total) and Chinook Salmon (59 total) that could have been harvested were released during operations due to scheduling limitations with WDFW commercial sampling crews and other project partners.

In 2020, commercial test fishing occurred over 25 d during the late-summer and fall fishery. A total of 1,645 hatchery-origin salmon were selectively harvested, of which 77% were

Coho Salmon (1,268 total; mean weight = 7.7 lbs.) and 23% were Chinook Salmon (377 total; mean weight = 13.0 lbs.). A total of 14,610 lbs. of salmon were harvested, consisting of 9,711 lbs. of Coho Salmon (100% GMC) and 4,899 lbs. of Chinook Salmon (54% GMC) (Table VI-11). At the request of the processor, hatchery-origin jack salmon were released due to their poor commercial value. Furthermore, smaller-bodied hatchery adult Coho Salmon and Chinook Salmon that could have been harvested were occasionally released during operations at the request of the processor.

Table VI-11. Revenue generated from the sale of harvested hatchery-origin Coho Salmon and Chinook Salmon in 2018-2020. The test fishery accepted Columbia River gill net market prices in 2018-2019, but achieved added ex-vessel value in 2020.

	2018			**2019**			**2020**		
	Price	**Lbs. Harvested**	**Revenue**	**Price**	**Lbs. Harvested**	**Revenue**	**Price**	**Lbs. Harvested**	**Revenue**
Coho Salmon	$1.50	3,400	$5,100	$2.00	307	$614			
	$1.85	369	$683	$1.80	10,090	$18,162	$1.70	9,711	$16,509
				$0.55	269	$148			
	Total	**3,769**	**$5,783**	**Total**	**10,666**	**$18,924**	**Total**	**9,711**	**$16,509**
Chinook Salmon	$3.50	5,078	$17,773	$2.75	897	$2,467	$3.75 $3.25	2,646	$8,799
	$0.60	2,242	$1,345	$0.55	1,089	$599	$0.50	2,253	$1,127
	Total	**7,320**	**$19,118**	**Total**	**1,986**	**$3,066**	**Total**	**4,899**	**$9,926**
Total		**11,089**	**$24,901**		**12,652**	**$21,990**		**14,610**	**$26,435**

All fish harvested between 2018 and 2020 were sold by WDFW to C&H Fish Company (Cathlamet, WA). Revenue generated by WDFW from mark-selective test fisheries was calculated for each stock harvested (Table VI-11). Salmon prices differed by year and season. Furthermore, prices varied based upon good (GMC) or poor meat color (PMC), with salmon in a later state of maturity being valued lower (Table VI-11).

In 2018, total revenue from the harvest and sale of hatchery-origin fish was approximately $24,900.85, with over 97% of total revenue generated in the 20 d period from August and September ($24,219.20; $1,210/d) (Table VI-11). The majority of revenue generated in the 2018 test fishery was from the harvest of GMC Chinook Salmon ($17,773; 5,078 lbs.), followed by early-season Coho Salmon ($5,100; 3,400 lbs.), PMC Chinook Salmon ($1,345; 2,242 lbs.), and late-season Coho Salmon ($683; 369 lbs.).

In 2019, total revenue was approximately $21,989.65 with 84% of total revenue generated in the 24 d period between August and September ($20,072.10; $836/d). In contrast with 2018, most of the revenue generated in the 2019 test fishery was from the harvest of Coho Salmon ($18,923.95; 10,666 lbs.) (Table VI-11).

In 2020, total revenue was approximately $26,435 over the 25 d test fishing period, with 99% of revenue generated over 21 d in August and September ($1,245/d). Approximately 62% of total revenue generated in the 2020 test fishery was from the harvest of Coho Salmon, with 38% generated from Chinook Salmon (Table VI-11). It is worth noting that Chinook Salmon prices received in 2020 exceeded that of the conventional gill net fishery (PFMC 2021) and revenue generated per fishing day increased relative to 2018-2019 test fisheries. Significant demand from high-end restaurants in the Seattle area was generated in 2020, with James Beard award winning Chef Renee Erickson promoting the "unparalleled quality and sustainability" of trap-caught fish. Erickson stated that she was willing to pay $6.50 – 9.00/lb for Coho and $16.50 – 19.00/lb for Chinook Salmon (Personal Communication, October 2020). Furthermore, she expressed interest in purchasing Coho Salmon jacks in future fishing seasons.

Added Value Revenue Projection

Investigating the potential for added value, WA coast troll prices for Chinook Salmon (8-11 pounds) and Coho Salmon for the month of September were applied to GMC Chinook Salmon and Coho Salmon lbs. harvested in 2018-2020 test fisheries (PFMC 2019, 2020, 2021). Since there is no troll market equivalent to Chinook Salmon or Coho Salmon landed in a later state of sexual maturity (PMC), added-value prices were not considered in this exercise. Given troll market prices, the fishery could have added approximately $24,293 in value in 2018, generating an estimated $49,194 in revenue. In 2019, the fishery could have added approximately $16,173 in value, totaling $38,163 in revenue (Table VI-12). In 2020, the fishery could have added approximately $23,694 in value, totaling $50,129 in revenue (Table VI-12).

Table VI-12. Projected revenue from securing WA coast troll market prices (PFMC 2019, 2020, 2021).

	2018			2019			2020		
	Price	Lbs. Harvested	Revenue	Price	Lbs. Harvested	Revenue	Price	Lbs. Harvested	Revenue
Coho Salmon	$2.86	3,769	$10,779	$3.13	10,397	$32,543	$3.12	9,711	$30,298
				$0.96	269	$258			
	Total	**3,769**	**$10,779**	**Total**	**10,666**	**$32,801**	**Total**	**9,711**	**$30,298**
Chinook Salmon	$7.30	5,078	$37,069	$5.31	897	$4,763	$7.07	2,646	$18,704
	$0.60	2,242	$1,345	$0.55	1,089	$599	$0.50	2,253	$1,127
	Total	**7,320**	**$38,415**	**Total**	**1,986**	**$5,362**	**Total**	**4,899**	**$19,830**
Total		**11,089**	**$49,194**		**12,652**	**$38,163**		**14,610**	**$50,129**

Estimated Capital Costs

Fish trap capital costs will vary depending on materials chosen, site-specific river bathymetry, lead length, complexity of the trap design, and fluctuations in market prices for materials and labor. Estimated low-end costs of trap construction—including engineering, permitting, pile driving, dock construction, net construction, and all winches, solar, platforms, and hardware expenses—total $102,370 (Table VI-13). The low-end cost estimate was determined by review of realized costs associated with 35 untreated piles and quoted costs of materials needed for a passive fishing single pot design (Figure VI-9) similar in size to the prototype fish trap in Cathlamet Channel, WA. Estimated high-end costs of trap construction—including engineering, permitting, pile driving, dock construction, net construction, and all winches, solar, platform, and hardware expenses—total $150,394 (Table VI-13). The high-end cost estimate was generated after review of realized costs associated with 46 untreated steel piles and quoted costs of materials needed for a passive double pot trap design (Figure VI-9). Skiff price was set to ODFW's estimated value of a Columbia River gillnet vessel, $25,000 (ODFW 2013).

Table VI-13. Estimated capital costs include all elements of trap construction, including skiff purchase, but excluding annual trap deployment.

a. UPFRONT CAPITAL COSTS	*Low-End Estimate (Single Pot - 35 Piles)*	*High-End Estimate (Double Pot - 46 Piles)*
Consulting / Engineering / Permitting	$7,000	$7,000
Pile Driving	$58,278	$81,820
Docks/Live Well	$14,754	$29,508
Navigation Lights	$1,009	$1,009
Net Construction	$16,264	$20,240
Winches	$789	$1,578
Solar	$455	$910
Deployment Poles / Hardware	$2,343	$0
Pipe Clamps	$0	$696
Diver	$0	$1,000
Catwalk / Platforms	$425	$5,093
Line / Hardware	$1,053	$1,540
Total	$102,370	$150,394
Skiff	$25,000	$25,000
TOTAL UPFRONT COSTS	$ 127,370	$ 175,394

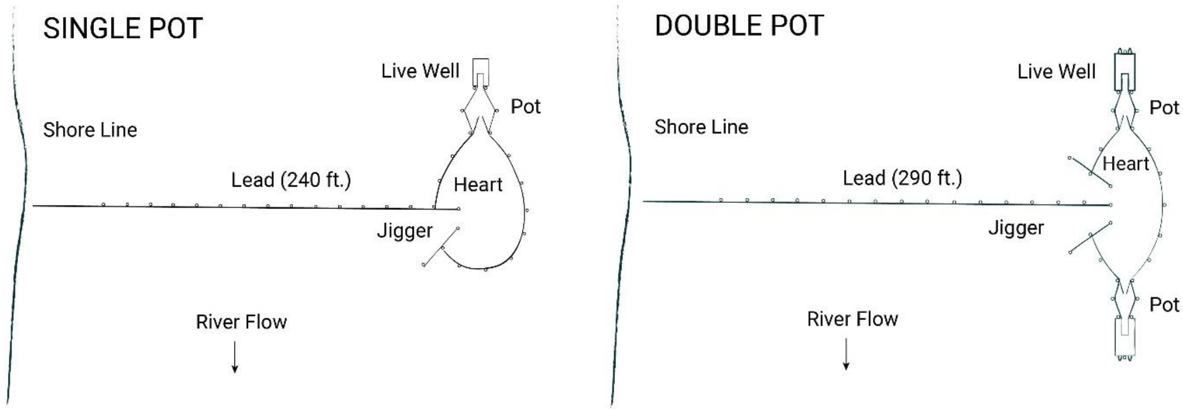

Figure VI-9. Sketch of a single pot passive design (left) and double pot passive design (right).

Annual Costs

Total annual costs of a 20 d commercial trapping operation excluding labor inputs were estimated at $6,515 (Table VI-14). Costs were split between fixed costs and variable costs. Estimated annual fixed costs totaled $4,836 and included fees for miscellaneous supplies (e.g., replacement hardware, lumber, steel cable, rope), skiff fuel, potential skiff repairs, skiff launch/moorage, permits, licenses, insurance, and annual land-use fees. These fixed costs can only be avoided if a fisher chooses not to participate in the fishery (due to run size forecasts, limited allocation, or other issues). Estimated variable costs for a 20 d fishing period totaled $1,679 and were associated with daily fees for ice and skiff fuel. Once a fish trap is constructed, these variable costs are incurred with each day of harvest and delivery.

Table VI-14. Estimated fixed, variable, and total costs for a salmon trap fisher over a 20 d commercial fishing period excluding the costs of labor.

b1. ANNUAL FIXED COSTS	*Rate*	*Quantity*	*Costs*
Misc. Hardware	--	--	$800
Permits and Licenses	$750	1	$750
Insurance	$2,000	1	$2,000
Annual Land Use Fee	$500	1	$500
Moorage	$110	1	$110
Fuel for Construction / Deconstruction	$17.60	10	$176
Boat Maintenance	--	--	$500
TOTAL ANNUAL FIXED COSTS			$4,836
b2. ANNUAL VARIABLE COSTS	*Daily Rate*	*Quantity*	*Costs*
Fuel	$12.50	20	$250
Ice	$71.43	20	$1,429
TOTAL DAILY MARGINAL COSTS			$84
TOTAL ANNUAL VARIABLE COSTS			$1,679
TOTAL ANNUAL NON-LABOR COSTS			$6,515

Annual Labor Requirements

Total cumulative labor needed for a 20 d commercial operation was estimated at 80 ten-hour days (Table VI-15). Labor was split between fixed labor needs and variable labor needs. Annual fixed labor totaled 30 ten-hour days, including onsite construction and net deployment, on-site deconstruction and net removal, and off-site end-of-season gear maintenance. These fixed labor needs can only be avoided if a fisher chooses not to participate in the fishery (due to run size forecasts, limited allocation, or other issues). Annual variable labor for a 20 d fishing season totaled 50 ten-hour days. It was assumed that during 10 days of peak fishing, a permit holder would operate with two deckhands, accounting for 30 days of cumulative labor. For the remaining 10 days of off-peak fishing, it was assumed that a permit holder would operate with a single deckhand, accounting for 20 days of cumulative labor. Total wage earnings for deckhands would then be dependent on percentages paid out from total profits (revenue - cost).

Table VI-15. Estimated fixed, variable, and total labor needs for a salmon trap fisher over a 20 d commercial fishing period.

c1. ANNUAL FIXED LABOR ESTIMATE	*Rate*	*Days*	*Wages*
Labor: On-Site Construction / Net Deployment			
Lead Fisher - Permit Holder	***	5	***
Deckhand #1	***	5	***
Deckhand #2	***	5	***
Labor: On-Site Deconstruction / Maintenance			
Lead Fisher - Permit Holder	***	5	***
Deckhand #1	***	5	***
Deckhand #2	***	5	***
TOTAL ANNUAL FIXED LABOR	***	30	***

c2. ANNUAL VARIABLE LABOR ESTIMATE	*Rate*	*Days*	*Wages*
Labor: On-Site Construction / Net Deployment			
Lead Fisher - Permit Holder	***	20	***
Deckhand #1	***	20	***
Deckhand #2	***	10	***
TOTAL ANNUAL VARIABLE LABOR	***	50	***
TOTAL ANNUAL LABOR		80	***

Estimated Annual Earnings

Estimated annual earnings were achieved by reviewing revenue generated at the prototype fish trap in Cathlamet, WA during test fishing operations conducted in 2018, 2019, and 2020. Revenue from harvested hatchery Coho Salmon and Chinook Salmon during 20 days of late summer / early fall fishing (Aug-Sep) was averaged across the three seasons resulting in a mean seasonal revenue of $21,946 for a 20 d season (Table VI-16). Subtracting the annual

$6,515 costs associated with a 20 d fishing season, a total of $15,431 remain. Dividing this remainder evenly across the labor inputs results in average earnings of $192.89 per 10 h work day, per individual (Avg. Wage = $19.29/h. for all hours of work during deployment, fishing, and post-season maintenance). During the 2018, 2019, and 2020 fishing seasons, sale prices of Coho Salmon and Chinook Salmon harvested at the fish trap were set at or near the lower river gill net price, failing to adequately represent the meat quality and value-added practices reflected in the annual variable costs. When conservative value-added prices quoted from the fish buyer (Personal Communication, 2021) are applied to 20 days of late summer / early fall fishing for each season, and then averaged across the three years of test fishing, the result is an increased mean revenue of $32,356 per season (Table VI-16). Subtracting the annual $6,515 costs associated with a 20 d fishing season, a total of $25,841 remain. Dividing this remainder evenly across the labor inputs results in average earnings of $323.01 per 10 h day, per individual (Avg. Wage = $32.30/hr. for all hours of work during deployment, fishing, and post-season maintenance).

Table VI-16. Average revenue from 20 days of late summer / early fall test fishing in 2018, 2019, and 2020 with achieved prices and conservative value-added prices. *Conservative value-added prices set at, GMC Chinook - $4.50, PMC Chinook - $0.70, Coho - $2.50.*

d1. AVG. TEST FISHING REVENUE (2018 - 2020)	
20 Day Season (Realized Prices)	$21,946
Fisherman's Annual Cost	$6,515
Revenue Remaining	$15,431
Fixed Labor (Deployment, Removal, Maintenance)	30 Days
Variable Labor (Fishing)	50 Days
Average Daily Rate (Permit Holder & Deckhands)	$192.89

d2. AVG. TEST FISHING REVENUE (2018 - 2020) VALUE ADDED	
20 Day Season (Conservative Value Added Prices)	$32,356
Fisherman's Annual Cost	$6,515
Revenue Remaining	$25,841
Fixed Labor (Deployment, Removal, Maintenance)	30 Days
Variable Labor (Fishing)	50 Days
Average Daily Rate (Permit Holder & Deckhands)	$323.01

Catch Comparison to Tangle Net Fleet

Total catch and CPUE of hatchery-origin Chinook Salmon and Coho Salmon were analyzed for an 8 d period in which fish trap and tangle net operations overlapped in Zones 1-3 of the lower Columbia River in 2019 (ODFW 2019). Tables VI-17 and VI-18 summarize the results for each gear-type in the fall fishery. During this period, the fish trap outperformed the mean tangle net fisher for catch of hatchery-origin adult Coho Salmon by a factor of 2.31.

Although the fish trap captured few Chinook Salmon during the fall 2019 season, the trap outperformed the mean tangle net fisher by a factor of 1.98 for combined catch of hatchery-origin Coho Salmon and Chinook Salmon (Figure VI-10). Analyzing CPUE (catch/hr.), the fish trap more than tripled the efficiency of the mean tangle net fisher ($CPUE_{trap}$ = 4.3; $CPUE_{tanglenet}$ = 1.3). It must be noted, however, that the period for comparison between gears was minimal and further investigation of capture effectiveness is warranted.

Table VI-17. Fish trap total catch of hatchery-origin adult salmon and CPUE (catch/hr.) during overlap with the fall tangle net fishery in 2019.

Date	Effort	Coho Captured	Chinook Captured	Combined Catch	CPUE (Catch/hr.)
30-Sep	6.3	79.0	1.0	80.0	12.6
7-Oct	9.2	10.0	0.0	10.0	1.1
9-Oct	8.2	36.0	0.0	36.0	4.4
14-Oct	6.4	21.0	0.0	21.0	3.3
16-Oct	11.0	9.0	0.0	9.0	0.8
18-Oct	8.7	73.0	0.0	73.0	8.4
21-Oct	7.5	11.0	0.0	11.0	1.5
23-Oct	9.0	17.0	0.0	17.0	1.9
Mean	**8.3**	**32.0**	**0.1**	**32.1**	**4.3**

Table VI-18. Mean tangle net fisher catch of hatchery-origin adult salmon and CPUE (catch/hr.) during overlap with salmon trap operations in 2019.

Date	Effort	Coho Captured	Chinook Captured	Combined Catch	CPUE (Catch/hr.)
30-Sep	12.0	18.6	9.4	28.0	2.3
7-Oct	12.0	9.8	2.2	12.0	1.0
9-Oct	12.0	13.4	2.5	15.8	1.3
14-Oct	12.0	9.6	1.4	11.0	0.9
16-Oct	12.0	12.8	1.2	13.9	1.2
18-Oct	14.0	18.8	1.5	20.3	1.5
21-Oct	14.0	12.5	0.7	13.3	0.9
23-Oct	14.0	14.9	0.4	15.3	1.1
Mean	**12.8**	**13.8**	**2.4**	**16.2**	**1.3**

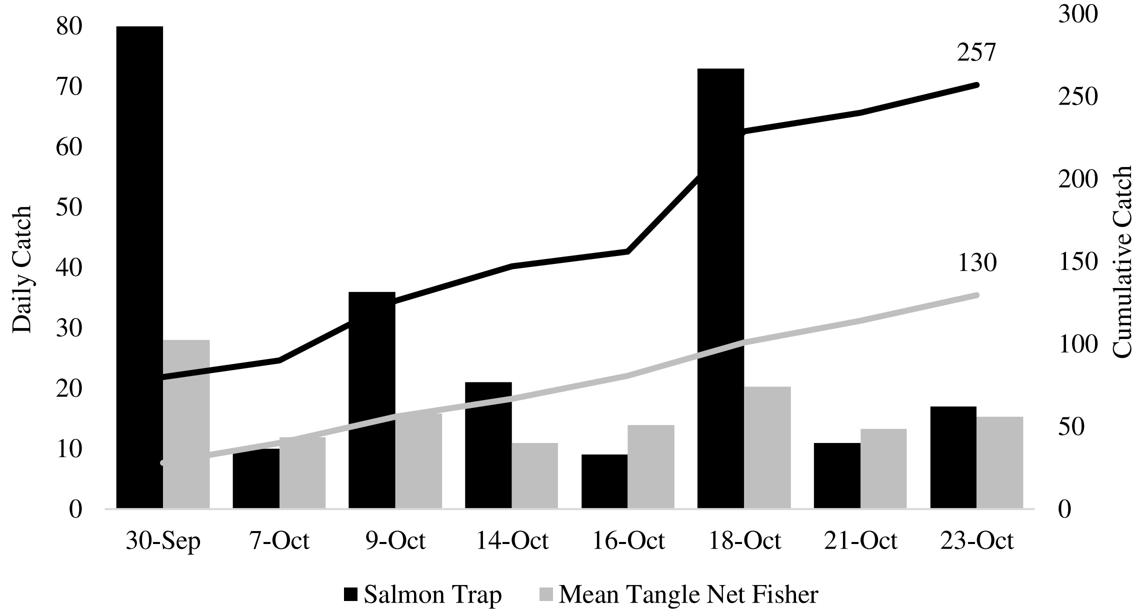

Figure VI-10. Total combined catch of hatchery-origin Chinook Salmon and Coho Salmon for the mean tangle net fisher and the salmon trap during days of overlap in the fall fishery.

B. Actual Accomplishments and Findings – Other Project Results

Emerging Commercial Fishery Process

Having demonstrated research and test fishery success from 2016-2019, WDFW initiated the Emerging Commercial Fishery process to potentially legalize salmon trap (pound net) gear at a broader scale for selective commercial harvest in the lower Columbia River in the fall of 2019 (RCW 77.65.400). This WDFW effort was at the direction of policy C-3620, which encourages implementation of more techniques to harvest hatchery-origin fish, while reducing impacts to wild fish (WFWC 2013). An Emerging Commercial Fishery designation functions to legalize "the commercial taking of a classified species with gear not previously used for that species" (RCW 77.65.400). Participation is limited through RCW 77.70.160 in an Emerging Commercial Fishery in order to ensure the "preservation and protection of the state's food fish and shellfish resources" as additional scientific information are gathered to inform future management of the expanding fishery (1990 c 63 § 1).

In preparation for an Emerging Commercial Fishery designation from the Director, WDFW appointed a five-person advisory board representative of the affected fishery industry in accord with RCW 77.70.160. This advisory board was tasked with developing rules for limiting issuance of experimental fishery permits in an Emerging Commercial Fishery by reviewing relevant information and making recommendations to the Director.

To form the advisory board, WDFW submitted letters to the affected industry in the fall of 2019 to identify willing participants. Five WA State Columbia River gill netters were appointed to the board by the Director: Mike Clark, Bryce Devine, Greg Johnson, Jon Blair Peterson, and Ken Wirkkala (WDFW 2020). Meetings occurred monthly beginning in November 2019 to discuss the legalization of alternative gears (specifically pound net traps, purse seines, and beach seines) and make recommendations regarding rules for issuance of experimental fishery permits.

In June 2020, WDFW decided to postpone potential implementation of the Emerging Commercial Fishery due to early season forecasts for a poor wild Steelhead return to the Columbia River and allocation constraints. Nevertheless, the Emerging Commercial Fishery advisory board was once again reassembled for monthly meetings starting in November 2020 to discuss a potential path forward for implementing alternative gears in 2021-2022.

Conclusions of 2020-2021 advisory board meetings and research results encouraged WDFW staff to formally recommend to the Director that the Emerging Commercial Fishery Designation proceed throughout 2021 to officially legalize fish traps at a localized-scale. In April 2021, the Director issued a formal statement on his decision to advance the fish trap legalization process through the Emerging Commercial Fishery designation in the lower Columbia River (WDFW 2021). In his announcement, the Director stated that the designation was "just the beginning of a much longer process toward potential wider adoption of these alternative gears" (WDFW 2021). As further information is collected during the Emerging Commercial Fishery trial period, WDFW (2021) notes that "fishery managers will prepare a report to the Washington Legislature and, if warranted, request changes to existing statutes that prohibit the use of these gear types in the river".

Sustainable Market Certification

WFC coordinated with Marine Stewardship Council (MSC) and Monterey Bay Aquarium Seafood Watch (MBASW) during the S-K project to initiate recognition of the emerging salmon trap fishery. This effort was made to achieve a future sustainable market certification or 'green label' for the gear upon broader-scale implementation of fish traps in Washington State. Prior to the fishing season, WFC distributed outreach materials, research findings, and invitations for site visits to MSC and MBASW.

On 16 September 2019, MSC toured the project site with members of the working group to better understand the functionality of the tool for selective harvest. A follow-up meeting was conducted on 25 November to investigate a path forward for MSC certification. With encouragement from MSC, WFC is now seeking funding for the MSC pre-assessment process to certify the emerging trap fishery.

WFC presented to MBASW in Monterey, CA on 9 December 2019. This presentation focused on fish trap research findings and the potential implications of WDFW's Emerging Commercial Fishery process. MBASW verbally agreed to consider rating the fish trap gear as they undertake review of west coast salmon fisheries, assuming the gear is legalized.

Although the Director of WDFW has announced the Emerging Commercial Fishery will be implemented and fish traps legalized for use in the lower Columbia River, the process to formally authorize the gear within the commercial fishery is not expected until the fall of 2022. Ecolabeling through MBASW remains a priority of WFC moving forward and the likelihood of a green label certification is expected to increase as the Emerging Commercial Fishery process nears completion.

Working Group Conclusions: Evaluation of the Test Fishery

Before, during, and after the 2018-2020 test fisheries, working group meetings were conducted with representatives from WFC (contacts: Adrian Tuohy, Aaron Jorgenson, Kurt Beardslee, Jamie Glasgow), WDFW (contacts: Lisa Harlan, Ryan Lothrop, Ronald Reeves, William Tweit), and the commercial fishing industry (contacts: Blair Peterson, Mike Clark, Billie Delaney, Ben Cramer) to direct the research and marketing project. All research activities were reviewed by the UW Columbia Basin Research Lab (contact: Dr. John Skalski). Prior to initiation of the fishing season, discussions were held on 19 February, 3 April, 7 August, and 15 August 2019 to determine the potential duration of the commercial test fishery, weekly fishing effort, field protocol for research and commercial sampling, and the marketing plan. In 2020, conference calls were scheduled to discuss research and marketing plans due to the Covid-19 pandemic.

Throughout each test fishing season, meetings were held at the conclusion of daily operations to adaptively manage the fishing and marketing strategy based on the successes or failures experienced each day. In between fishing weeks and at the conclusion of the fishing season in 2019, meetings were held on 3 October, 12 November, and 19 February to discuss next steps for fish trap research, commercial implementation, and marketing. With the Covid-19 pandemic continuing through 2020, conference calls were held at the completion of the fishing season to discuss successes, failures, and next steps.

Between 2018-2020, the working group members generally concluded that the fish trap translated well to a commercial, selective-harvest setting. The fishers (Blair Peterson, Mike Clark, Billie Delaney), processors (C&H Fish Company), and buyers (C&H Fish Company, J&B Sales) involved in the project commented on the ease of trap operation for mark-selective harvest, the low-impact nature of the gear for successful release of bycatch, and the quality of seafood products harvested with the capture method. All working group members have commented on the potential of a trap fishery to secure substantial added value from future branding, marketing, advertising, and sustainable market certification. All working group members have also commented on the potential for additional engineering advancements to increase gear efficiency, further reduce bycatch mortality rates, and reduce bycatch encounters.

The primary concerns of the working group after three years of commercial operation regard annual variation in catch composition, unmarked Steelhead encounters, upfront costs of building a fish trap, permitting challenges, community acceptance of an alternative gear transition, future allocation of fishery impacts, and consistency in state management direction for alternative gears.

Trap Fishery Successes

- Ease of gear operation – The trap requires minimal effort or labor to operate. The tool can actively fish while sorting of the catch occurs. Labor necessary for operations can be adjusted based upon the daily run encountered, requiring anywhere from 1-3 individuals.
- Low-carbon footprint - The trap is powered by a 12-v car battery that is solar charged, almost eliminating the need for fossil fuels.
- Ability to release bycatch unharmed and selectively harvest hatchery fishes - Bycatch appear in excellent condition at capture and release and data show that post-release survival is very high, enabling fishers to effectively release ESA-listed fishes and selectively harvest only hatchery-origin fishes. Data collected for the gear suggests that implementation and transition toward fish traps could function to improve escapement of wild salmon stocks and reduce the percentage of hatchery origin spawners (pHOS).
- High likelihood of sustainable market certification – Site visits, meetings, and presentations were given to MSC and MBASW. Both certifiers commented on the potential for certification or a green label for the fish trap gear. In particular, MBASW stated that it would consider rating the gear as they undertake review of west coast salmon fisheries. Legalization of the gear should increase the likelihood of a green label certification in the coming years.
- High product quality - All fish harvested are in nearly pristine condition, with little scale-loss, bruising, net marks, gaping of the meat, or damaged egg skeins. Industry experts believe there is potential to secure troll market prices or greater with appropriate marketing, branding, and advertising.
- 'Wild Salmon Safe' branding - Since the trap can effectively release wild salmon unharmed, the fishery can be branded for sustainability to increase product value.
- 'Orca Whale Safe' branding - Since the trap fishery operates in-river rather than in the marine environment, operations do not diminish Chinook Salmon resources for ESA-listed orca whales. Sale of Chinook Salmon has become increasingly challenging due to orca whale recovery concerns in the Pacific Northwest. Fish trap marketing strategies in 2019-2020

showed promise to address the marketing problem and spur significant demand from high-end restaurants and markets in the region for trap-caught seafood products.

- Added-value potential – There is considerable potential for added-value due to exceptional product quality, high likelihood for sustainable market certification, and the ability to brand the gear 'wild salmon and orca safe'. Working group members believe the gear can secure troll market prices or greater once a reputation for the product is established.

Test Fishery and Implementation Concerns

- Site-specific nature of the gear - Catch of Chinook Salmon decreased dramatically in 2019 despite an increase in run size (suggesting a change in river migration patterns); annual variation in species specific catch and harvest revenue demonstrates the limitation of a fixed-gear as the tool cannot be shifted in-season to account for changes in fish migration patterns.
- Unmarked Steelhead encounters - Relative to other gears, it appears that the Steelhead encounter rate with the fish trap may be high. However, these investigations only analyzed one trap site in the river, and preliminary data from a separate site in Clifton Channel, lower Columbia River, OR suggests that Steelhead encounters may differ dramatically depending on river location. The working group encourages investigations of fish trap designs in other river locations where bycatch encounters may differ due to location or design. There is also a need to observe all fishing gears for bycatch encounters through consistent methods to effectively compare each gear-type.
- Established released mortality rate for Steelhead - Although the established steelhead mortality rate is low for the prototype spiller design (5.6%), Steelhead bycatch encounters and overall wild Steelhead mortality (given the current TAC approved mortality rate for the gear) could constrain a future fishery. Research has now been conducted on modified passive trapping techniques and review of the data by TAC should result in a reduced mortality rate for Steelhead (and all other bycatch species), addressing the existing fishery constraint and expanding fishing opportunities for users of passive fish traps. However, as long as TAC does not recognize the modified passive trapping method as separate from the prototype spilling technique, the currently approved TAC mortality rate will constrain fishing.
- There is a need to collect data and evaluate release mortality from gill nets to enable comparison and evaluation of relative benefits between conventional and alternative gears.
- TAC review processes – Working group members understand that post-release survival for conventional and alternative commercial gears in the lower Columbia River has been assessed using inconsistent methodologies. Furthermore, gill net post-release survival data for critical bycatch stocks (e.g., ESA-listed Steelhead) do not exist and mark-recapture or net pen holding studies have not been conducted in the lower Columbia River (NMFS 2018; TAC 2018). These inconsistencies for approved mortality rates in the lower Columbia River make management determination of ESA-impacts potentially biased. Furthermore, the perceived applicability of alternative gears relative to conventional gill nets may also be biased, limiting the potential for alternative gear implementation that may stand to benefit wild salmonid recovery.
- Marine mammal encounters - Sea lion populations have increased in recent years and have been a nuisance to commercial fisheries in the lower Columbia River. Marine mammal encounters at the trap site have been variable over the period of study and fish predation effects associated with the fish trap and all other fishing gears used in the lower Columbia

River remain unknown. It is recommended that marine mammal predation effects associated with all fishing gears used in the lower Columbia River are assessed through a consistent methodology to allow for unbiased comparison amongst gear-types.

- Costs of a fish trap - A lower Columbia River fish trap costs roughly $102,370 - $150,394 depending on the location, materials, and design. Although many other fishing gears cost more in other salmon fisheries, the cost of a fish trap remains high for Columbia River fishers and a subsidy or other financial incentives may be necessary for most fishers to consider transitioning.
- Permitting challenges - Various permits from multiple government agencies are required to install a fish trap. The process takes considerable time and must be streamlined in the future.
- Community acceptance of fish traps – Some working group members have voiced concerns over acceptance of the gear by the gill netting community, which is known for its strong sense of tradition. A lack of community acceptance of fish trapping could slow a transition to alternative gears, impede county permitting of new fish traps, and reduce a fisher's willingness to participate in the fishery.
- Consistency in management direction/policy – WDFW receives management policy directives from the WA Fish & Wildlife Commission, for which commissioners are seated by the Governor. Therefore, priorities of WDFW within the fishery can change abruptly to either encourage or discourage use of alternative gears.

C. Future Recommendations: Regulations, Trap Siting, and Proposed Locations

Recommended Gear Regulations

With commercial fish traps set for broader-scale implementation in Washington State, WFC has developed recommendations for fish trap regulatory requirements. At present, the following regulations are recommended for consideration by state management agencies:

a) *Temporary Location and Permit Restriction*

- We recommend that commercial fish traps only be permitted for use in river locations similar to those that have been studied to ensure compatibility with the ecosystem. If commercial use is desired in a notably different environment (e.g., the marine environment), we encourage research to be conducted first.
- Consideration must be given to the proximity of fishers to one another; we recommend that traps be permitted no closer than ~6,000' from another permitted trap site on the same bank (unless written consent is given by the adjacent permit holder).

b) *Permits and Licenses*

- Management agencies need to consider who should be eligible to apply for a salmon trap permit. By allowing only existing Columbia River permit holders to apply for salmon trap permits, new generations of fishers and minority groups could be excluded; therefore, we do not recommend requirements of this nature. Additionally, lottery systems for permits can create additional uncertainty that could reduce a fisher's willingness to pursue alternative gear.

- To operate a salmon trap, an individual must hold all required permits for pile driving and leasing of aquatic lands through local, State, and Federal permitting agencies.
- To avoid consolidation of the fishery, it is recommended that a licensed commercial trap fisher and his/her legal spouse and dependents be allowed to permit only one trap site in the lower Columbia River.

c) *Pilings*

- We recommend that all pilings driven at a permitted commercial trap site be of untreated material, and under no circumstances should creosote be used.
- To avoid consolidation of the fishery and harm to the environment, we recommend that a maximum number of pilings be established by the agencies. At the time being, we recommend a ~60 piling maximum be established for pile driving during the approved in-water work window.
- Permitted fishers must have valid permits from all relevant local, State, and Federal permitting agencies to keep pilings within the river, lease aquatic lands, or reconfigure trap designs.
- We further recommend that the fisher holding permits for piles at a trap site be responsible for removal of piles or transition of ownership to a new fisher upon expiration of his/her permits.

d) *Lead and Jigger*

- Lead length must be regulated to avoid consolidation of the fishery; currently we recommend that the lead of a trap be less than 500' in total length and extend no more than 1/3 the width of the channel (measured from mean-low-water).
- Given the current status of fish trap research at limited depths, we encourage agencies to develop regulations for net depth. At the time being, we recommend that nets for the lead and jigger extend no deeper than 35' at mean-high-water.
- Based upon our research, we encourage regulation of mesh size and material. We recommend that lead and jigger nets be constructed of material no larger than 3-1/8'' stretch mesh and no smaller than 2-1/2'' stretch. Net material must be highly visible and no smaller than #21 twine.
- Agencies must also regulate when fishers can deploy components of a trap into the water. We recommend that a permitted fisher deploy lead nets into the water column only one day in advance of a fishery opener. Based upon our experiences with deployment, this should be feasible for all fishers.

- Fishers should ensure fish passage when fishing is not occurring through design of at least two escapement points in the lead net exceeding a minimum of 12' in width (one shoreward, and one within 100' of the heart).
- The entire lead net should be retrievable within the fishing season by a fisher if directed to do so by management agencies.
- At the conclusion of a designated fishing season, lead and jigger nets should be completely removed from the water and the pilings.

e) *Heart Compartments*

- Regulations should be established to limit the total number of heart compartments. Currently, we recommend that no more than two heart compartments be constructed at a given site.
- Given the current status of fish trap research at limited depths, nets should not extend deeper than 35' at mean-high-water.
- Based upon prior research, heart nets should be constructed of 2-1/2'' stretch nylon mesh to avoid gilling jacks. Net material should be highly visible and no smaller than #21 twine.
- To avoid entry of marine mammals to the heart, it is recommended that all heart compartments be equipped with a mesh bottom or have mesh walls deployed fully to the riverbed with a weighted apron extending at least 4' along the riverbed toward the center of the heart.
- Agencies must also regulate when fishers can deploy heart compartments into the water. We recommend that a permitted fisher deploy heart nets into the water column no more than one week in advance of a designated fishery opener. Based upon our experiences with deployment, this should be highly feasible, and without the lead deployed, the heart will not function to corral fishes (and therefore, should be of little concern by management agencies).
- Marine mammal deterrent gates should be installed at the entrances to the heart compartment from the lead.
- A permitted fisher should ensure fish passage when fishing is not occurring through design of escapement points exceeding 6' in width at upstream and downstream locations of each heart compartment.
- At the conclusion of a designated fishing season, heart nets should be completely removed from the water and the pilings.

f) *Spiller and Pot Compartments*

- We recommend that spiller or pot nets extend no deeper than 35' at mean-high-water.
- Based upon prior research, spiller or pot nets should be constructed of 2-1/2'' stretch knotless nylon mesh to avoid gilling jacks. Net material should be highly visible and no smaller than #21 twine.

- Spiller/pot configuration and operation must be approved by WDFW prior to use during a fishing season and we encourage WDFW to incentivize use of trap designs that allow for passive capture and release of bycatch. We further recommend that any changes to spiller/pot configuration and operation be approved by WDFW before operations proceed.
- The spiller and pot should be lifted out of the water column when fishing is not occurring to enable fish passage.
- At the conclusion of a fishing season, spiller and pot nets should be completely removed from the water.

g) *Live Well Compartment*

- The live well compartment should be at least 6’ long, 2.5’ wide, and 2.5’ deep.
- Upstream and downstream walls of the live well must be constructed of highly visible knotless mesh less than 2’’ stretch to minimize potential damage to small bodied fishes.
- Shore side walls should be perforated to encourage water circulation.
- An exit door should be installed to enable passive release of bycatch and to minimize handling and air exposure of bycatch to the greatest practicable extent.

h) *Marine Mammal Deterrent Devices*

- Marine mammal deterrent gates should be installed for deployment at all entrances to the outer heart of a trap.
- Deterrent devices should be approved by WDFW. From recent experiments, 2-1/2’’ stretch knotless nylon mesh has worked effectively to enable rapid deployment and retrieval in a cost-effective manner.

i) *Soak Period and Entrapment*

- Soak period limits should be established by WDFW. Currently, we recommend that a trap pot be cleared at least every eight hours by a trap operator if the trap design allows for passive capture/release. If the trap is designed for spilling, we recommend that the spiller be cleared at least every hour.
- Fish should not be entrapped in a live well for longer than 30 minutes.
- Handling and air exposure of bycatch must be minimized to the greatest practicable extent during capture and immediate release.
- Trap operations should not result in immediate mortalities of ESA-listed fishes, adult salmonids, and sturgeon.

j) *Electronic Video Monitoring and Observation*

- We encourage electronic monitoring requirements for salmon traps. During the soak period and sorting of the catch, live-streaming video cameras directed at the spiller and live well should be in operation for potential review by management agencies.
- Permit holders should allow for WDFW access for observation and data collection.

k) *Safety Requirements*

- Permit holders should install and maintain aids to navigation in accordance with U.S. Coast Guard requirements: A light should be positioned at least 6 feet above normal high water at the pile farthest riverward and the pile closest to shore, with two more lights placed so as to break the line of pilings into three equal parts for a total of four lights. The lights should be 1) yellow, 2) visible for no less than one nautical mile, and 3) have a flash timing of "FL Y 4s" (flashing yellow four seconds, 15 flashes per minute, [on for 0.5 seconds, off for 3.5 seconds for a total of four seconds]).

Recommended Criteria for Siting Commercial Salmon Traps

As fishers and state agencies begin the process of identifying potential trap locations in the Columbia River, various criteria must be carefully considered in order to achieve desired environmetal, economic, and social objectives. WFC has provided trap siting recommendations, with site selection tips available to fishers and the public through WFC's online blog and website: https://thefishtrapjournal.org/want-to-build-a-fish-trap/. Based on experiences siting, permitting, constructing, and researching fish traps in the Columbia River, WFC recommends consideration of the following criteria during siting and permitting processes (Table VI-19).

Table VI-19. WFC recommended criteria for siting salmon traps in the lower Columbia River.

Criteria	Description
1. Fish Migration	Traps should be located in or near expected salmonid migration corridors, or historically known successful trap locations. Applicants should consider the ecology of aquatic species present at a site during all life-history stages.
2. Shipping Lanes	Traps should be placed outside of established shipping lanes.
3. Water Depth	Water depth at spiller location should be no less than 3 m at mean low water and no greater than 10 m at mean high water.
4. Substrate	Substrate is limited to silt and sand for pile driving.

5. Woody Debris	Applicants should consider natural features such as islands, peninsulas and river bends for protection from large woody debris if fishing is expected to occur during spring freshets.
6. River Currents	Applicants should avoid strong river currents.
7. River Usership	Trap location should not impede existing, commercial, and/or recreational opportunities.
8. Land Ownership	Applicants should site traps on WDNR aquatic lands and consider adjacent land ownership to avoid unnecessary conflict.

Where are Fish Traps Effective?

Fish traps are generally most effective toward the mouths of rivers and streams and in shallow estuarine settings. If the gradient is too steep in a large river system, chances are that pilings or nets will fail. Additionally, steeper gradients tend to have greater scour and firm substrate, which may prevent successful pile driving. Based upon these constraints and historical records, we suggest that traps are sited in the lower reaches of a low-gradient river where the substrate and flows are appropriate. Fishers should further consider the fact that fish traps located in-river (rather than the marine environment) will have less bycatch of species from other river systems; therefore, in-river fishing operations will generally be more selective and sustainable.

Land-Ownership, River Usership, and Navigation Channels

Fishers must be aware of land-ownership and river usership constraints. For example, fishers should avoid primary navigation channels and private tidelands, and keep distance from federal projects such as levees and dams. To avoid conflict with nearby landowners, it is recommended that fishers target locations offshore of relatively undeveloped lands and out of sight from residential land-owners. Although it may sound difficult to site a trap with these constraints, the vast majority of lower Columbia River waters are public aquatic lands/waters and there are various remote locations available to accommodate many trap sites. Although no location will completely avoid conflict with all user groups, it is recommended that fishers be aware of commercial "drift-rights" and popular recreational fishing areas and make efforts, if possible, to avoid these locations.

Substrate

Since the fishing gear requires pile driving, traps are limited to locations consisting of sand or silt substrate. For the most part, the lower reaches of most rivers should be appropriate as the finer sediments tend to settle out in these regions. However, we recommend that fishers view government map layers (e.g., https://www.nauticalcharts.noaa.gov/RNCOnline/rnconline.html) to investigate substrate composition. Also, we recommend that fishers pay attention to sediment on-shore and at low-tide; this may provide an indicator of what lies below the water-column. Efforts can also be made to prod the river-bed with a long pole to sound for hard substrate;

alternatively, diving can reveal patches of challenging substrate. Given that core-sampling is generally cost-prohibitive, these rudimentary investigations provide some of the only cost-effective means to determine if pile driving may be successful. Beyond these basic tests, fishers should consult with their pile driver to discuss the feasibility of pile driving in a given location.

Depth

There are depth limitations to pile driven traps. It can be cost-prohibitive to secure piling lengths greater than 80 feet, and generally, 40-50 foot pilings are cheaper than the longer options. Since most pilings should be driven approximately 15 feet into the ground and it is necessary to have at least 5 feet of pile above the high-water line, the standard 50 foot pile limits fishers to depths of approximately 30 feet at high-water. It may be possible to drive longer pilings at deeper depths, however, fish traps have not been studied in these conditions.

Given budget constraints and limitations of pile length, we recommend that fishers use 50-foot piles for the majority of a trap and target depths near 30 feet at high-water. To help secure the benefits of fishing the deeper waters (for benthic oriented species such as Chinook Salmon), it may be beneficial to find a location at the upriver terminus of an underwater canyon or gut.

River / Tidal Currents, Woody Debris, and Ice

Fishers should be aware of strong river and tidal currents. We recommend that fishers consider natural features such as islands, peninsulas, and river bends for protection from large woody debris if fishing is expected to occur during spring freshets. If fishers are siting a trap in a colder climate, it is recommended that a protected location be selected to avoid ice flows in the spring. Generally, if a trap is located near a river mouth, estuarine conditions and flood/ebb tidal cycles should help clear piles of both ice and woody debris.

Fish Migration Corridors

Lastly, known fish migration corridors should be considered during trap siting, as well as any available historical records of trap locations (available at the Wahkiakum County Courthouse, and special collections at Western WA University and the University of WA). Any relevant fishing data from government agencies should also be considered for selection of a productive trap site.

Recommended Fish Trap Sites

Considering the criteria described above for siting of fish traps (Table VI-19), WFC has identified various potential fish trap sites in the Columbia River that may be effective. Potential trap sites can be viewed through an interactive web-map accessible through WFC's online blog at: https://thefishtrapjournal.org/want-to-build-a-fish-trap/. We provide a direct link here: https://wildfish.maps.arcgis.com/apps/instant/basic/index.html?appid=ebe3b7b2114642cba8d6d

379b67b4f98. Although WFC has identified over 20 potential sites ranging from Zones 2-4 of the lower Columbia River, detailed bathymetry mapping has been conducted by WFC in Zone 2, specifically within the Cathlamet Channel and Clifton Channel (Figure VI-11). These locations have been identified as high priority regions for the further development of emerging salmon trap fisheries; bathymetry maps are provided below for reference.

Bathymetry Mapping and Potential Trap Locations

In order to identify locations in Cathlamet Channel and Clifton Channel with depths suitable for future permit applicants, WFC preformed a series of bathymetric surveys. Utilizing a Helix 7 depth sounder with Auto Carts live software, WFC field staff ran a series of transects in both channels of interest from early November 2019 - March 2020. The recorded data were then offset to depict water depths at mean lower low water (MLLW) during river flows experienced on 11 November 2019. After review of bathymetry, WFC recommends permitting between 4-6 trap sites in Cathlamet Channel and up to 4 trap sites in Clifton Channel (Figures V-12 – V-18).

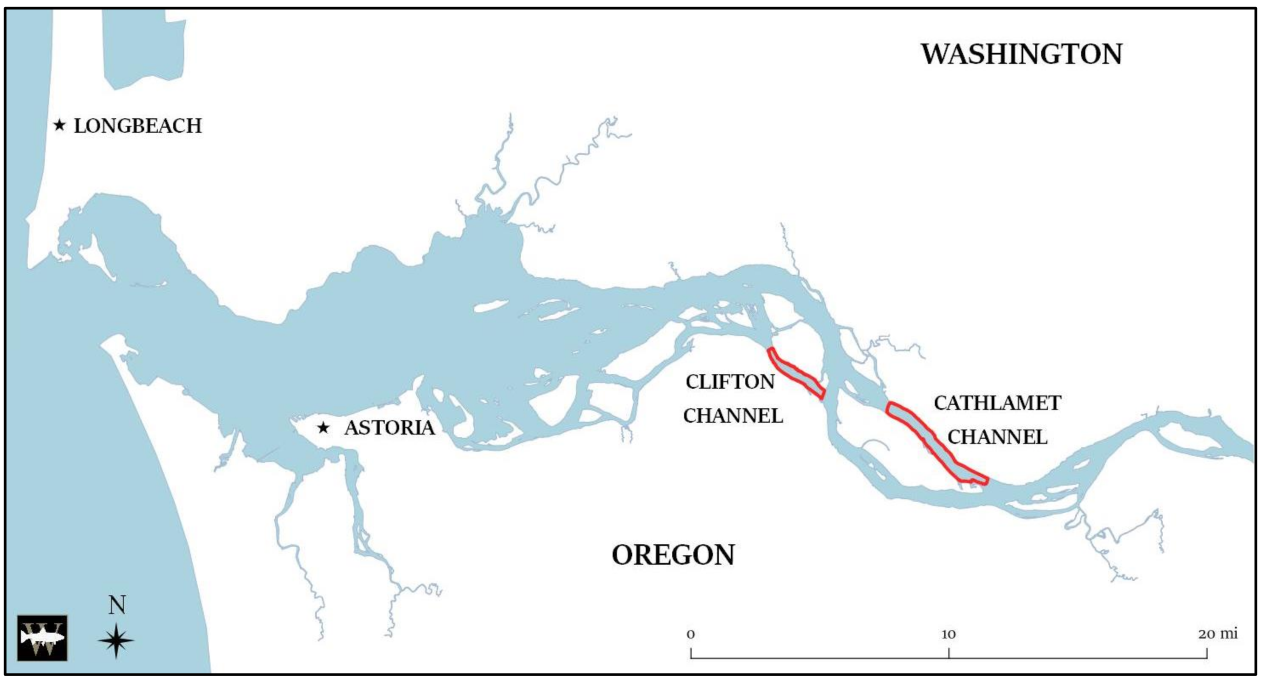

Figure VI-11. Location of Cathlamet Channel, WA and Clifton Channel, OR.

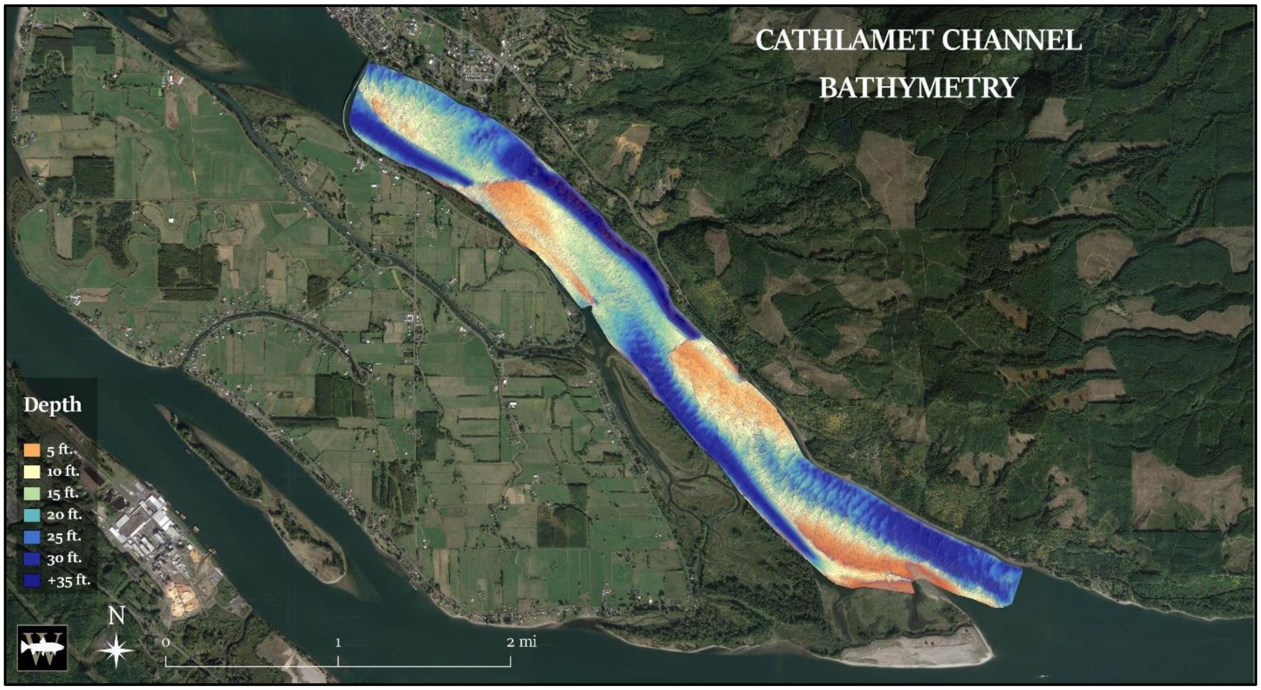

Figure VI-12. Overview of Cathlamet Channel bathymetry as mapped by WFC.

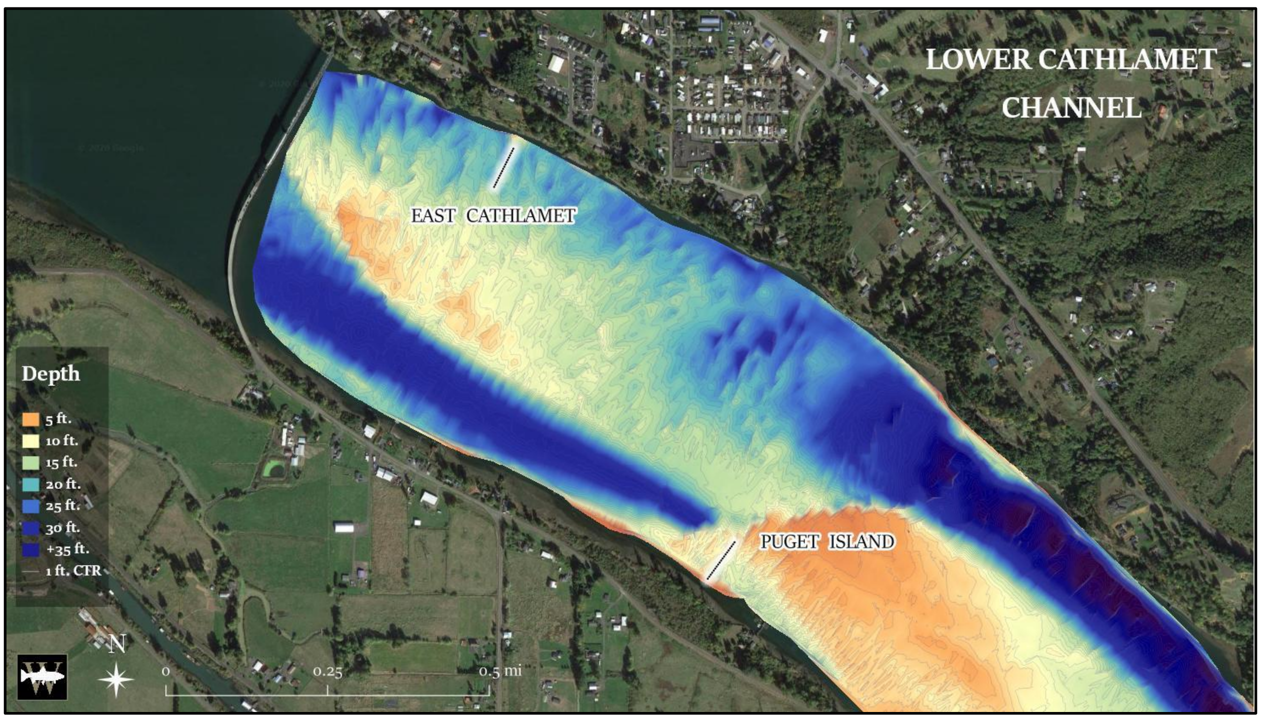

Figure VI-13. Bathymetry of the lower Cathlamet Channel and potential fish trap sites.

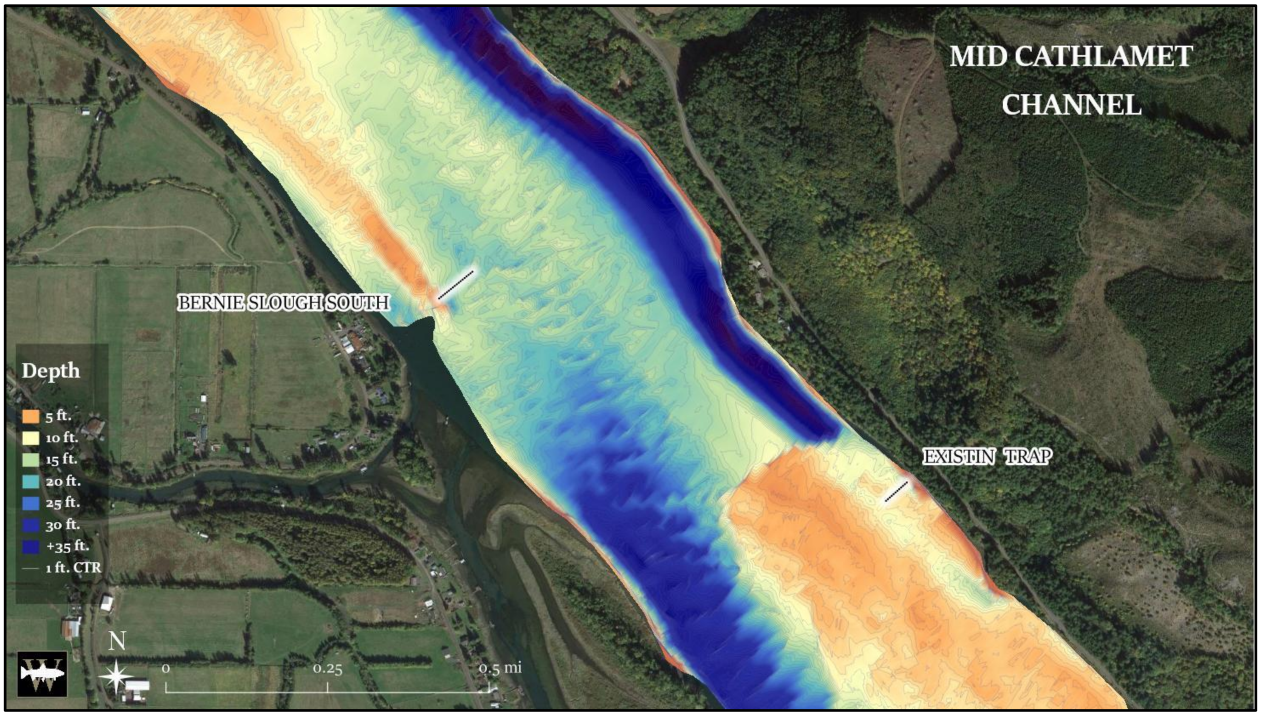

Figure VI-14. Bathymetry of mid Cathlamet Channel and potential fish trap sites identified by WFC.

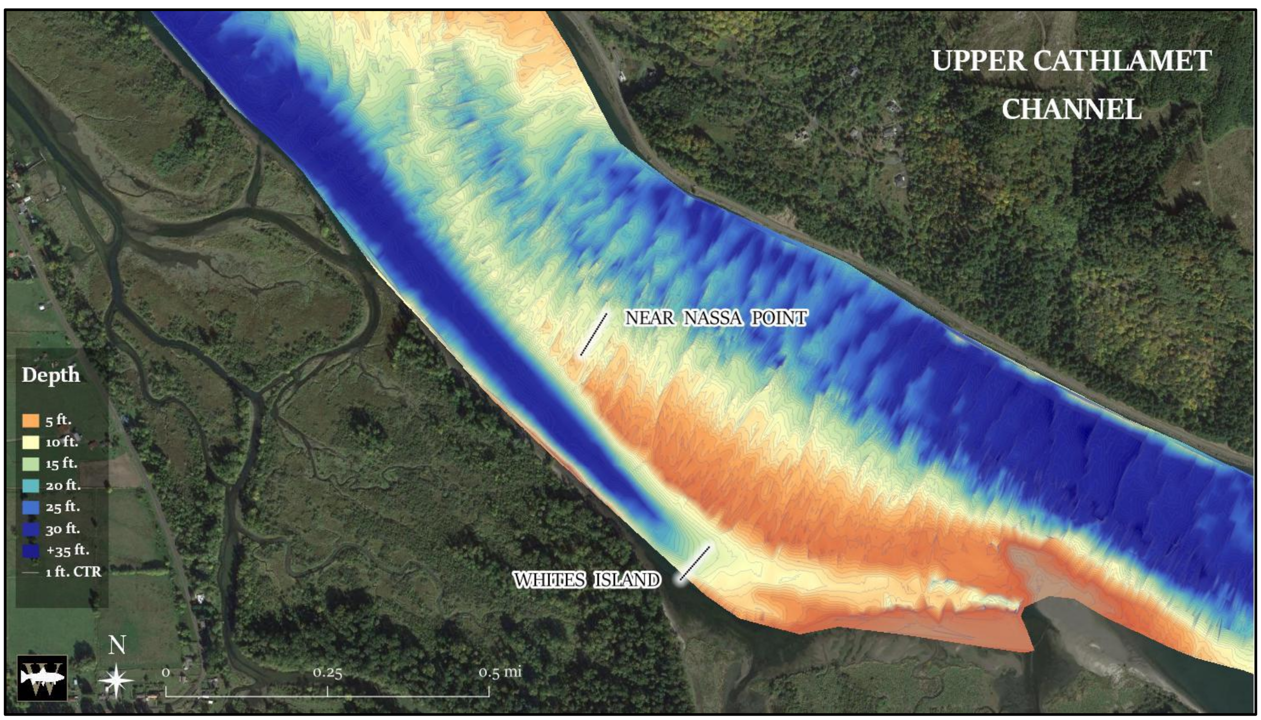

Figure VI-15. Bathymetry of the upper Cathlamet Channel and potential fish trap sites identified by WFC.

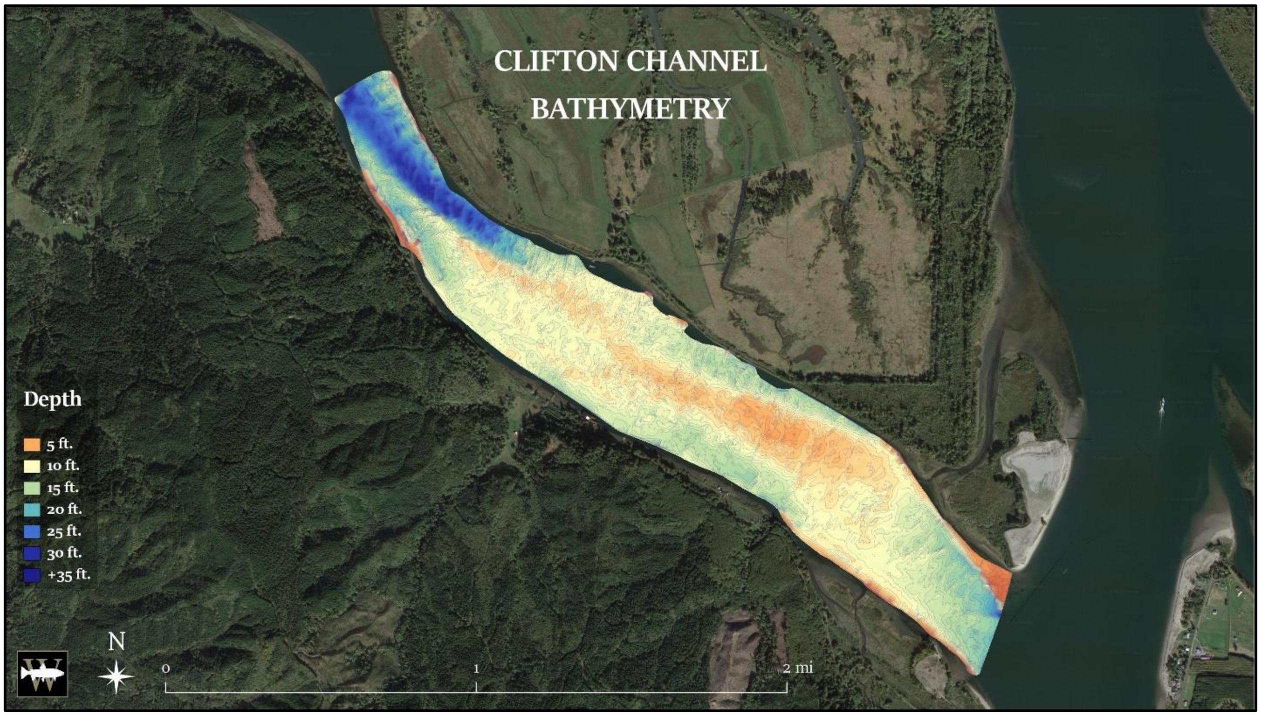

Figure VI-16. Overview of Clifton Channel bathymetry as mapped by WFC.

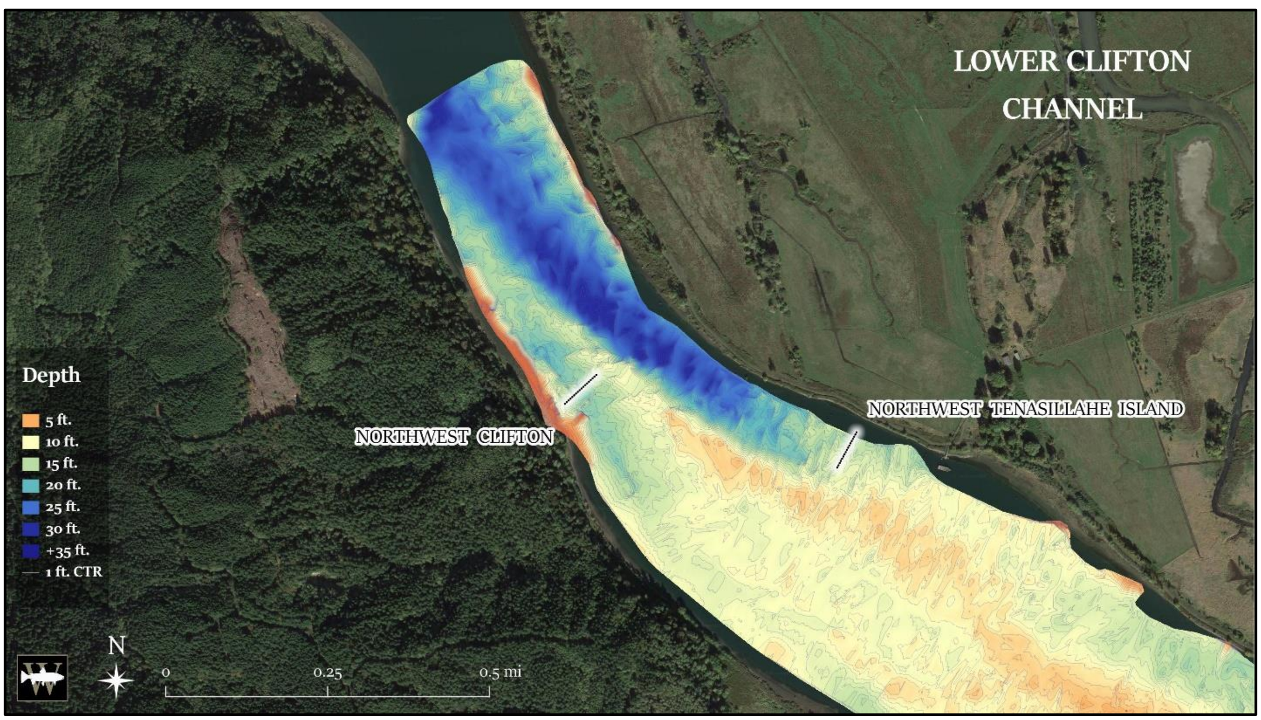

Figure VI-17. Bathymetry of the lower Clifton Channel and potential fish trap sites identified by WFC.

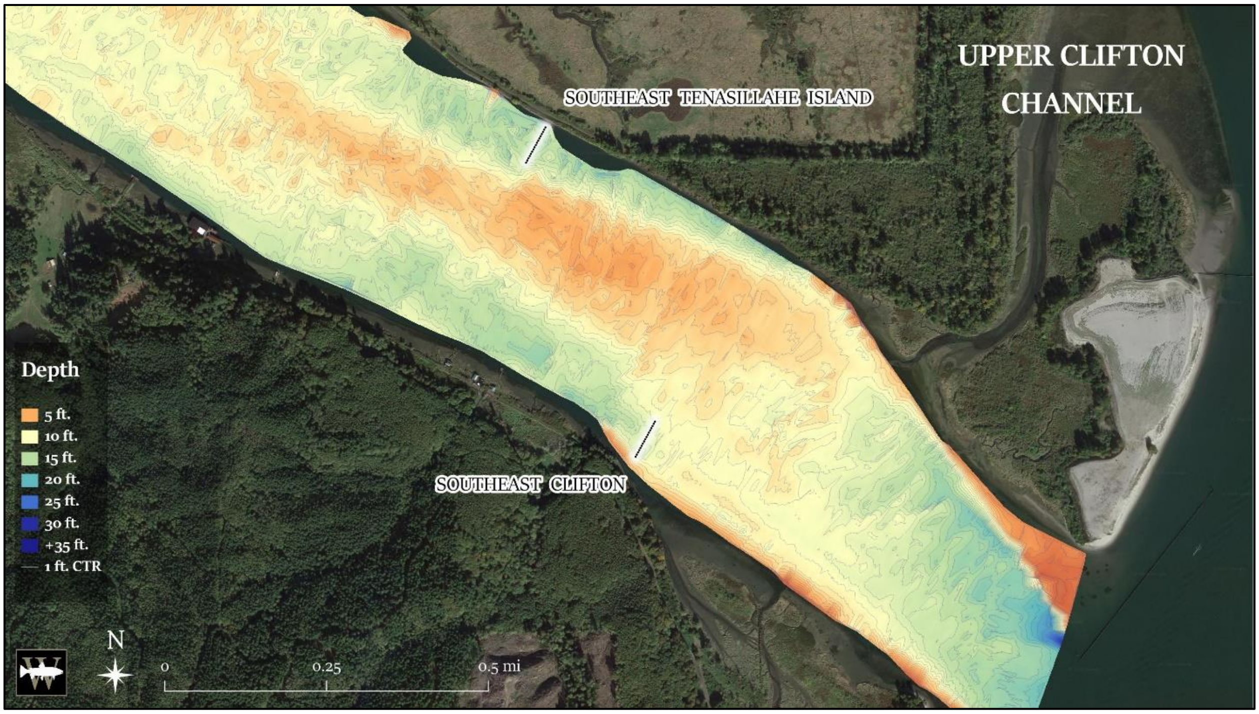

Figure VI-18. Bathymetry of the upper Clifton Channel and potential fish trap sites.

D. Significant Problems

No significant problems occurred during the S-K project. At the start of the project period, there were concerns that the poor upriver Steelhead return to the Columbia River would constrain test fishing activities in 2019. Throughout the project, WDFW and WFC closely monitored handle of ESA-listed stocks to ensure impacts were not exceeded. In the end, test fishing activities from August through October were not impacted and project objectives were achieved.

Although test fishing was not affected by ESA-impact constraints in 2019, the post-release survival study plan had to be modified to minimize encounters with Steelhead. Since a mark-recapture Steelhead study required handle of nearly 800 Steelhead in the month of August, research efforts were shifted to late-September and October for Coho Salmon to save Steelhead ESA-impacts for the commercial test fishing project. Despite this setback, the modified study plan filled a crucial data gap identified by WDFW and ODFW for Coho Salmon post-release survival (previously unstudied). Results of this post-release survival study have been summarized in a manuscript published in the North American Journal of Fisheries Management titled "Modified Commercial Fish Trap to Help Eliminate Salmonid Bycatch Mortality" (Tuohy et al. 2020). The submission was peer-reviewed and published in 2020. Data from this study may be used by Columbia River TAC to set official Coho Salmon mortality rates for the fish trap gear and the modified passive fishing technique.

Test fishing operations were expanded to the fall 2020 season to advance the marketing project and post-release survival investigations for Coho Salmon. The reason for this expanded project timeline was due to the postponement of the Emerging Commercial Fishery designation and a delay in permitting for the Clifton Channel, OR fish trap research project for investigation of post-release survival from a modified passive fish trap design. The expanded timeline of the S-K project allowed for research and marketing progress for the fish trap project in the presence of these unexpected delays.

In 2020, test fishing and research operations were temporarily postponed between 10-16 September due to hazardous air quality conditions from the Pacific Northwest wildfire crisis. In addition, the Covid-19 pandemic affected the salmon market and demand from local restaurants. The working group successfully navigated these challenges to market harvested fishes and secure added-value. Furthermore, an additional Coho Salmon post-release survival study was completed to inform approval of mortality rates for the modified passive trapping method.

E. Need for Additional Work

The following activities may be necessary for the advancement of alternative gears in the lower Columbia River salmon fishery:

- TAC mortality rate review for modified passive capture technique – The currently approved TAC mortality rates for the fish trap are based upon data for the spilling technique that now appear to be mostly obsolete. Data relevant to fish trap passive capture and release processes now exists for Coho Salmon (Tuohy et al. 2020; Tuohy and Jorgenson 2021), Sockeye Salmon (Tuohy et al. 2020; Fryer et al. 2020), Chinook Salmon (Cox and Sippel 2020), and Steelhead (Cox and Sippel 2020). The modified passive capture process operates in a substantially different manner from the prototype spilling technique and the relevant data should be reviewed to set new mortality rates for the passive gear. A new set of mortality rates for the passive capture method will better represent the current status of fish trap engineering and will further function to incentivize use of low-impact capture/release processes that minimize mortality to encountered bycatch species. Given the data that have been collected, the passive capture method should have lower mortality rates for all bycatch species and approval of these rates will increase selective fishing opportunities with the gear.
- Steelhead release survival research for gill nets – To date, gill nets have not been studied for release mortality effects on critical bycatch stocks (e.g., summer Steelhead) (NMFS 2018). Furthermore, annual gill net bycatch encounters are unobserved (WDFW 2018). All fishing gears should be studied using a consistent methodology to better enable unbiased assessment of bycatch mortality impacts and inform gear implementation and allocation decisions by management.
- Assess bycatch encounters at new fish trap sites – Relative to other gears, it appears that the Steelhead encounter rate with the fish trap may be high. However, these investigations only analyzed one trap site in the river, and preliminary data from a separate site in Clifton Channel, lower Columbia River, OR suggests that Steelhead encounters may differ dramatically depending on river location. There is a need to investigate fish trap designs in other river locations where bycatch encounters may differ. There is also a need to observe all fishing gears for bycatch encounters through a consistent methodology to effectively compare each gear-type.
- Establish economic incentives to address existing barriers to using alternative gears – There are various barriers to entering an emerging alternative gear fishery that must be addressed for a successful transition outcome: (1) Fishers are heavily invested in gill netting, (2) Costs are high for a fish trap or seine transition, (3) Traps are difficult for fishers to permit and design, (4) Financial risk is high from piloting the first trap or seine prototypes, (5) There are unknown allocations for an Emerging Commercial Fishery, and (6) Financial risk is high from the unknown fate/status of the Emerging Commercial Fishery in the Columbia River.
- Establish rules and regulations for Emerging Commercial Fishery – There is a considerable need for management agencies to develop very clear rules for permitting / licensing fish traps, as well as gear regulations. Currently, fishers are hesitant to participate as it remains unclear as to who will be allowed to participate (e.g., only existing commercial license holders from WA and OR with demonstrable landings in recent years); it is also unclear whether participation will be determined through a lottery system (which can create uncertainty and hesitancy for site permitting / installation). Lastly, fishers that are interested

in permitting and installing traps do not know which designs will be allowed, how the gear will be regulated, or whether lower impact passive processes will be incentivized through approval of new mortality rates for the passive gear.

- Secure sustainable market certification – In 2019, WFC achieved site visits, meetings, presentations, and discussions with MSC and MBASW. Now that the fish trap gear is set to be legalized, efforts should be made to advance sustainable market certification to enable the sale of fish to high end restaurants and markets and add-value to harvested products.
- Advance direct marketing efforts – Maintain and increase market demand for trap-caught seafood products; further build a reputation of quality and sustainability for trap-caught seafood products; advance value-added practices in harvesting, live-bleeding, icing, and processing; strengthen collaborative regional relations and direct marketing of sustainably-harvested fish to high-end local restaurants; maximize pricing and profits.
- Provide technical support for fish trap siting and design – Given that fish trap deployment and operations are radically different than that for gill nets, a technical support team should be established to assist fishers with fish trap siting, design, and installation in the lower Columbia River.
- Streamline the permitting process and provide technical support – A technical support program should be developed to assist fishers with the difficult task of permitting fish traps. Currently, trap permitting requires multiple applications to federal, state, and local government agencies. This process may be challenging to fishers unfamiliar with the process. Beyond technical support to fishers, the permitting process should eventually be streamlined into one application form.
- Consider developing a funding program to subsidize implementation of alternative gear – A funding program may be necessary to help the first users of fish traps and other alternative gears overcome short-term barriers to entering the Emerging Commercial Fishery. Given the risks and uncertainties associated with investing in the first alternative gear operations, a subsidy could help encourage participation in the fishery so that economic viability could be better assessed by future participants.

VII. EVALUATION

A. Attainment of Project Goals and Objectives

Award NA19NMF4270028 is now complete and proposed objectives have been mostly achieved. From August through October 2019 and 2020, WFC and partners completed all trap modifications, secured required permits/contracts, and successfully constructed, tested, and evaluated the commercial trap fishery (Objective #1) (Table VII-1). During this fishery evaluation, the working group determined the successes and failures of bringing underutilized hatchery salmon resources to market with a new technology for fishing fleets. Research was also performed from August through October to monitor stock-composition, further assess bycatch mortality, and identify means to improve gear efficiency/sustainability (Objective #2). Throughout commercial test fishing operations, the S-K working group (including fishermen, processors, WDFW, WFC) served to ensure use of best practices in harvesting, icing, processing, and marketing to maximize customer base and future pricing for sustainably-harvested fish (Objective #3). WFC worked to secure recognition of the emerging trap fishery to initiate sustainable market certification or rating processes with MBASW and MSC (Objective #4). Lastly, WFC and partners planned for the future (Objective #5) and the establishment of a legalized fish trap fishery through the Emerging Commercial Fishery designation (RCW 77.65.400), developed recommended gear regulations, identified potential trap sites, proposed stakeholder mitigation options and economic incentive plans, and raised awareness of alternative harvest tools through completion of proposed outreach activities.

Objective #1 - Evaluate a Commercial Trap Fishery

This S-K award was designed to fund commercial test fishing over the 2019 season to evaluate how the experimental fish trap gear could translate to a commercial selective harvest setting. Although the award was intended for one year of research in 2019, the project was extended to 2020 to address additional data gaps. Since commercial test fishing also occurred in 2018 and no report had been generated, this report summarizes findings of three consecutive years of commercial test fishing that occurred between 2018-2020 to add-value to the S-K project and document all commercial test fishery findings in one report.

Between August and November 2018-2020, the fish trap was successfully deployed, operated, refined, and tested (pg. 27-48). WFC collaborated with local fishers (Jon Blair Peterson; Billie Delaney), fish buyers/processors (C&H Fish Company; J&B Sales), WDFW, and Sea Creatures restaurant group to operate the gear for the first time in a commercial setting since 1935, evaluate mark-selective harvest operations over each fall fishing season, and bring trap-caught fish to the market to assess product quality and potential for added-value. Over the course of each fall season, the pros and cons of the mark-selective fishery were identified (pg. 50-53). Based upon commercial test fishing, the mark-selective fishery generated sufficient revenue to cover anticipated annual costs (pg. 40-48) while accepting the established gill net market price for harvested products. Fishers noted the ease of operating the trap after seasonal installation, necessitating 1-3 operators depending on fish abundance at the trap site. This suggested that the trap could be used cost-effectively and with minimal labor during periods of lower fish abundance when other gears (e.g., beach and purse seines) may be cost-prohibitive due to labor requirements.

Over the course of the fishery, commercial fishers and industry experts ranging from buyers to processors and chefs noted the exceptional quality of trap-caught fish (with essentially zero bruising, scale-loss, or net damage). These partners noted an increased willingness to pay for sustainable trap-caught fish, suggesting that future trap fishers could achieve considerable added value depending on their preferred marketing strategy.

Despite the potential for added product value and the fact that annual revenue exceeded estimated annual costs of a standard commercial trap operation, it is clear that upfront capital costs for the gear (pg. 43-44) are high and may require time to recoup (depending on the productivity of a particular site and the added value that may be realized). Given the uncertainties and risks of piloting a legalized alternative gear in the Emerging Commercial Fishery, it is likely that grant support or some other form of subsidy may be necessary to help the first fishers participate in the Emerging Commercial Fishery. Nevertheless, there appears to be considerable potential for trap fisheries to generate profits while benefiting wild salmon recovery through reduced bycatch mortality and removal of hatchery-origin fishes. Authorization, implementation, and further assessment of the gear's economic performance in a real-world commercial fishery setting (e.g., WDFW's Emerging Commercial Fishery) will better allow fishers to determine whether fish traps can meet their economic and social needs.

Objective # 2 - Perform Research

Over the fall fishing seasons of 2018-2020, WFC and partners monitored stock-composition (pg. 29-35), immediate bycatch mortality (pg. 36-37), and post-release bycatch mortality of Coho Salmon (pg. 37-39). After each year, WFC worked to identify means to improve gear efficiency and sustainability to meet conservation and management goals.

In each year of operation, stock-composition and stock-specific exploitation varied, highlighting the site-specific nature of a fixed gear located in only one river location (pg. 29-35). When accounting for differences in fishing effort and run size in each year, the gear was most effective for capture of the Coho Salmon run. Catch of the Chinook Salmon and Steelhead run varied considerably between years of operation. In 2018, the fish trap functioned effectively for Chinook Salmon (much like the prior 2017 research season; Tuohy et al. 2019). However, catch of the Chinook Salmon return in 2019 declined dramatically. Similarly, catch of the Steelhead return varied with a notable increase in 2020 relative to prior years of test fishery operation. These results suggest that the fixed-gear may be sensitive to annual changes in species-specific migration patterns.

Throughout the study, WFC and partners investigated mortality effects of the gear. During all 2018-2020 test fisheries, zero immediate mortalities occurred for adult salmonid species. To determine post-release mortality, net pen holding studies were conducted for Coho Salmon for the modified passive capture technique. Holding studies occurred at the Cathlamet Channel trap site in 2019-2020. In 2021, yet another holding study was conducted for Coho Salmon at a new fish trap site in Clifton Channel, OR designed for passive capture and release of all fishes. Results of these holding studies (including 2021 findings from Clifton Channel) are summarized within this report (pg. 37-39) with discussion provided below.

Results from three years of net pen holding studies for Coho Salmon in two different research locations largely confirm the findings of prior mark-recapture studies for passively captured and released Chinook Salmon, Sockeye Salmon, and Steelhead from the modified fish trap gear in the lower Columbia River. Between 2019 and 2020, there was no detectable mortality effect from passive capture and release of Coho Salmon with zero immediate or post-release mortalities occurring in the short-term (48 h) and intermediate (96 h) periods of study (Table VI-10). In 2021, estimates of survival supported the findings of prior years of study (despite lethal water quality conditions during captivity) with statistically equivalent results within 96 h post-release (Table VI-10). Coho Salmon survival from the gear approached 1.000 with immediate, short-term, and intermediate survival estimated at $\hat{S}_0$ = 0.999 (CI (0.997 ≤ $\widehat{immediate}$ ≤ 0.9998) = 0.95), $\hat{S}_1$ = 0.995 (CI (0.978 ≤ $\widehat{short-term}$ ≤ 0.9997) = 0.95), and $\hat{S}_2$ = 0.995 (CI (0.978 ≤ $\widehat{intermediate}$ ≤ 0.9997) = 0.95), respectively. Lacking a control group for this study, these post-release survival results may simply reflect the natural environmental baseline for adult salmon upriver survival during the upriver migration in the lower Columbia River.

Although Coho Salmon post-release survival declined between 96 and 144 h in captivity in 2021 with long-term survival estimated at $\hat{S}_3$ = 0.974 (CI (0.946 ≤ $\widehat{long-term}$ ≤ 0.991) = 0.95) (Table VI-10), it must be noted that this analysis lacked a control group, meaning that estimates of mortality represent the pooled mortality effect from the natural environmental baseline, confinement effects, adverse water quality conditions, research processes (e.g., dip-netting, fish handling, and other stressors unique to the study), and the passive capture process with the modified fish trap. Given the low-impact nature of the gear and the environmental conditions experienced during the holding study, it is likely that the few mortalities that occurred in this long-term period of captivity were primarily due to the prolonged effects of confinement in sublethal to lethal water quality conditions and abrasion in the holding pen. In sub-sample period two when the majority of the long-term mortalities occurred (Table A-1), water temperatures consistently neared or exceeded thresholds identified as potentially lethal for fall runs of salmon in the Columbia River (20-22°C; Coutant 1970; Becker 1973; EPA 2003; EPA 2021), with the mean temperature during captivity estimated at 20.3°C (CI (20.2°C ≤ $\widehat{temp}$ ≤ 20.5°C) = 0.95). In the captive net pen environment, fishes in the study could not find temperature refugia available in the wild and remained subject to adverse water quality conditions (> 20°C) known to increase fish susceptibility to disease, parasites, stress, and mortality (EPA 2003; EPA 2021). Nevertheless, the study design—lacking a viable control group of fish that could be sourced in a lower-impact manner than the gear itself—provided no means to isolate potential mortality effects of passive capture from that of confinement, research processes, sublethal temperatures, natural mortality, and other factors. Therefore, post-release survival estimates from this study should be considered as conservative, or negatively biased (Takata and Johnson 2018).

Despite lacking a control group for these three years of study, results suggest that passive capture and release with the modified fish trap gear achieves immediate and post-release survival rates greater than any other conventional or alternative fishing gear tested in the lower Columbia River for Coho Salmon (WDFW 2014; Takata and Johnson 2018). The findings of this study continue to indicate that passive capture with modified fish traps has little to no detectable effect to the survival of released adult salmonids. Given these findings over three years in two separate locations, it is evident that passively operated fish traps may provide an improved means to monitor adult salmonid stocks, and/or increase selective harvesting of hatchery-origin Coho Salmon while reducing impacts to wild-origin Coho Salmon in the lower Columbia River.

Objective # 3 - Develop and Implement Value-Added/Direct Marketing Practices

In all three years of commercial test fishing, WFC and industry partners worked together to ensure use of best practices in harvesting, icing, processing, and marketing to develop a reputation for trap caught seafood products and maximize pricing for sustainably harvested fish.

Unlike most conventional gill netting operations in the lower Columbia River, all trap-caught salmon were selectively harvested based upon the absence of an adipose fin (indicating hatchery-origins) and all wild salmon and Steelhead bycatch were released without immediate mortality. Selectively harvested fishes were live captured from the trap live well and immediately live-bled and placed in a slush ice tote to maximize product quality. Industry experts confirmed that fishes could not be handled or harvested in any better manner to further improve product quality, stating that the quality of the fish neared or exceeded that of troll-caught salmon.

All harvested fish within a commercial test fishing day were kept on ice and delivered each evening to the local fish processor within two miles of the trap site in Cathlamet, WA (C&H Fish Company). Live-streaming video of trap operations enabled fish buyers and chefs to observe the commercial process and harvesting of their product in real-time. Fish were sold to markets in the U.S. and Canada to develop a reputation for trap-caught seafood products. Small deliveries were made throughout the project to Sea Creatures Restaurants in Seattle, WA (owned by James Beard Award winning chef Renee Erickson).

From these marketing experiments, significant demand was generated from high-end restaurants in the Seattle area. James Beard award winning Chef Renee Erickson promoted the "unparalleled quality and sustainability" of trap-caught fish in an article published by Wild Salmon Center (2019). Erickson and other chefs of Sea Creatures Restaurants expressed a willingness to pay $6.50 – 9.00/lb for Coho and $16.50 – 19.00/lb for Chinook Salmon (Personal Communication, October 2020). Furthermore, these restaurants were interested in purchasing Coho Salmon jacks captured with fish traps that would otherwise be released due to their low marketability.

In an interview with Wild Salmon Center (2019), Chef Erickson of Sea Creatures Restaurant Group (Seattle, WA) stated that the trap "redefined what we can serve people…fish out of a trap are remarkable; they're untouched, pristine…there's very little you should do to it when it's so fresh and perfect." In a separate interview with North Fork Studios (2020), Erickson stated the following: "We focus on sustainability. We are super excited about the Columbia River fish trap as an option that is obviously more sustainable and producing a fish that's untouched, essentially. It's very beautiful to see fish that haven't been damaged by the fishermen or the gear."

J&B Sales (Tacoma, WA) noted the following in an interview with North Fork Studios (2019): "I moved most the fish that were harvested last summer, and the response has been fantastic. In 45 years of being in the industry, I've never seen a better way to catch fish for quality, gentleness to the fish, and sustainability."

C&H Fish company stated the following in an interview with North Fork Studios (2019, 2020): "The trap is a great way to market fish. First of all, for the freshness; the fish come out of the water and within 20-30 seconds, the fish are bled and iced…There's no stress [to the fish], which makes a big difference when you're filleting it…there's no gaping in the meat, there's no blood in the meat, no blood in the row…I butcher a lot of fish in Alaska, and these are by far the best fish I've ever done."

Objective # 4 - Initiate Sustainable Market Certification Processes

WFC made efforts to initiate the certification process for fish trap fisheries with Monterey Bay Aquarium's Seafood Watch (MBASW) to increase product profile, customer base, and future fish value in the marketplace (pg. 50). WFC coordinated with Marine Stewardship Council (MSC) and MBASW during the S-K project to initiate recognition of the emerging salmon trap fishery. WFC distributed outreach materials, research findings, and invitations for site visits to MSC and MBASW. In 2019, site tours, meetings, and presentations were held with MSC and MBASW.

From these efforts, MBASW agreed to consider rating the fish trap gear as they undertake review of west coast salmon fisheries, assuming the gear is legalized. WFC will continue to follow-up with MBASW to ensure the fish trap fishery is considered for rating as the gear becomes legalized and production expands. Nevertheless, WFC fell short of its objective to secure either green label status for the fishery or a letter confirming that the gear may be likely to achieve green label status from MBASW within the timeframe of this project.

Objective # 5 - Plan for a Future Fishery

During the timeframe of this S-K project, information collected by WFC and partners, as well as outreach and education efforts, informed WDFW's decision to proceed with the legalization process for commercial fish traps in the lower Columbia River (WDFW 2021; pg. 49). This represents a significant achievement, with research results from NOAA funded projects informing a major policy decision by WDFW to allow for alternatives to gill netting for the first time in over 87 years in the lower Columbia River non-tribal fishery. This will allow for mark-selective fishing and release of wild bycatch to address harvest and hatchery factors known to limit recovery of ESA-listed wild salmonids.

Beyond informing the legalization of a new selective salmon fishery, efforts were made to plan for the future of the fishery. WFC and partners developed proposed gear regulations (pg. 54-64), identified potential trap sites, streamlined the permitting process, raised awareness of alternative harvest tools, and identified necessary stakeholder mitigation options and appropriate economic incentives to facilitate an alternative gear transition in the lower Columbia River.

Proposed gear regulations are provided within this report on pages 54-57. At present, uncertainty regarding gear regulations is creating an additional barrier to fishers' permitting salmon traps in anticipation for the Emerging Commercial Fishery. WFC believes it is critical for resource managers to consider the recommendations in this report and clearly define regulations as soon as possible to guide permitting and implementation efforts within the Emerging Commercial Fishery. Consideration must be given to fish trap location, length, depth, configuration, mesh sizes, and operations. Furthermore, WFC recommends that electronic monitoring equipment be required to improve fishery observation of bycatch encounters and compliance with management regulations. Although fish traps have considerable potential to reduce bycatch mortality within commercial fisheries, traps must be designed and operated in specific ways to achieve the desired conservation benefits. Generally, it is recommended that all future traps are required to operate for passive capture and release of bycatch, rather than employing the spilling technique originally evaluated in 2016-2018. Passive capture and release will ensure that fishers are minimizing potential impacts to encountered bycatch; this outcome can only be achieved through regulation of pot/spiller configuration and operations.

WFC developed a list of constraints to consider when permitting and implementing fish traps (pg. 58-60). Based upon this information, WFC and partners identified various sites in the lower Columbia River that appear to be worthy of consideration for fish trap implementation. These potential fish trap sites are available through WFC's fish trap journal blog and website: https://thefishtrapjournal.org/want-to-build-a-fish-trap/. This website further describes step-by-step processes for fish trap siting and permitting in both Washington and Oregon in the lower Columbia River to streamline gear implementation within the Emerging Commercial Fishery. A permitting fact sheet summarizing information provided on our website is also available for download and physical distribution.

Within this report, WFC has identified various barriers to fishers transitioning to alternative gears and participating in the Emerging Commercial Fishery (pg. 66-67). Due to the various barriers identified within this report, WFC recommends development of a competitive grant program or subsidy to facilitate an alternative gear transition in the lower Columbia River. These funds could be provided by private foundations or the state legislature in efforts to benefit coastal fishing communities and wild salmon recovery.

Table VII-1. Project timeline for cooperative agreement NA19NMF4270028. Highlights in green indicate a task is accomplished; yellow indicates a task is pending action.

Project Task	Date	Increment
Initiate correspondence with MBASW	1/5/2019	Month 0
Secure all required permits/contracts	6/1/2019	Month 0
Form test fishery working group and initiate monthly meetings	6/1/2019	Month 0
Identify processing/marketing strategy	7/1/2019	Month 0
Modify design and install trap	8/1/2019	Month 0
Initiate test fishery	8/20/2019	Month 0
Initiate bi-weekly working group meetings	9/1/2019	Month 1
Complete testing	11/15/2019	Month 3
Remove trap hardware	11/16/2019	Month 3
Enter and began analyzing data	11/17/2019	Month 3

Initiate monthly working group meetings	12/1/2019	Month 4
Submit 6-month performance progress report / financial report	2/28/2020	Month 6
Draft proposed trap regulations	4/30/2021	Month 20
Develop permitting info. fact-sheet	5/31/2021	Month 21
Secure letter from MBASW	6/1/2021	Month 22
Identify potential trap sites and publish interactive web-map	6/30/2021	Month 22
Draft, review, and edit progress report	9/30/2021	Month 25
Publish final report	12/29/2021	Month 28

B. Dissemination of Project Results

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. WFC and partners achieved almost all goals, objectives, and dissemination requirements for the NA19NMF4270028 grant agreement (Table VII-2).

Table VII-2. Major project deliverables for the S-K project. Highlights in green indicate a task is accomplished; yellow indicates a task is pending action.

Deliverable	Anticipated Date	Increment
Online blog launch	8/1/2019	Month 0
WFC newsletter and journal (results and summary)	2/1/2020	Month 9
NOAA 6-month progress/financial report	2/28/2020	Month 9
Video release	3/1/2020	Month 10
Draft proposed trap regulations	4/30/2021	Month 20
Release permitting info. fact-sheet	5/31/2021	Month 21
Release letter from MBASW	6/1/2021	Month 22
Publish web-map for potential trap locations	6/30/2021	Month 22
Brochure (results and summary)	7/31/2021	Month 23
NOAA 6-month progress/financial report	9/30/2021	Month 25
Final manuscript submission and report publication/raw data	12/29/2021	Month 28

Similar to prior WFC projects with NOAA Fisheries Service, an online blog was maintained throughout the project period, enabling the public to track WFC's progress with the study and preliminary results (http://thefishtrapjournal.org/). Social media platforms and live-video streaming were also used to raise public awareness of the project. These online digital strategies once again proved successful, drawing considerable attention from the media. For example, Oregon Public Broadcasting (OPB) filmed a piece on S-K fish trap research with the televised broadcast occurring in October 2020 (https://www.opb.org/video/2020/10/29/banned-fish-trap-returns-to-columbia-as-sustainable-way-to-catch-salmon/). Furthermore, Wild Salmon Center released an article titled *Seattle Chef Renee Erickson: Eat This Salmon* describing the sustainability of fish traps, the high quality of trap-caught seafood products, and the response from a renowned Seattle chef and restaurant owner serving trap-caught salmon in 2019 and 2020 (https://www.wildsalmoncenter.org/2019/10/30/seattle-chef-renee-erickson-eat-this-salmon/).

A short-video was released describing results of the S-K project and potential benefits of in-river selective harvest techniques for recovery of wild salmonids and rejuvenation of coastal fishing communities. This film, titled *The Fish Trap*, was directed by Shane Anderson of North Fork Studios and released in March 2020 (https://vimeo.com/397820822). *The Fish Trap* 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 in 2019. This short-film served as an excellent tool to raise awareness and spur demand for trap-caught salmon with high-end restaurants and markets.

As described in the proposed *Data Sharing Plan*, all data/metadata were documented by WFC and WDFW staff. Throughout the research period, data were shared on a daily basis with WDFW and NOAA Fisheries for reference and review to ensure ESA-impacts were not exceeded. All raw data/metadata from the 2019-2021 Coho Salmon post-release survival studies 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. Data will remain secure and available to the public at all times through these means.

To summarize results of 2019 research, an 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). An article was similarly released summarizing findings of 2020 research. These summary pieces were circulated to thousands of WFC's members, which include the general public and members of the scientific and resource management communities. The tri-fold brochure that was originally proposed to facilitate result dissemination was not pursued due to the Covid-19 pandemic and the increasing obsolescence of the outreach strategy; resources intended for this purpose were used to support digital outreach strategies.

Various active outreach efforts were made at conferences, meetings, and events throughout the project period to disseminate results of the study. Presentations/meetings were accomplished at the following events: 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); the lower Columbia River Emerging Commercial Fishery Advisory Board (2/2020); WDFW Region 6 Staff Meeting (4/2020); the WA Fish and Wildlife Commission Meeting (9/2020); lower Columbia River Emerging Commercial Fishery Advisory Board Meetings (11/2020, 12/2020, 1/2021, 2/2021, 3/2021), ODFW/WDFW U.S. v. OR TAC Representative meeting (3/2021), WA State Recreation and Conservation Office Salmon Recovery Conference (4/29/21), and NOAA's Monster Seminar Jam Series (12/9/21). In addition to these events, WFC invited various visitors on site for tours of the gear in 2019 and 2020. Visitors included lower Columbia River fishers, fish buyers, resource managers from WDFW, ODFW, and NOAA Fisheries, the Columbia River

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.

During the project, WFC was invited by WDFW to attend Columbia River Emerging Commercial Fishery Advisory Board meetings. During these board meetings, WFC staff presented information, provided recommendations, and answered industry / management questions regarding fish traps and the transition to alternative gears in the lower Columbia River.

A manuscript focusing on survival of Sockeye Salmon and Coho Salmon from the modified fish trap design in 2019 was submitted, peer-reviewed, and accepted as-is for open access publication in the *North American Journal of Fisheries Management* (7/2020). Publication of the study "Modified Commercial Fish Trap to Help Eliminate Salmonid Bycatch Mortality" occurred in October 2020 (Tuohy et al. 2020) (https://doi.org/10.1002/nafm.10496). A new manuscript focused on Coho Salmon post-release survival results between 2019-2021 is currently in preparation for submission to a scientific journal for peer-review and publication.

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 (Tuohy 2020) (https://wildfishconservancy.org/TheOspreyJournal_January2020.pdf).

Coho Salmon post-release survival results from 2019-2021 were further submitted to WDFW and ODFW to inform mortality estimates for future management of the modified passive fish trap gear in the Columbia River Basin (https://wildfishconservancy.org/WFC.2020.ShortandlongtermpostreleasesurvivalofcohosalmoncapturedwithapassivefishtrapinthelowerColumbiaRiverWA.3.pdf).

Fish trap results and broader applications of the technology were published in the journal of *BioScience* in December 2020, with the co-authored article "Indigenous Systems of Management for Culturally and Ecologically Resilient Pacific Salmon (*Oncorhynchus spp.*) Fisheries" (Atlas et al. 2020) (https://doi.org/10.1093/biosci/biaa144).

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APPENDICES

A. Project Photographs

Figure A-1. Constructing the modified live well dock for passive capture in February 2019.

Figure A-2. The heart compartment apron is mended and extended in Cathlamet, WA by WFC staff to prevent entry of marine mammals.

Figure A-3. Commercial fisher Billie Delaney hanging the shore lead in 2019.

Figure A-4. Completed fish trap in 2019 looking upriver.

Figure A-5. Completed fish trap viewed from above in 2019.

Figure A-6. Salmon swimming in the heart of the trap.

Figure A-7. Salmon swimming in the heart of the trap.

Figure A-8. WFC staff fishing the passive spiller trap design in 2019.

Figure A-9. Chinook captured through the modified passive spiller treatment in 2019.

Figure A-10. Commercial fisher Jon Blair Peterson views the spiller from above in preparation for a spill of fish to the live well.

Figure A-11. Spilling fish to the live well for sorting through the prototype capture process.

Figure A-12. Hatchery-origin Chinook Salmon selected for harvest.

Figure A-13. Commercial fisher Billie Delaney releases a wild Coho Salmon.

Figure A-14. WDFW sample and weigh the commercial catch in preparation for sale to buyer Mike Clark of C&H Classic Smoked Fish.

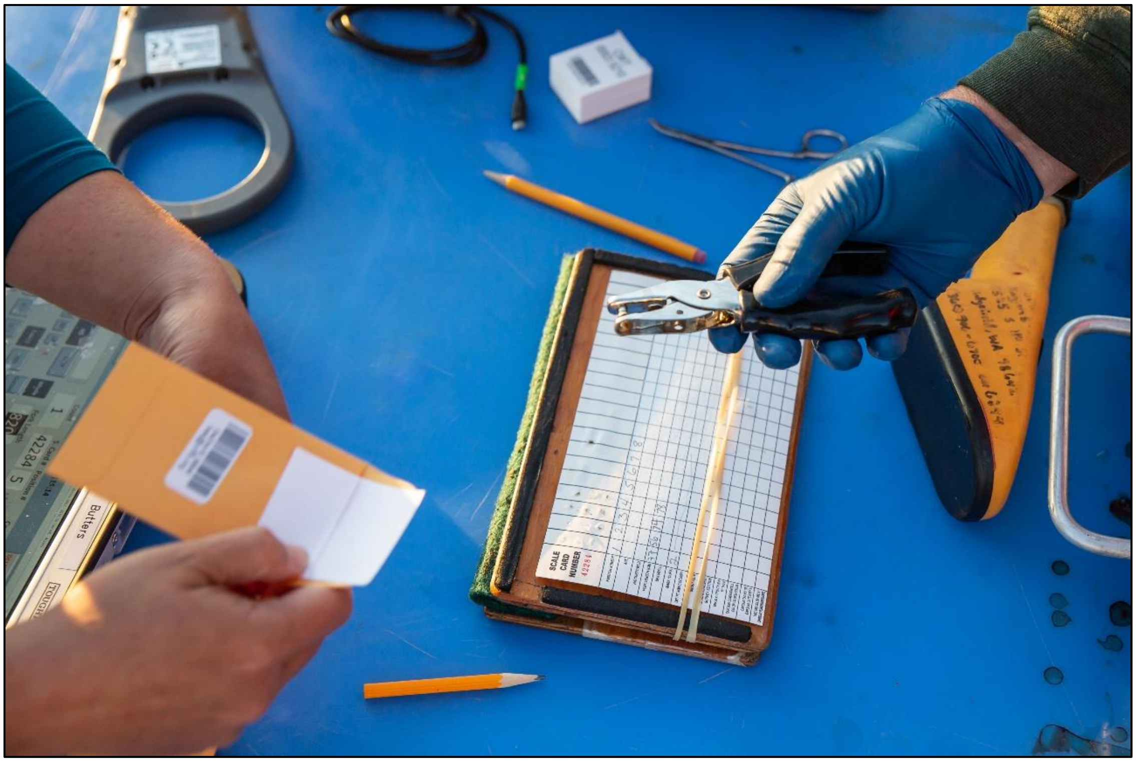

Figure A-15. WDFW gathers genetic samples from the commercial catch to determine stock composition.

Figure A-16. Fish buyer Mike Clark weighs the catch and assists WDFW in scanning for CWTs.

Figure A-17. Commercial fisher Jon Blair Peterson weighs his catch of hatchery-origin Coho.

Figure A-18. Working group members Clark (left), Peterson (center), and Tuohy (right) discuss fishing plans for the week.

Figure A-19. Commercial fisher Jon Blair Peterson tenders his catch for delivery to the processor in Cathlamet, WA.

Figure A-20. Harvested fish are hoisted to C&H Classic Smoked Fish for processing.

Figure A-21. James Beard award winning Seattle chef and restaurant owner Renee Erickson receives a shipment of trap-caught salmon in October 2019.

Figure A-22. Chef Erickson prepares trap-caught salmon at her restaurant Willmott's Ghost.

Figure A-23. Commercial fisher Jon Blair Peterson and WFC educate a Cathlamet High School science class regarding fisheries issues in October 2019.

Figure A-24. Commercial fisher Jon Blair Peterson and WFC conduct outreach in October 2019.

Figure A-25. WFC's Joe Verrelli scuba dives to check the trap nets in August 2020.

Figure A-26. Commercial fisher Jon Blair Peterson waits for a haul of salmon in August 2020.

Figure A-27. Hatchery Coho and Chinook Salmon live-bled and iced at the trap in fall 2020.

Figure A-28. Commercial fisher Jon Blair Peterson with a full tote of harvested salmon in 2020.

Figure A-29. WDFW commercial sampling crews gather data from harvested fish in 2020.

Figure A-30. Commercial fisher Jon Blair Peterson delivers his catch to the processor in 2020.

Figure A-31. WDFW observers document daily catch and release at the fish trap in 2020.

Figure A-32. The Cathlamet Channel fish trap viewed from above in September 2020. Photo by Duncan Berry.

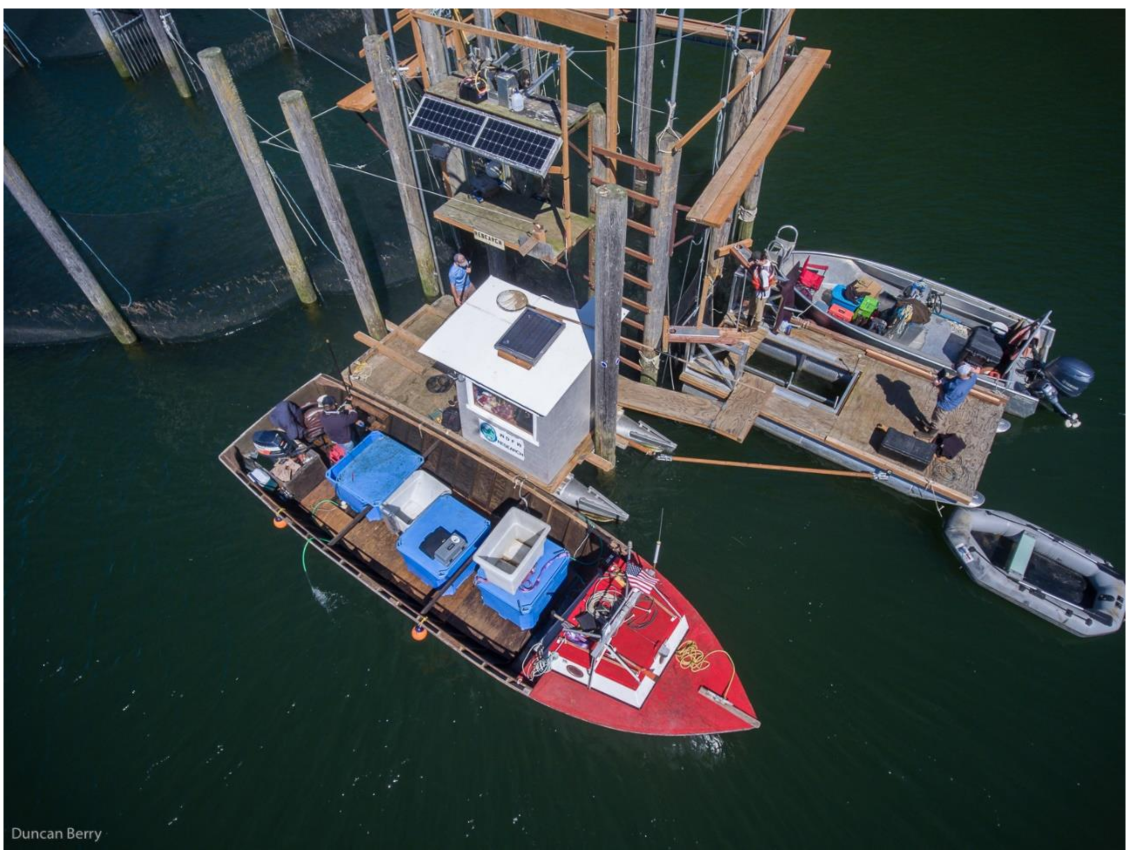

Figure A-33. The Cathlamet Channel fish trap viewed from above in September 2020. Photo by Duncan Berry.

Figure A-34. Trap-caught Coho salmon served at James Beard award winning chef Renee Erickson's restaurant The Whale Wins in Seattle, WA, October 2020.

Figure A-35. Trap-caught Coho salmon served at James Beard award winning chef Renee Erickson's restaurant Willmott's Ghost in Seattle, WA, September 2020.

Figure A-36. Trap-caught Coho Salmon served at James Beard award winning chef Renee Erickson's restaurant Bistro Shirlee in Seattle, WA, October 2020.

Figure A-37. Trap-caught Coho Salmon harvested in October 2020.