Short and long-term post-release survival of Coho Salmon captured with a passive fish trap in the lower Columbia River, WA.

Wild Fish Conservancy

Prepared by Adrian Tuohy

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Background

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 Columbia River's Cathlamet Channel (Wahkiakum County, Washington; river kilometer (rkm) 67) to reduce bycatch impacts in commercial fisheries and improve selective harvesting of hatchery-origin salmon (Tuohy 2018; Tuohy et al. 2019). The experimental salmon trap was modeled after designs historically used in the lower Columbia River and was developed to minimize physical and physiological damage to salmonid bycatch. Post-release survival from this 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 (*Oncorhynchus tshawytscha*) and coho salmon (*O. kisutch*) while improving salmonid bycatch survival rates relative to conventional gill nets. Relative survival of trapped fish compared to controls over a 400-km migration 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 efforts to further improve post-release survival of captured fishes from the gear, the fish trap design and final capture processes were modified to largely eliminate fish air exposure, handling, overcrowding, and net contact associated with the 2017 prototype trapping process. The modified passive fish trap design was evaluated in 2019, with sockeye salmon (*O. nerka*) release survival estimated through paired release-recapture (Tuohy et al. 2020). Results of the pilot study demonstrated that the relative survival effect of catch and release compared to controls was 1.017 ($\widehat{SE}$ = 0.032) for adult sockeye salmon over a 400-km migration to McNary Dam (Tuohy et al. 2020). This finding suggested that the passive trapping technique may have no effect on salmonid bycatch release survival.

Although results from the 2019 pilot study for sockeye salmon indicated that the modified passive trapping technique may prove similarly effective for safe release of other salmonid bycatch stocks, release survival rates can vary depending on the species encountered, the timing of seasonal gear operation, and water quality conditions (among other factors) (Davis 2002). For these reasons, species-specific release survival studies have been encouraged by Columbia River management agencies for most commercial gears operating within a specific season in the lower Columbia River.

Methods

Research and commercial test fisheries were conducted in the fall of 2019 and 2020 at the experimental fish trap site located in the Columbia River's Cathlamet Channel (Wahkiakum County, Washington; river kilometer (rkm) 67) to further evaluate the performance of the gear in a selective harvest setting, and to assess immediate bycatch survival (from capture to release from the gear) and post-release survival effects. To fill a major data gap for early and late-run coho salmon, net pen holding release survival studies were conducted with the passive fish trap design similar to those conducted by Buchanan et al. (2002) and Takata and Johnson (2018). Due to the migratory nature of coho salmon (which tend to spawn below mainstem Columbia River dams), paired release-recapture with PIT tags has typically been ineffective in the absence of a very large sample size (WDFW 2014). As a result, coho salmon release survival from prior alternative gear investigations has been directly estimated via net-pen holding in the lower Columbia River (Takata and Johnson 2018). This holding study was therefore performed to provide comparable data to past studies for coho salmon while supplementing the sockeye salmon release-recapture study for the passive fish trap design (Tuohy et al. 2020).

At the completion of a commercial test fishing week from late-September through October 2019 and 2020, adult coho salmon (> 47 cm FL) randomly captured at the trap through the modified commercial treatment process were transferred one-by-one with a rubberized dip net to a designated temporary holding chamber of the live well until a sample of approximately 10 to 40 fish was retained. With the desired sample size achieved after a four to eight-hour collection period, investigators sealed outlets to all spiller tunnels and turned on a field video camera for recording (GoPro Hero 7). Coho salmon were once again enumerated, identified by origin (adipose fin clipped or unclipped), measured to fork length (FL), noted for capture condition ("lively", "lethargic", or "immediate mortality"), and released from the live well by hand to the sealed spiller compartment (now functioning as a net pen holding chamber with dimensions roughly equivalent to Takata and Johnson (2018)). Once the last fish was released into the net pen, investigators initiated a short-term (48-h) or long-term (96-h) observation period and noted the date, time, water surface temperature (°C; Extech), and presence of marine mammals. For collection of all holding samples, trap operators randomly selected the first ~10-40 adult coho salmon that migrated into the live well from the spiller. As in previous studies (Takata and Johnson 2018), coho salmon that exhibited prior injuries unrelated to the commercial gear were excluded from the holding study.

Post-release survival of coho salmon was estimated by holding and observing six treatment groups of fish (mean = 20, min = 13, max = 34) for a short-term 48-h period in 2019, and three treatment groups (mean = 35, min = 29, max = 38) for a long-term 96-h period in 2020 (Pollock and Pine 2007; Takata and Johnson 2018). To determine fish mortalities during the holding periods, treatment groups were checked twice daily at regular intervals from above and below the water surface (via snorkel or underwater video survey). At the end of the holding period, all fish were cleared from the holding pen to a live well (Tuohy et al. 2019). These fish were then enumerated, measured (FL), scanned for PIT tags, identified for species type and origin (hatchery/wild), noted for condition, and released. Post-release survival from the holding studies and immediate survival from both commercial test fishing and research operations were directly estimated by a binomial proportion (p = # survived/# total) with associated binomial variance. In the case of no observed mortality, a lower one-tailed interval estimate of survival was calculated using the method in Skalski (1981). As in prior lower Columbia River holding studies, the effects of confinement on coho salmon were not controlled (Takata and Johnson 2018).

Results

Coho Salmon Short-Term Post-Release Survival - 2019

As a supplement to the 2019 sockeye salmon mark-recapture study for the passive fish trap design, a short-term 48-h coho salmon holding study was conducted between 27 September and 30 October 2019 when commercial coho fisheries commonly occur in the lower Columbia River. During the research period, water temperatures ranged from 19.2 ºC to 12.1 ºC (mean = 15.79 ºC). Encountering 3,521 adult coho salmon at the trap site in 2019 through test fishery and research operations, there were zero adult coho salmon immediate mortalities resulting in an immediate survival rate of $\hat{S}$ = 1.000 with a 95% lower confidence interval of CI ($S \geq 0.999$) = 0.95. A total of 121 coho salmon were held in captivity post-release from the commercial gear in six separate sub-sample groups (Table 1). Zero mortalities occurred during the 48-h holding period for a post-release survival estimate of $\hat{S}$ = 1.000 with a 95% lower confidence interval of CI ($S \geq 0.978$) = 0.95. All coho salmon encountered during the fish collection process for the 2019 holding study were lively and vigorous upon capture and release after 48-h, with zero fish appearing lethargic.

Table 1. Sub-samples of coho salmon captured with the modified fish trap were held for a short-term 48-h captive period to directly estimate release survival in 2019; water quality conditions were recorded.

Sub-sample number	2019 Date	Mean water temperature (°C) and 95% confidence interval	Fish sample size	Coho salmon survived	Coho salmon survival
1	27 Sep - 29 Sep	18.77 (18.69-18.85)	13	13	1.000
2	30 Sep - 2 Oct	17.74 (17.64-17.84)	27	27	1.000
3	3 Oct - 5 Oct	16.31 (16.24-16.39)	34	34	1.000
4	10 Oct - 12 Oct	15.63 (15.53-15.74)	13	13	1.000
5	23 Oct - 25 Oct	13.57 (13.50-13.65)	24	24	1.000
6	28 Oct - 30 Oct	12.75 (12.64-12.85)	10	10	1.000
-- Total --		--	121	121	1.000

Coho Salmon Long-Term Post-Release Survival - 2020

Between 25 September and 15 October 2020, a long-term 96-h net pen holding study was conducted to further confirm post-release survival of salmon from the passive fish trap design. During the research period, water temperatures ranged from 19.3 ºC to 16.7 ºC (mean = 18.08 ºC).

Encountering 2,209 adult coho salmon at the trap site in 2020 through test fishery and research operations, there were zero adult coho salmon immediate mortalities resulting in an immediate survival rate of $\hat{S}$ = 1.000 with a 95% lower confidence interval of CI ($S \geq 0.999$) = 0.95. A total of 105 coho salmon were held in captivity post-release from the commercial gear in three separate sub-sample groups (Table 2). Zero mortalities occurred during the 96-h holding period for a post-release survival estimate of $\hat{S}$ = 1.000 with a 95% lower confidence interval of CI ($S \geq 0.975$) = 0.95. 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 4-d of confinement in the net pen environment.

Table 2. Sub-samples of coho salmon captured with the modified fish trap were held for a long-term 96-h captive period to directly estimate release survival in 2020; water quality conditions were recorded.

Sub-sample number	2020 Date	Mean water temperature (°C) and 95% confidence interval	Fish sample size	Coho salmon survived	Coho salmon survival
1	25 Sep - 29 Sep	18.64 (18.54-18.73)	38	38	1.000
2	4 Oct - 8 Oct	18.37 (18.28-18.46)	38	38	1.000
3	11 Oct - 15 Oct	17.24 (17.15-17.34)	29	29	1.000
-- Total --		--	105	105	1.000

Discussion

Results from these short and long-term net pen holding studies confirm results from the sockeye salmon release-recapture study for the passive fish trap design (Tuohy et al. 2020) and demonstrate the potential of a modified commercial trapping technique to achieve 100% survival of adult salmon bycatch. Immediate survival in both years of study was 1.000 (CI ($S \geq 0.999$) = 0.95) after encounter with a combined total of 5,730 adult coho salmon. Estimated short-term release survival for the species was directly estimated at 1.000 (CI ($S \geq 0.978$) = 0.95) in 2019; long-term release survival was similarly estimated at 1.000 (CI ($S \geq 0.975$) = 0.95) in 2020. Regardless of the post-release duration of net pen holding, the modified passive capture design—which mostly eliminated air exposure and net contact, and minimized handling and crowding—had no detectable impact on salmon release survival. These results, paired with 2019 sockeye salmon release-recapture results (Tuohy et al. 2020), suggest that the passive fish trapping technique employed in this study could significantly reduce salmonid bycatch mortality if applied in terminal commercial salmon fisheries for selective harvest purposes.

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