



Indian Creek Pink and subyearling Chinook smolts

2022 Elwha River Smolt Enumeration Project Report

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Klallam Tribe

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Executive Summary

Smolt enumeration was conducted on the Elwha River, Little River and Indian Creek during the 2022 outmigration season. This represents the seventh year of monitoring during the post dam removal period, and the 17th consecutive year of smolt monitoring on the Elwha River. The mainstem trap was fished upstream of both hatcheries and we fished 185 of 186 possible days (99%). We generated watershed production estimates, 95% Confidence Intervals (CI), and coefficient of variation (CV) estimates for Chinook salmon (0+), Coho salmon (0+), Pink and Chum salmon. Because of catchability issues we did not generate estimates for any large-bodied smolts from this site in 2022 and those estimates were made at the lower river trap. We estimate a total of 111,454 Chinook salmon subyearling outmigrants for the Elwha River in 2022. This represents a dramatic decrease in Chinook outmigrants over the previous three years and is likely a direct result of low adult Chinook escapement in the 2021 brood year. Chinook productivity, expressed as the number of smolts/female, was significantly lower than in the previous four years and was likely affected by both low escapement as well as scour impacts from multiple high flow events during the incubation period. Production of Chum salmon remains very low (estimate 316) in the Elwha River and suggests that these populations have not begun to recover from the combination of low population size at the beginning of dam removal and the sedimentation impacts from dam removal.

In order to address the low catchability of large bodied smolts at the upper mainstem site, we added a second trap at the historic lower river site in 2022. Although operations were negatively affected by hatchery releases, the trap proved effective at capturing large bodied smolts. Although the trap fished only 52% of the potential days we generated estimates for Coho smolts (45,278), Chinook yearlings (670) and Steelhead (4,741). These estimates should be considered conservative minimums. We make recommendations for increasing the precision of these estimates in future years.

At the tributary sites, smolt trapping was continuous and we fished nearly 100% of potential fishing days. For Indian Creek and Little River we estimated Coho salmon (ages 0+ and smolts), Chinook salmon (0+ and 1+), Pink, Chum and and Steelhead smolts. At Indian Creek, we estimated 141,307 0+ Chinook outmigrants in 2022. Chinook productivity was 1,503 smolts/female reflecting stable incubation conditions. We estimated 13,038 (11,254-14,822) Coho smolts and 1,779 (1,206-2,353) Steelhead outmigrants from Indian Creek in 2022. For Little River, we estimated a total outmigration of 22,103 Chinook salmon 0+ smolts as well as 302 (129-475) Chinook yearling smolts. Chinook productivity was high at 553 smolts/female, possibly as a result of recently completed habitat restoration. Coho salmon smolts were estimated at 741 (384-1,098) outmigrants. The estimated number of Steelhead smolts was 104 (28-108). Based on ten years of trapping at Indian Creek, there is no evidence that anadromous

sockeye life history has expressed from the kokanne population in Lake Sutherland or by natural reoccupation. Significantly, the first signal of Pink salmon recovery was measured following dam removal at all sites in 2022. Pacific lamprey populations also continue to expand throughout the watershed as significant numbers of juveniles (ammocoetes) and outmigrating macrophthalmia were captured at the mainstem and Indian trap in 2022. A total of 400 ammocoetes were captured at Little River suggesting that Pacific lamprey have now reoccupied habitats in that tributary.

Introduction

Removal of two mainstem hydroelectric dams on the Elwha River was completed in 2014. This action was authorized by the Elwha River Ecosystem and Fisheries Restoration Act of 1994 (PL 102-495) and represents the largest dam removals conducted to date in the United States. The Elwha Act was designed to recover native salmon populations and their associated ecosystems. Dam removal on the Elwha has generated national attention and there is great interest amongst state, federal, and academic scientists to assess the effects of Elwha dam removals on aquatic and terrestrial ecosystems. The response of Pacific salmon to dam removal is of particular interest, and for the Elwha Project recovery goals have been developed. These goals include: 1) the preservation of native anadromous salmon before, during and after dam removal, 2) reestablishing self-sustaining anadromous salmon populations and habitats as quickly as possible, and 3) restoring the physical and biological processes of the ecosystem (Ward et al. 2008).

To evaluate the salmon recovery and adaptively manage restoration of Chinook salmon (*Oncorhynchus tshawytscha*) and Steelhead (*O. mykiss*) on the Elwha River, specific guidelines were developed in the Elwha Monitoring and Adaptive Management Plan (EMAM) (Peters et al. 2014). The EMAM (and closely related biological opinion for Elwha hatchery operations¹) provides quantitative performance targets that could be used to effect management actions necessary to achieve recovery of the populations. The EMAM uses performance indicators coupled with management triggers to guide project managers through four stages of recovery (Ward et al. 2008). Performance indicators used in the EMAM are based upon Viable Salmon Population (VSP) metrics including abundance, productivity, spatial distribution and diversity (McElhany et al. 2000). These metrics were chosen because they are predictors of extinction, reflect general processes important to salmon, and are measurable. They can be intrinsically connected to the recovery of depleted and federally listed Elwha salmon and Steelhead populations.

¹ NOAA Consultation #NWR-2012-9426

As lead for dam removal, the National Park Service (NPS) submitted a Chinook and Steelhead Monitoring Plan pursuant to Biological Opinion for the Elwha River Restoration Project (National Marine Fisheries Service 2012). This monitoring plan, based upon a draft version of the EMAM was approved by NMFS on March 7, 2012, and describes the specific tasks that NPS intends to undertake to document dam removal impacts to listed salmon species and meet the requirements of the Biological Opinion. Smolt outmigration monitoring is one of the required components of the Biological Opinion. This action has been contracted to the Lower Elwha Klallam Tribe (LEKT) by National Park Service (NPS).

Fundamental questions regarding the recovery and trajectory of Elwha River salmon populations can in part be addressed through smolt enumeration. These include not only abundance and productivity trends, but life history traits such as the timing and size at outmigration. LEKT established a smolt enumeration program on the Elwha River beginning in 2006. During the pre-dam removal period (2006-2011) LEKT successfully estimated the number of small-bodied 0+ Chinook salmon, Chum salmon (*O. keta*) and Pink salmon (*O. gorbuscha*) smolts using an 8' rotary screw trap fished at river kilometer (Rkm) 0.3. Funding of trap operations during this period was provided by the Pacific Coast Salmon Recovery Fund (NOAA). Estimation of larger sized Coho salmon (*O. kisutch*) smolts and Steelhead smolts has historically been more problematic because of their lack of abundance in the formerly highly degraded Elwha River combined with their ability to avoid the trap. However, overall improvements in the trapping program combined with increasing abundance of smolts has increased our ability to make estimates for large-bodied smolts in some years.

The 2022 trapping season represents the seventh year of mainstem Elwha monitoring following dam removal and the seventeenth year in total. The post-dam removal period is a significant project benchmark and metrics associated with smolt outmigration are important for assessing rates of recovery for Pacific salmon. The objectives of this document are to: 1) describe and to discuss the changes in abundance for natural origin salmon, 2) report on the ecological significance of those changes, 3) document field protocols for smolt outmigration data acquisition in the mainstem and tributary sites; 4) develop a procedure for deriving a smolt production estimates from raw catch counts; 5) describe the sources of uncertainty; and lastly to 6) document issues that resulted in a coefficient of variation estimate greater than 15%.

Methods

History of Operations

During the pre-project (2006-2011) and dam-removal periods (2012-2015), mainstem trapping operations were initiated in mid to late February and continued until late June. These

dates were predicated by flow conditions in the early portion of the season and interactions with releases of 2-4 million smolts from the WDFW/LEKT hatcheries in the spring. LEKT was aware that these dates were not ideal in terms of capturing the early portion of Chinook outmigration (Weinheimer & Zimmerman 2012) and has since extended mainstem trapping efforts during the post dam removal period (2016-2022). During the pre-dam removal period, the end of trap operations was determined by catch rates and the mainstem trap catches tended to drop toward near zero by mid to late June, due to the low natural production of salmon in the Elwha River. In other Puget Sound drainages, Chinook salmon outmigration is typically bimodal, with earlier peaks dominated by small, recently-emerged migrants and later peaks dominated by larger parr migrants that rear in freshwater for several to many weeks (Kinsel et al. 2008; Kiyohara and Zimmerman 2012). Yearling Chinook life histories are also observed in Puget Rivers, including the Elwha but are generally less abundant.

During the dam-removal period (2012-2015), sediment and debris entrained in the river negatively affected trapping operations. Conditions were so poor in 2013 that trapping operations were discontinued mid season as sediment and small organic debris overwhelmed the trap box and unacceptable levels of mortality occurred. The changes in river conditions forced changes in both trap size and mainstem location during the dam removal period. Due to sediment aggradation associated with dam removal, the lower river site was temporarily abandoned during the 2013-2014 seasons and operations were moved upstream to the Spruce Hole site at Rkm 2.5. By the early winter of 2015, the lower river site had evacuated enough sediment to support trapping operations with the smaller 5' screw trap. River conditions have steadily improved since 2015 and LEKT was able to reoccupy the lower river site using the larger 8'screw.

Changes in channel morphology during the dam removal period have not only affected the fishing sites, but also the size of trap used. During the pre-dam removal period (2006-2011) river conditions were quite stable and LEKT utilized an 8' rotary screw trap fished at Rkm 0.3 in all years. However, as dam removal progressed into 2013 the pool at Rkm 0.3 rapidly filled and was reduced from greater than 3.0 m to less than 1.0 m in depth. We adapted and used a smaller, 5' diameter screw trap. Since 2016, enough sediment had evacuated the lower river fishing site to again support the operation of the 8' screw trap. In 2019, LEKT decided to abandon the lower river trap site in favor of a site located at Rkm 4.0, which is above both hatcheries (Figure 1). This decision was made because the annual release of 2 to 4 million hatchery produced smolts overwhelmed the trap holding capacity and caused operations to be delayed for days to weeks at a time. It also eliminated identification errors between naturally produced and unmarked hatchery fish, particularly Chinook salmon.

While the upper mainstem trap site has proved effective at enumerating small bodied smolts, its performance capturing large bodied smolts has been inconsistent. To address this problem, LEKT fabricated a new 5' screw and redeployed it at the former lower river mainstem site at Rkm 0.3 during the 2022 season. This site had changed dramatically since dam removal and we were able to place the tribe directly into higher velocity areas of the main thalweg. While still impacted by hatchery releases the trap proved effective at catching large bodied smolts.

LEKT established tributary smolt monitoring sites on Little River in 2012 and Indian Creek in 2013 (Figure 2). We use county road bridge crossings in each tributary for trap deployment and retrieval. For Little River, we use the bridge crossing on Hot Springs Road located at Rkm 0.2, and for Indian Creek the bridge crossing Aldwell Reservoir Road located at Rkm 0.6. Both crossings are maintained by the Clallam County Road Department and their permission was obtained to utilize these sites. Traps are deployed and retrieved using a truck mounted crane. On Little River for the 2012-2015 period we used a standard 5' diameter screw trap in a pool approximately 1.5 m deep. In 2016 we retrofitted the Little River trap with a 4' screw to reduce drag during low flow periods. The Indian Creek site is narrow and shallow, and since the inception of fishing the the LEKT has used a 4' screw on a narrower pontoon to fish in all years (Figure 2). Both traps have fished with excellent results to date, with the exception of Little River, which in the later season can be prone to low flows that are insufficient to turn the screw. In 2020, we fabricated an entirely new trap for Little River which greatly improved fishing. The location of the traps over time within the Elwha watershed is depicted in Figure 3.

Daily Operations-2022

In 2022, LEKT commenced trapping operations in the upper mainstem on January 29 and ceased trapping efforts on August 2 when flows and daily catches declined to very low levels. In contrast to the pre-2019 period, when multiple days were lost to the combination of flows, damage by debris and hatchery releases we fished the mainstem trap for 188 of 189 (99%) possible fishing days in the 2022 fishing season. Fishing was not impacted by fine sediment and woody debris as in the dam removal period. The mainstem trapping effort by year is summarized in Figure 4. Because of trap construction issues, the lower mainstem trap was not deployed until March 31 and was fished to August 9. The lower trap fished 68 of 131 possible days (52%) and was not fished during the primary hatchery release periods in April and June.

At Indian Creek, trapping commenced on January 21 and ceased operations on August 30th, for a total of 222 of 222 (100%) potential fishing days. At Little River trapping was also initiated on January 21 and was concluded on August 18 for a total of 197 of 200 (100%) possible fishing days. The tributary fishing effort by year is summarized in Figures 5 and 6. In

2022, we did not install a fence weir on upper Indian Creek. LEKT staff considered this operation to be interfering with outmigration of smolts from Lake Sutherland, as well as an upstream migration of hundreds of yearling cutthroat from Indian Creek to the lake.

Field Methods

For all sites, the traps were inspected and cleaned either daily or every other day. All captured fish were removed from the trap box using dip nets and transferred to plastic buckets for identification. Each fish was individually examined for tags or marks, identified to species, counted and immediately released downstream of the trap. We use plexiglass fish viewers to facilitate fish identification.

A weekly subsample of all species (first 20 fish of each) caught was measured and weighed throughout the outmigration period. Fish greater than 55 mm were also scanned for presence of Passive Integrated Transponder (PIT) and coded wire (CWT) tags (mainstem trap only). PIT tags are being used in the middle Elwha to assess the movements, growth and survival of salmon (Liermann et al. 2017) and Pacific Lamprey. All fish that had PIT tags were also identified to species, measured, weighed and their unique tag number recorded. CWTs are inserted into the snouts of a portion of the juvenile Coho salmon and yearling Chinook salmon reared at the LEKT hatchery and Washington Department of Fish and Wildlife (WDFW) hatchery respectively, while all Steelhead and the majority of Coho salmon produced at the LEKT hatchery receive an adipose fin clip.

In order to evaluate catch efficiency (proportion of total outmigrants captured), we conducted a total of 34 mark recapture tests at all three trap sites using both small and large bodied smolts in 2022. For each test we marked a group of fish, released them upstream of the trap and then counted the number of marked fish recaptured in the trap. For all trap efficiency tests we used Bismarck Brown dye which gives the fish a distinctive mark that is readily recognizable by trap personnel. This is a non-toxic vegetable based organic dye that is absorbed into the fish's skin resulting in a brown coloration that contrasts well with silvery smolts. The mark fades over time but is visible for 7 to 10 days following marking. Trap efficiency tests for all sites are summarized in Table 1 (small bodied trials) and Table 2 (large bodied trials).

On the tributaries, weekly to biweekly samples of 12 to 167 fish, representative of the natural species migrating at any given time (i.e. 0+ Chinook, 0+ Coho salmon, Coho salmon and Steelhead smolts), were marked and released approximately 100 meters upstream of the trap site. These trials of natural fish were also supplemented with additional tests using hatchery origin 0+ Chinook from the Washington Department of Fish and Wildlife (WDFW) Elwha River hatchery. The percentage of smolts recaptured varied depending upon flow and site conditions. In general, the tributary sites had relatively high mean recapture rates in

comparison to the mainstem sites. The majority of tests utilized small-bodied 0+ Chinook salmon, which were abundant at both tributary sites in 2021. A total of 15 and 11 recapture trials were completed for Indian Creek and Little River, respectively. Recapture rates for small bodied fish averaged 25% and 14% at Indian Creek and Little River, respectively. For large bodied fish recapture rates averaged 40% and 14% for Indian Creek and Little River, respectively.

For the upper mainstem trap efficiency trials we conducted a total of 10 trap efficiency tests only using small-bodied 0+ Chinook salmon obtained from the WDFW fish hatchery. We conducted thirteen separate trials between early March and late May using releases of 722-1,510 marked 0+ Chinook and the average recapture rate was 4.3% (range 2.2-6.7%). At the lower site we conducted five mark-recapture trials using on large-bodied smolts (CohoCoho and Steelhead). The recapture rate averaged 4.3% (range 1.9-12.2). For both sites marked fish were released approximately 500 m above the mainstem trap and were typically recaptured within 1-4 days.

Data Analysis

The daily catch data along with efficiency trials were used to estimate total numbers of fish migrating past the traps for the season. We calculated estimates for all fish/trap combinations where 10 or more fish were captured. To incorporate uncertainty due to expansion based on trap efficiency we applied a modified version of the Lincoln-Peterson estimator described by Carlson et al. 1998, and expanded to accommodate missing catch by Weinheimer et al. 2011. See the Appendix C for details. We filled gaps in the catch series using the average of catches a week before and after the missing day. For days with less than 24 hours of trap operation we expanded the catch using 24 hours/# hours fished that day. In 2021, we did not account for uncertainty due to missing days or partial days because the traps were fished almost continuously. We summarize the results with the median and 95% confidence interval for total passage. We also include the coefficient of variation (standard deviation/mean) and the geometric coefficient of variation (which is more appropriate for skewed distributions).

For juvenile Chinook outmigrants (0+), we first estimated the number of outmigrants to the individual trap sites. Because the traps are located upstream of the confluence of the Strait of Juan de Fuca (mainstem) and the Elwha (tributaries), we expanded the estimates to include Chinook production downstream of the traps. To do so we assessed the geospatial distribution of redds on the Elwha River collected during 2020 Chinook peak spawning ground surveys (McHenry et al. 2020). At each trap site the number of redds distributed upstream of each trap site was divided by the estimated number of outmigrants collected in 2021 to generate an average number of smolts produced per redd. To account for redds produced downstream of

each trap site we multiplied the number of redds downstream of each trap by the average number of smolts produced per redd. This product was added to the estimate at the trap.

We calculated the number of smolts/female Chinook by dividing the smolt estimate by the number of females from the outmigration brood year. We used the SONAR estimates generated by Denton et al. (2020) for total in river escapement, subtracting the number of fish taken for broodstock by the WDFW hatchery. This number is multiplied the sex ratio of sampled carcasses from the brood stock program (Weinheimer et al. 2018).

$$\text{Smolt/female} = \# \text{ 2021 Chinook Outmigrants} / (\text{2020 Sonar Adult Estimates} - \text{Hatchery Broodstock Removed}) * \text{proportion of females}$$

To generate Chinook egg to outmigrant survival, we divided the outmigration estimate by the product of the total number of redds observed during peak Chinook surveys (McHenry et al. 2020) multiplied by the average fecundity of females used in the broodstock program (Weinheimer et al. 2018).

$$\text{Egg to Outmigrant Survival} = \text{2021 Outmigration Estimate} / \text{2020 Redd Count} * \text{Average Fecundity}$$

Results

Smolt trapping on the Elwha River was successfully completed at all sites in 2022. Moving the trap upstream has eliminated hatchery release impacts resulting in an increase in fishing time and precision. Similar to the last six seasons, the 2022 trapping season was not significantly interrupted by sediment or small woody debris at the mainstem site as river conditions have stabilized following dam removal. During the incubation season one moderate peak flow of ~24,000 cfs occurred with several smaller flood events. Flow conditions were mostly benign during the 2022 trapping season and fishing was briefly halted during periods in April and June (Figure 7).

In 2022, production estimates were made for Chinook salmon (0+), Coho salmon (0+), Pink and Chum salmon, at the upper mainstem site (Table 3). Low catch rates of large-bodied smolts continue to affect this site. In 2022, 0+ Chinook salmon were the most numerous species captured in the mainstem trap with a total of 3,780 captured. We estimated a total 0+ Chinook salmon smolt outmigration of 91,640 (80,600 - 102,680) to the trap. Using the number of Chinook salmon redds (407) counted upstream of the trap in 2021, we calculated that each redd produced an average of 225 smolts. In order to account for the number of Chinook salmon redds constructed below the trap (88) we used the average Chinook salmon smolts/redd value multiplied by the number of redds below the trap to account for an additional 19,814 0+ Chinook salmon. Therefore, the total 0+ Chinook salmon estimate for the Elwha River in 2022 is

111,454 (98,027 – 124,881). In addition, we estimated the production of 60,992 (49,762 - 72,223) 0+ Coho salmon, 316 (104 - 528) Chum and 1,240 (556 - 1,923) Pink salmon smolts for the Elwha River in 2022. Estimated catch and production estimates for the upper mainstem trap in 2022 are summarized in Table 3.

In 2022, we added a lower mainstem trap to assess its ability to capture large-bodied smolts. We fished the original mainstem site at Rkm 0.3 using a 5' screw. This site had changed since dam removal and is characterized by a river right meander with a high velocity riffle that feeds a glide. The trap was placed in this location on March 31 and fished until August 9. The trap proved successful at capturing large-bodied smolts including 1,065 Coho, 205 Steelhead and yearling Chinook despite only fishing 52% of the possible days as a result of not fishing during hatchery releases in April and June. Based on these catches we generated estimates of 45,278 Coho, 4,741 Steelhead and 670 yearling Chinook (Table 5). These estimates should be considered as minimums as a result of the late date of launch as well as the number of missed days.

We estimated adult, juvenile Chinook salmon abundance and productivity in the Elwha River, Indian Creek and Little River over the period of record using outmigration estimates along with annual redd counts (2005-2022) and SONAR escapement estimates (2011-2022). For the mainstem site, the production of 0+ Chinook salmon averaged 48,185 during the pre-dam removal (2005-2011) period. During dam removal period (2012-2015) the number of subyearling Chinook outmigrants did not change significantly and averaged 46,973. During the post-dam removal period (2016-2021) natural Chinook salmon estimates remained low through 2018 but increased dramatically for the 2019 (571,817) and 2020 (1,057,329) outmigration years. The 2022 Chinook outmigration of 111,454, while less than half the 2021 estimate, is still the fifth highest recorded during the period of record. As a result, the post-dam removal average is 310,746 subyearling Chinook salmon outmigrants (Table 4). Trends in Chinook salmon sub-yearling abundance over time are summarized in Figure 8.

We assessed Chinook salmon productivity by calculating the number of smolts produced per female over the period of record (2005-2022). In general, the productivity of Elwha Chinook salmon has exhibited two trends over period of record: low or declining levels prior to and during dam removal followed by increasing productivity as channel conditions stabilized following dam removal. During the pre-dam removal period (2005-2011), productivity averaged 130 (range 44-395²) smolts/female. During dam removal Chinook salmon smolts/female further declined further and averaged 63 (13-113) smolts/female. During the post dam removal period Chinook salmon productivity remained low until the 2019 outmigration year when productivity

² 395 smolts per female appears to be an outlier for the pre-dam removal period. If this value is removed the pre-dam removal average is 81.

increased dramatically to 309 smolts/female. The 2022 outmigration year declined to 106 smolts/female and this decreased the post-project average to 161 smolts/female (range 43-309). The four year geometric mean for the period from 2019-2022 was 230 smolts/female. Trends in Chinook salmon sub-yearling productivity over time are summarized in Figure 8.

The 2022 tributary trapping season was again successful and both screw trap sites were fished continuously and we fished a total of 222 and 197 days on Indian Creek and Little River, respectively. Production estimates for Indian Creek continue to be high for a number of species. We generated estimates for 0+ Chinook salmon (141,307), 1+ Chinook salmon (45), 0+ Coho salmon (71,791), Coho smolts (13,038) and Steelhead (1,779) at Indian Creek (Table 6). We estimated a total Pink salmon outmigrants at 1,937, the highest since the project began Chum and 125 Chum. In 2022, Chinook productivity remained high and we estimated 1,044 smolts/female and 553 smolts/female for Little River and Indian Creek, respectively.

In Little River, species-specific estimates were generated for 0+ Chinook salmon, 1+ Chinook salmon, 0+ Coho salmon, Coho smolts, Chum, Pink and Steelhead (Table 7). The estimate of 22,103 Chinook 0+ is of the lowest to date. Moderate numbers of Chinook salmon redds (40) were observed in Little River in 2021 and we estimated that brood produced 16,577 sub yearling migrants to the trap site. Chinook salmon yearlings were also encountered and we generated an estimate of 302. For Coho salmon we estimated a total of 16,599 (11,840-21,358) and 741 (384-1,098) for 0+ fry and smolts, respectively. A record number of Pink salmon were captured, progeny of the record high adult escapement observed in 2021. This generated an estimate of 14,065 (7,992-20,137) Pink salmon. Finally, we estimated the number of Steelhead produced from Little River at 104 (28-180). For all trap sites we plotted estimated catch and expansion factors for all species in 2022 (Appendix A and B).

We assembled the miscellaneous species catch records for all three trap sites that included three year classes of *O. mykiss*, three year classes of Cutthroat (*O. clarki*), Bull trout (*Salvelinus confluentus*), Brook trout (*Salvelinus fontinalis*), plus all non-salmonids (Table 8). No total production estimates were made for these species, however total catches were summarized and analyzed for ecological significance. For trout there were large numbers of *O. mykiss* 0+, 1+ and 2+ age classes that were captured at Indian Creek and Little River in 2022. In contrast Cutthroat trout are rarely encountered in Little River. Thirteen Cutthroat smolts were captured at Indian Creek. Four Bull trout were captured in Little River and 14 were encountered at Indian Creek. The only non-native fish encountered during trapping operations are Brook trout, which are well established in Indian Creek. The 9 Brook trout captured at the trap were removed from the system.

For non-salmonids we report three interesting results: 1) the continued expansion of Pacific lamprey (*Entosphenus tridentatus*) in the Elwha River, 2) the rapid increase in sculpin

populations encountered at the mainstem trap, and 3) the rapid increase of Redside shiner (*Richardsonius balteatus*) encountered at Indian Creek. In 2022, total Pacific lamprey captures were the highest to date at Indian Creek (Figure 9) and were the highest to date on the mainstem trap. At Little River we caught 400 juvenile lamprey, also a new record. For sculpin the number of encounters at the mainstem were generally less than 600/year during the pre-dam removal period. That number dropped precipitously during dam removal but has averaged between one to two thousand since 2019 (Figure 9). In 2022 we also identified sculpin to species and found that the vast majority (>95%) of sculpin captured at the mainstem trap were Coastrange (*Cottus aleuticus*). Prickly sculpin (*Cottus asper*) were also encountered at the mainstem but were much more common at both sites in Indian Creek. Prickly sculpin at the upper Indian Creek are exceptionally large, likely from rearing in Lake Sutherland.

Discussion

The outmigration estimates for Elwha 0+ Chinook salmon smolts in 2022 was 111,454, which represents a significant decrease over the last three years. While reduced from the previous three years, the 2022 outmigration estimate is similar to the annual estimates from other Puget Sound Rivers. For example, the Dungeness and Nisqually Rivers have averaged 51,968 and 146,641 naturally produced Chinook subyearling smolts respectively for the period from 1999-2018 (Unpublished Data, WDFW). In contrast, the Skagit River, the largest Chinook river in Puget Sound (8.4 times as large as the Elwha), has averaged 3,455,290 Chinook sub-yearling smolts for the period 1993-2018.

Juvenile Chinook productivity as expressed as the number of smolts produced per female has increased on the Elwha following dam removal and the stabilization of channel spawning habitat over time (Figure 10). The pre-project, dam removal and post-project averages are 130, 63, and 161 smolts/female. Additionally, the four year geometric year productivity for the period from 2019-2022 is 230 smolts/female. The low productivity values prior to dam removal are explained by the combination of low numbers of natural spawners, limited habitat area for spawning, and degraded spawning habitat conditions (sediment starvation). Before dam removal, the river had incised and its bed coarsened to the point there were only a handful of areas where Chinook salmon could actually construct nests (Pess et al. 2008). Additionally, low numbers of returning Chinook salmon adults resulted in the majority of fish being cycled into the hatchery program as brood stock. During dam removal, large volumes of sediment were released resulting in unstable channel conditions and high levels of fine sediment creating poor incubation environments for Chinook salmon. Based upon smolt production data it appears incubation conditions remained poor into the post project period at least through the 2017 brood year. In other Puget Sound Rivers, Chinook salmon productivity is

variable and based on data from six Puget Sound Rivers ranges from less 100 to nearly 1,200 smolts/female (average 192 smolts/female) (Unpublished Data, WDFW; Hall et al. 2018).

The 2022 Chinook estimate, while approximately one-quarter of 2019 and one-tenth of 2020, is still twice the pre-project average (Table 3). In 2021, adult Chinook salmon escapement to the Elwha River was greatly reduced and only 495 redds were enumerated during spawning ground surveys (McHenry et al. 2022). Those eggs were subjected to a flow year with moderate to high peak flows including a 24,000 cfs event during the incubation period (Figure 7). It was previously hypothesized that egg-to-emergence survival of Chinook salmon that spawned during the dam removal period was low as a result of unstable streambed incubation conditions due to the high sediment supply associated with dam removal. This was corroborated by low Chinook salmon production through the 2018 trapping season along with the highest egg to outmigrant survival rates recorded between 2019-2021. A negative correlation between peak flows and Chinook salmon survival has been reported in Puget Sound (Greene et al. 2005; Waples et al. 2008). Unstable bed conditions, particularly in the areas affected by peak sediment transport (downstream of former Glines Canyon dam) during dam removal has also likely limited the survival of incubating embryos on the Elwha River to date. (Pess et al. in review). We previously explored the relationship between flow, suspended sediment levels and Chinook survival (fry/spawner) on the Elwha River between 2011-2017. The index of flow and suspended sediment concentrations were negatively correlated with Chinook survival for those years (McHenry et al. 2019, Pess et al. in review). During the 2022 incubation period, September 2022 to December 2022, there were 15 “bedload” moving flow events (Ritchie et al. 2018) of greater than 2,000 cfs, some of which were greater than 10,000 cfs. The number of such events has not occurred since 2015, one of the lower survival years since initiation and completion of the Elwha dam removals.

Based on estimates of adult Chinook abundance obtained by SONAR (Denton et al. 2021) combined with an average fecundity of 5,800 eggs/female (WDFW, Unpublished Data) we estimated the survival of Chinook eggs to the outmigrant stage over time (Figure 10). In 2022 the survival of Chinook eggs to the outmigrant stage was 4%; half the previous year’s value. This metric has tracked the recovery of the river from dam removal (Figure 10). The pre-project (2005-2011) average was 3%. During dam removal (2012-2015) the average declined to 1.2%. During the post-project period (2016-2021) the survival of Chinook outmigrants increased to an average of 5%, with the highest values occurring in between 2019-2021.

The large number of Chinook salmon subyearling outmigrants produced between 2019-2022, while encouraging, will need to survive the remainder of their life history in order to produce significant numbers of adult Natural Origin Recruits (NOR). Based on weekly samples of fish length and weights measured at the mainstem trap, the majority of outmigrating Chinook

salmon were small (<60 mm) (Figure 11). For Puget Sound Chinook salmon, size at outmigration may be related to survival to adulthood. Using otolith analysis, Campbell & Claiborne (2017) have shown that small outmigrants exhibit different degrees of survival to adults. The authors found that small Chinook salmon outmigrants contributed up to 35% of returning adults in northern Puget Sound watersheds (Skagit, Nooksack). In contrast, southern Puget Sound watersheds (Cedar, Green, Puyallup) small Chinook salmon contributed to <5% of the returning adults. These differences were attributed to estuary conditions that are mostly intact in northern Puget Sound and severely degraded in South Puget Sound (with exception of Nisqually). Dam removal on the Elwha resulted in a restored estuary that is seeing increasing utilization by juvenile Chinook and other salmonids (Unpublished Data, Lower Elwha Klallam Tribe).

The estimated number of 0+ Chinook salmon produced from Indian Creek (141,307) was significant and likely an underestimate as unknown numbers of outmigrants likely passed the trap site prior to trap installation on January 21. Indian Creek had moderate numbers of Chinook spawners in the 2021 brood year with 94 redds counted. In contrast, Little River produced an estimated 22,103 Chinook outmigrants based on a redd count of 40 in the 2021 brood year. Little River has had four of nine years where few or no Chinook salmon entered the system. We hypothesize this is due to the combination of low attraction flows and relative small stream size, along with location of the mainstem on the west side of the valley (opposite of the mouth of Little River) in those years. Based on redd counts, along with estimation of outmigrating Chinook smolts, productivity of the two tributaries is very high (Figure 12) as compared to the mainstem. We hypothesize that this because the tributaries are much more resistant to scour impacts than the mainstem Elwha River.

We compared the total outmigration estimates between tributaries and found some noticeable differences in abundance and timing (Appendix A and B). In past seasons, large numbers of 0+ Coho salmon parr outmigrants were detected moving downstream through PIT antenna arrays in Little River and to lesser extent Indian Creek, presumably to rear in other habitats or immigrating to the Strait of Juan of de Fuca as parr (Liermann et al. 2017). Coho parr emigration during the fall has been documented in other nearby Strait of Juan de Fuca watersheds and has been shown to result in survival to adulthood (Bennett et al. 2014). This pattern was not observed in 2016 for Indian Creek and Little River, likely as a result of the record low escapement of Coho salmon in 2015. This pattern reappeared in 2017, 2018, 2019, 2020 and 2021 at both sites. In 2022 we estimated the total outmigration of 0+ Coho salmon at 67,497 and 16,599 for Indian Creek and Little River, respectively. The consistently higher proportion of fall migrants from Little River is likely a result of habitat differences between the two tributaries. Little River is cold, steep, and degraded from historic land use practices. In contrast, Indian Creek contains abundant low gradient habitat with vast off-channel areas such

as beaver dam complexes and wetlands. We hypothesize this is a density-dependent response and in Little River habitat for rearing quickly becomes limiting. For Coho salmon smolts, Indian Creek produced an estimated 13,038 fish, which is the third lowest since monitoring began in 2013. For Little River we estimated a total of 741 Coho smolt outmigrants, the fourth highest over the period of record

Steelhead smolt production in the Elwha River has generally increased since the LEKT was able to generate its first production estimates from 2015-2019. This is supported by increasing number of Steelhead counted by SONAR and in snorkel surveys for summer steelhead. Prior to 2015, and 2020 and 2021 we encountered so few Steelhead smolts (less than 50/year) that we were unable to generate a valid estimate at the mainstem. In 2022 we captured only 10 individual Steelhead smolts at the upper trap and as a result there is no mainstem estimate for that site. Steelhead are also capable of avoiding capture in screw traps and even if caught can escape by swimming out of the capture box. Other Puget Sound smolt trapping programs also struggle with Steelhead estimation in some years (Personal Communication, Joe Anderson, WDFW). In 2021 LEKT conducted trap efficiency testing using Steelhead smolts on the mainstem. We conducted three separate trials using a total 882 Bismark brown Steelhead smolts obtained from the LEKT hatchery and only recaptured three individuals (0.34%). As a result, LEKT fished a fourth screw trap in the lower river in 2021. The trap was successful at catching large-bodied smolts and we generated an estimate of 4,741 smolts.

Production of Steelhead smolts from Indian Creek has been generally increasing over time, from 85 in 2013 to 7,773 (5,880-17,754) in 2021 (Figure 13). However, numbers of steelhead fell in 2022 to 1,779. Little River Steelhead smolt numbers have been consistently low over the period of record (1-799). This has been despite the moderate number of Steelhead redds that are observed in annual redd surveys (McHenry et al. 2022). Similar to Coho parr, large numbers of juveniles *O. mykiss* outmigrate as parr in the fall when the screw trap is not operating in Little River (Unpublished data, LEKT). We have documented this movement since 2012 through the PIT antenna array near the mouth of Little River.

Small numbers of Steelhead smolts were first observed in Little River in 2012 (2 total) and 2013 (24 total) and from Indian Creek in 2013 (16 total) well before Steelhead colonized these habitats following dam removal in 2013. These outmigrants were likely the progeny of resident rainbow trout populations that had retained anadromous life histories. This strategy has been previously documented in the Elwha during downstream fish passage studies in the late 1980's (Hiss and Wunderlich 1994) and in recent genetic analysis of Elwha wild Steelhead (Winans et al. 2017) from 2013-2015. Steelhead adults were first observed in both tributaries during the spring of 2012, immediately following the removal of Elwha Dam. Assuming two

years of freshwater residency, 2014 represented the first significant smolt production for both tributaries in over a hundred years.

Coho salmon smolt production in the Elwha River has varied over time since dam removal. The mainstem site captures increased dramatically in 2019 (69,874), but declined to 8,470 in 2020 and 6,082 in 2021. These reductions may be attributed to a very weak adult Cohorts in 2018 and 2019. Indian Creek has consistently produced larger numbers of Coho salmon smolt outmigrants relative to Little River over the period of monitoring (Figure 11). The larger numbers of Coho smolt outmigrants from Indian Creek are likely due to the amount and quality of habitat within the basin as previously discussed. Indian Creek also includes Lake Sutherland, a mesotrophic lake, at the headwaters of the system. Coho salmon adults were first documented spawning in Falls Creek (Sutherland tributary) in 2018. Outmigrant trapping in Sutherland's outlet in 2018-2021 has determined that Sutherland is producing Coho smolts that on average are very large in size. In 2021, we generated an estimate of 234 Coho smolts outmigrating from the lake, our first estimate of Lake Sutherland Coho production.

While the overall trend for Chinook salmon smolt outmigrants is favorable since dam removal, the total number of Chum and Pink salmon outmigrants is still alarmingly low. Both populations entered dam removal at low levels and it is likely that dam removal itself has further stressed both populations. The 2022 Elwha Chum salmon estimate was 390; well below the pre-dam removal average of 141,802 (2006-2012). The Elwha Pink salmon population is primarily an odd-year timed run, and in 2022 the estimates of 1,394, 1,937 and 14,065 for the mainstem, Indian and Little were all records since dam removal. For years in which we caught enough Pink salmon smolts to generate a mainstem production estimate, the trend had been a steady decline (Figure 14). Before 2019, neither Indian Creek or Little River had been colonized by significant numbers of returning adult Chum or Pink salmon.

Chum and Pink salmon are thought to be critical to the overall Elwha salmon recovery primarily for their contribution of marine derived nutrients to the river. The lack of response of these species is a serious concern to project co-managers. The empirical evidence suggests that these populations, already at very low abundance prior to dam removal, were further impacted by dam removal and the transport of millions of tons of sediment stored behind the dams. Historically abundant, Pink and Chum salmon likely returned large amounts of marine derived nutrients to the Elwha River. Those nutrients contributed to aquatic food webs that supported wildlife and other Pacific salmon of the Elwha.

Smolt trapping operations have documented several ecologically significant events that suggest the "reawakening" of anadromy or natural reoccupation events and the successful results of hatchery programs and relocation efforts. Those include the rapid recovery of Steelhead and Coho salmon in the tributaries, the first large outmigration of naturally produced

Chinook salmon, the natural reoccupation of Indian Creek by Pacific Lamprey, and the continued presence of eulachon in the lower river. However, other species including Pink, Chum and sockeye salmon show little or no signal of recovery to date. The Elwha Fisheries Recovery Plan (Ward et al. 2008) indicates that natural recovery is the preferred means of rebuilding sockeye populations. Because Elwha sockeye salmon were thought to have extirpated by dam construction, the plan states that the primary mechanism for recovery of sockeye salmon is from adults straying from other watersheds or by contribution of smolts originating from the landlocked kokanee salmon population in Lake Sutherland. While there have been adult sockeye salmon observations in the Elwha mainstem and in Indian Creek since Elwha Dam was removed, the numbers have been very low. Most appear to be riverine spawners and the analysis of 45 adult sockeye from the Elwha River collected since dam removal found that none were of local origin (Lake Sutherland kokanee), and only one was from the proximal Fraser River. Roughly half were strays from the West Coast Vancouver Island and the other half were from northern regions including the Stikine River, British Columbia and Alaska (Quinn et al. 2021).

Based on nine consecutive years of smolt trapping on Indian Creek, there is no evidence that Sutherland kokanee population is producing Sockeye smolts. This mechanism has been previously documented in the Coquitlam and Allouette Rivers in British Columbia where Sockeye salmon were extirpated by dams constructed in the early twentieth century and anadromous life history recovered following fish passage improvements. (Godbout et al. 2011). The retention of anadromous life history by a population of sockeye thought to have been trapped by dam construction in 1914 and retained for 25 generations bodes well for the Elwha River. Indeed, analysis of egg size showed that Sutherland kokanee have a larger egg than other known Kokanee populations and are similar only to a land locked population in New Zealand derived from an anadromous population (Quinn et al. 2015). The authors infer that Lake Sutherland Kokanee may have an anadromous origin.

Based on the downstream capture of gravid cutthroat trout below the outlet of Lake Sutherland, there appears to be a spring adfluvial population in Lake Sutherland. McMillan et al. (2014) documented an unusual fall spawning adfluvial population in Lake Sutherland and surmised that the early spawning date was related to low gradient and lake dampened hydrologic conditions that reduced scour and allowed small bodied fish to survive. Spring spawning is typical for cutthroat trout and has also been documented for populations in adjacent Lake Crescent.

Reintroduction is successfully occurring for Pacific Lamprey in Indian Creek and Little River, where adult were first documented in 2013 and subsequently again in later years at the smolt trap (Hess et al. 2021). These adults were the early colonizers to Indian Creek.

Ammocoetes (juveniles) were first encountered at Indian Creek in 2013, one year following the initial reoccupation event by adults in 2012. Lamprey appear to be expanding rapidly in Indian Creek (Figure 14). In 2014, we captured 132 ammocoetes, in 2015 the number increased to 407, and in 2016 the number again increased to 1,805, and in 2017 the number again increased to 3,474. In 2018, we captured 2,029 ammocoetes, and in 2019 3,914 were captured, and in 2020 1,954 were captured. In 2021 we had a raw catch of 3,919 ammocoetes, a new record. The 2022 total was 3,716. We expected that downstream migrating macrophthalmia from Pacific Lamprey would eventually be encountered at Indian Creek; however this was not anticipated for several more years because of their prolonged freshwater residency estimated at 5-6 years (Scott & Crossman 1973). However, in 2016 we encountered a total of 71 Pacific Lamprey macrophthalmia and in 2017 that number increased to 600. In 2018-2022, the total number of macrophthalmia was 649, 546, 441, 675 and 654, respectively. In 2022, we report that Pacific lamprey continue the early reoccupation of Little River with the first captures of 44, 34, and 400 juveniles during trapping operations in 2020-2022.

We have strived to keep sources of uncertainty low in order to stay within a coefficient of variation of 15% or less. However, continuously maintaining in-stream infrastructure in a steep gradient river with a rain-on-snow and snow hydrology for up to 7-8 months is difficult. The possibility exists of unknown circumstances that reduces the amount of data collected, and subsequently reduces the accuracy of our outmigration estimates. This phenomenon was exacerbated by dam removal and elevated sediment and debris transport on the Elwha River, at least through 2014. In contrast to previous years, when fishing was lost (flow, breakdowns and hatchery releases), only three days of fishing were lost in on the mainstem Elwha in 2021. The overall abundance of NOR fish is generally increasing and as a result more fish are being captured. The net effect of this has been a reduction in the Coefficient of Variation (CV) over time. In 2022, we report a decrease in the CV over 2021 for the mainstem where the CV ranged from 6% (Chinook 0+) to 28% (Chum) and averaged 17% for all species. At the lower mainstem site, the CV was fairly consistent and ranged from 25-38% for three large-bodied species (Coho, 1+ Chinook, Steelhead)

Fishing effort on the tributaries was also nearly continuous and the new trap at Little River fished a record number of days. The coefficient of variation at Little River was less than the 15% target threshold for two of seven species/life histories and averaged 30.7%. Little River estimated CV was 24% for 0+ Coho salmon and 43% for 1+ Coho salmon, while Steelhead was 34%. Indian Creek CVs were variable and ranged from 13% for 0+ Coho and Coho smolts to 55% for Chinook 0+. For all species the CV for the Indian Creek site was 28%.

Recommendations

For mainstem trapping efforts we will continue the trapping operations at both the upstream and downstream sites. The upper site has the advantage of being above both Elwha River hatcheries and has dramatically reduced the number of lost days from hatchery releases. It also increases the precision of fish identification. In theory more fishing time should result in higher catches of all species. However, an ongoing problem for large-bodied smolts is the expansion of raw catch estimates to generate production estimates. It seems clear that larger bodied smolts are able to avoid capture at the upriver site presumably due to flow velocities. In order to address this issue, we have deployed an additional 5' screw trap at the lower river site in 2022. This site has faster velocities and has proven effective at capturing large-bodied smolts. In 2023 we will also subsample randomly selected two hour time periods during periods of hatchery releases in an effort to provide daily estimates during those periods. The lower river trap has also improved the precision of Chum salmon estimates, the majority of which we believe spawn downstream of the upriver trap.

The majority of mainstem trap efficiency tests on the Elwha River have historically relied on small-bodied hatchery produced smolts (Figure 15). These fish are readily available to use for trap efficiency tests. We will continue calibrating the trap using small- and increase the number of large-bodied trials in future years. When using large-bodied smolts for trap efficiency trials there is evidence that those releases should be made at or near dusk when the natural migration of salmonids occurs (Roper and Scarnecchia 1996). Tattam et al. (2013) assessed the capture efficiency of *O. mykiss* in a screw trap on the South Fork John Day River, Oregon and found that capture efficiency was highest for releases made near dusk.

We will continue to refine our estimation approach to reduce the sensitivity of the analysis to extreme efficiency values while still maintaining defensible assumptions. In particular, we will investigate hierarchically modeling the efficiency estimates which would provide a compromise between taking the average over all periods and using the individual estimates (Bonner and Schwarz 2011). This will reduce the effects of extreme efficiency trials while still allowing for variation in efficiency over time. We will also further investigate the sensitivity of the estimates to violations of the model assumptions (Rawding and Rodgers 2013).

The tributary sites have generally performed well with the only real issues being the Little River trap performance at the end of the season. Following the cessation of snow melt, Little River flows may drop to the point that stream velocity is no longer sufficient to turn the screw. In 2020, we deployed a new trap to the site and were successful fishing into August in 2020-2022. On Indian Creek, we experimented with a fence weir in 2021 and 2022 and will discontinue its use in future years. We believe the fence weir encouraged residualism of Coho

to Lake Sutherland. It also interferes with an observed upstream migration of yearling Cutthroat trout from Indian Creek to Lake Sutherland. These fish likely have an adfluvial life history (McMillan et al. 2014).

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Tables

Table 1. Results of mark-recapture tests for Elwha River, Indian Creek and Little River for the 2022 smolt outmigration season, small bodied trials (0+).

Site	Date	Species	Number	Recaptures	Percentage (%)
Elwha	2/1/22	Chinook 0+	1,091	73	6.78
Elwha	2/8/22	Chinook 0+	1,207	57	4.80
Elwha	2/16/22	Chinook 0+	1,510	65	4.37
Elwha	2/22/22	Chinook 0+	1,212	49	4.12
Elwha	3/11/22	Chinook 0+	722	25	3.60
Elwha	3/17/22	Chinook 0+	994	50	5.13
Elwha	3/24/22	Chinook 0+	1,010	32	3.26
Elwha	3/30/22	Chinook 0+	1,005	21	2.19
Elwha	4/5/22	Chinook 0+	1,005	54	5.47
Elwha	6/1/22	Chinook 0+	1,004	37	3.78
<i>Total</i>			<i>10,760</i>	<i>463</i>	
<i>Elwha Average</i>			<i>1,076</i>	<i>46.3</i>	<i>4.35</i>
Little	2/1/22	Chinook 0+	100	10	10.0
Little	2/8/22	Chinook 0+	200	12	6.47
Little	2/16/22	Chinook 0+	200	27	13.93
Little	2/22/22	Chinook 0+	100	9	9.00
Little	3/11/22	Chinook 0+	100	17	17.00
Little	3/17/22	Chinook 0+	100	26	26.00
Little	3/24/22	Chinook 0+	100	10	10.00
Little	3/3/22	Chinook 0+	100	7	7.00
Little	4/5/22	Chinook 0+	100	19	19.00
<i>Total</i>			<i>1,100</i>	<i>137</i>	
<i>Little Average</i>			<i>122</i>	<i>15.2</i>	<i>13.82</i>

Indian	2/1/22	Chinook 0+	100	19	19.00
Indian	2/8/22	Chinook 0+	200	19	9.95
Indian	2/16/22	Chinook 0+	200	65	32.84
Indian	2/22/22	Chinook 0+	100	21	21.00
Indian	3/11/22	Chinook 0+	100	22	22.00
Indian	3/17/22	Chinook 0+	100	23	23.00
Indian	3/24/22	Chinook 0+	100	18	18.00
Indian	3/30/22	Chinook 0+	100	33	33.00
Indian	4/5/22	Chinook 0+	100	23	23.00
Indian	5/3/22	Chinook 0+	80	34	42.50
<i>Total</i>			<i>1,180</i>	<i>277</i>	
<i>Indian Ave.</i>			<i>118</i>	<i>27.7</i>	<i>25.03</i>

Table 2. Results of mark-recapture tests for Elwha River, Indian Creek and Little River for the 2022 smolt outmigration season, large bodied trials.

Site	Date	Species	Number	Recaptures	Percentage (%)
Upper Elwha	5/5/22	Coho 1+	100	4	4.00
Upper Elwha	5/25/22	Coho 1+	36	4	11.11
<i>Total</i>			136	8	
<i>Average</i>					7.5
Lower Elwha	5/17/22	Coho 1+	362	7	1.93
Lower Elwha	5/17/22	Steelhead	33	2	6.00
Lower Elwha	5/25/22	Coho 1+	100	5	5.00
Lower Elwha	6/1/22	Coho 1+	95	7	7.36
Lower Elwha	7/21/22	Coho 1+	57	7	12.28
<i>Total</i>			647	28	
<i>Average</i>					4.32
Little	5/5/22	Coho 1+	30	4	13.33
Little	6/15/22	Steelhead	73	10	13.69
<i>Total</i>			103	14	
<i>Little Average</i>					13.59
Indian	5/3/22	Steelhead	69	19	27.53
Indian	5/11/22	Coho 1+	107	48	44.85
Indian	5/11/22	Steelhead	13	3	23.07
Indian	5/25/22	Coho 1+	50	26	52.00
Indian	6/1/22	Coho 1+	50	19	38.00
<i>Total</i>			289	115	
<i>Indian Ave.</i>					39.79

Table 3. Total catch, estimated outmigrants, 95% C.I., CV, and geometric CV for smolt outmigration from the mainstem Elwha River (Upper trap site), 2022 outmigration year.

Species	Catch	Estimated Outmigrants	95% C.I.	CV
Chinook Salmon(0+)	3,780	91,640 ³ 111,454 ⁴	80,600 - 102,680	0.06
Chinook Salmon(1+)	20	NE	NE	NE
Coho Salmon(0+)	2,429	60,992	49,762 - 72,223	0.09
Coho Smolt	NE	NE	NE	NE
Chum Salmon	14	316	104 - 528	0.28
Pink Salmon	45	1,240	556 - 1,923	0.25
Steelhead	NE	NE	NE	NE

³ Estimated number of smolts to the trap.

⁴ Expanded estimate accounting for redds below trap.

Table 4. Estimated number of Chinook salmon subyearling outmigrants and productivity (smolts/female) for the Elwha River, Indian Creek and Little River (2005-2022).

Year	Elwha 0+ Outmigrants	Elwha Smolts /Female	Indian 0+ Outmigrants	Indian Smolts /Female	Little 0+ Outmigrants	Little Smolts /Female
2005	106,348	109				
2006	44,256	113				
2007	16,228	50				
2008	18,352	103				
2009	14,533	66				
2010	125,772	395				
2011	11,808	44				
2012	65,901	165				
Pre-Project Average	48,185	130				
2013	NE	NE	118,109	1,845	38,601	NE
2014	93,981	113	35,822	607	10,628	443
2015	16,200	13	84,318	3,243	8	NE
Dam Removal Average	46,973	63				
2016	45,818	29	112,074	7,472	21,863	429
2017	73,152	59	3,024	108	3	NE
2018	23,236	40	3,916	112	5,205	578
2019	571,817 ⁵	309	256,058	1,730	125,585	1,993
2020	1,057,329 ⁵	312	188,825	891	356,327	2,874
2021	292,418 ⁵	274	100,248	1,319	21,963	3,138
2022	111,454 ⁵	106	141,307 ⁵	1,503	22,103	553
Post-Project Average	310,746	161				
Project Average	146,514	131	115,065	1,876	60,229	1,430
4YR GeoMean	374,664	230	161,774	1,322	68,270	1,776

⁵ Total production estimate including estimate to the trap and additional production below the trap

Table 5. Total catch, estimated outmigrants, 95% C.I., CV, and geometric CV for smolt outmigration from the mainstem Elwha River (Lower trap site), 2022 outmigration year.

Species	Catch	Estimated Outmigrants	95% C.I.	CV
Chinook Salmon(0+)	386	NE	NE	NE
Chinook Salmon(1+)	20	670	167-1,173	0.38
Coho Salmon(0+)	85	NE	NE	NE
Coho Smolt	1,065	45,278	23,347-67,208	0.25
Chum Salmon	25	NE	NE	NE
Pink Salmon	84	NE	NE	NE
Steelhead	205	4,741	2,095-7,388	0.28

Table 6. Total catch, estimated outmigrants, 95% Credible Interval (C.I.), Coefficient of Variation (CV) and geometric CV for smolt outmigration from Indian Creek, 2022 outmigration year.
NE=Not estimated.

Species	Total Catch	Estimated Outmigrants	95% C.I.	CV
Chinook Salmon(0+)	14,920	91,625 ⁶ 141,307 ⁷	80,671- 102,579	0.09
Chinook Salmon(1+)	17	45	26-65	0.22
Coho Salmon(0+)	16,961	71,791	62,291- 81,292	0.07
Coho Salmon(1+)	236	NE	NE	NE
Coho Smolt	5,781	13,038	11,254- 14,822	0.07
Pink Salmon(0+)	446	1,937	1,568- 2,307	0.10
Chum Salmon(0+)	29	125	69-182	0.23
Steelhead	537	1,779	1,206- 2,353	0.28

⁶ Estimated number of smolts to trap.

⁷ Expanded estimate accounting for redds below trap.

Table 7. Total catch, estimated outmigrants, 95% Credible Interval (C.I.), Coefficient of Variation (CV) and geometric CV for smolt outmigration from Little River, 2022 outmigration year.

Species	Total Catch	Estimated Outmigrants	95% C.I.	CV
Chinook Salmon(0+)	2,226	16,577 ⁸ 22,103 ⁹	12,736- 20,418	0.12
Chinook Salmon(1+)	45	302	129-475	0.29
Coho Salmon(0+)	2,385	16,599	11,840- 21,358	0.15
Coho Salmon(1+)	87	NE	NE	NE
Coho Smolts	115	741	384-1,098	0.25
Pink Salmon(0+)	1,391	14,065	7,992- 20,137	0.22
Chum Salmon(0+)	7	NE	NE	NE
Steelhead	16	104	28-180	0.37

⁸ Estimated number of smolts to trap.

⁹ Expanded estimate accounting for redds below the trap.

Table 8. Total catch of miscellaneous fish encountered at Elwha River, Little River and Indian Creek smolt traps, 2022. For trout the first entry is Rainbow and the second is Cutthroat (*mykiss/clarkii*).

Site	0+ Trout	1+ Trout	2+ Trout	Bull Trout	Brook Trout	Cutthroat Trout (Smolts)	Cottids	Redside Shiner	Ammocoete	Macrophthalmia	Adult Pacific Lamprey
Elwha (Upper)	114/0	28/0	3/0	0	0	0	1,520	5	611	35	4
Elwha (Lower)	40/0	30/0	1/0	0	0	0	180	0	129	18	0
Little	24/0	156/0	21/0	4	0	0	16	0	400	0	0
Indian	381/51	533/99	159/21	14	9	13	109	1,947	3,716	654	1

Table 9. Summary of fishing effort for 2022 smolt outmigration season, Elwha River, Little River and Indian Creek Traps.

Site	Date Trap In	Date Trap Out	Days Fished	Days Missed	Percent Fishing
Elwha ¹⁰	1/29/22	8/2/22	190	2	99
Elwha ¹¹	3/31/22	8/9/22	131	68	52
Little	1/21/22	8/8/22	199	3	98.5
Indian	1/21/22	8/30/22	221	0	100

¹⁰ Upper Site

¹¹ Lower Site

Figures

Figure 1. Top Elwha River 8' rotary screw trap fishing at Rkm 4.0 during the post-project period. Bottom 5' rotary screw trap fishing at Rkm 0.6, spring 2022.



Figure 2. Little River (top) and Indian Creek smolt traps.



Figure 3. Elwha River, Indian Creek and Little River smolt trap locations.



Figure 4. Elwha mainstem smolt trap fishing effort by year, 2005-2022. Green are days fishing, blue is day fishing but trap not checked, and black are days not fishing. Black horizontal bars underneath the multicolored bars represent the four days including and immediately following efficiency trials.

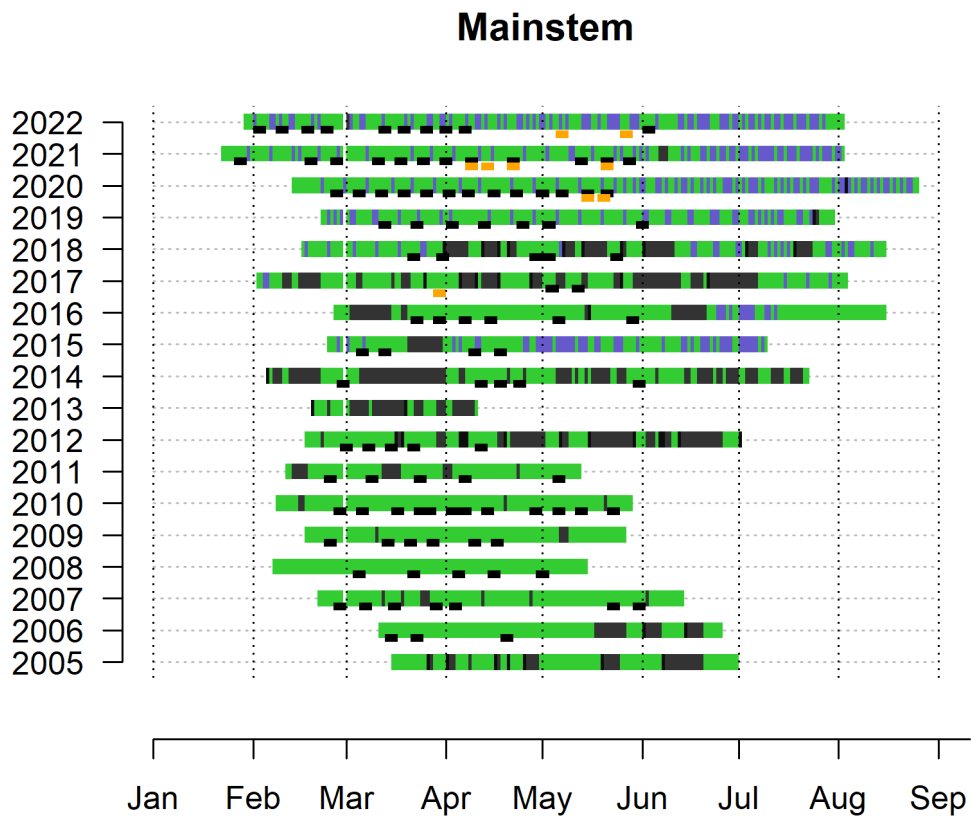


Figure 5. Indian Creek smolt trap fishing effort by year, 2012-2022. Green are days fishing, blue is day fishing but trap not checked, and black are days not fishing. Black horizontal bars underneath the multicolored bars represent the four days including and immediately following efficiency trials.

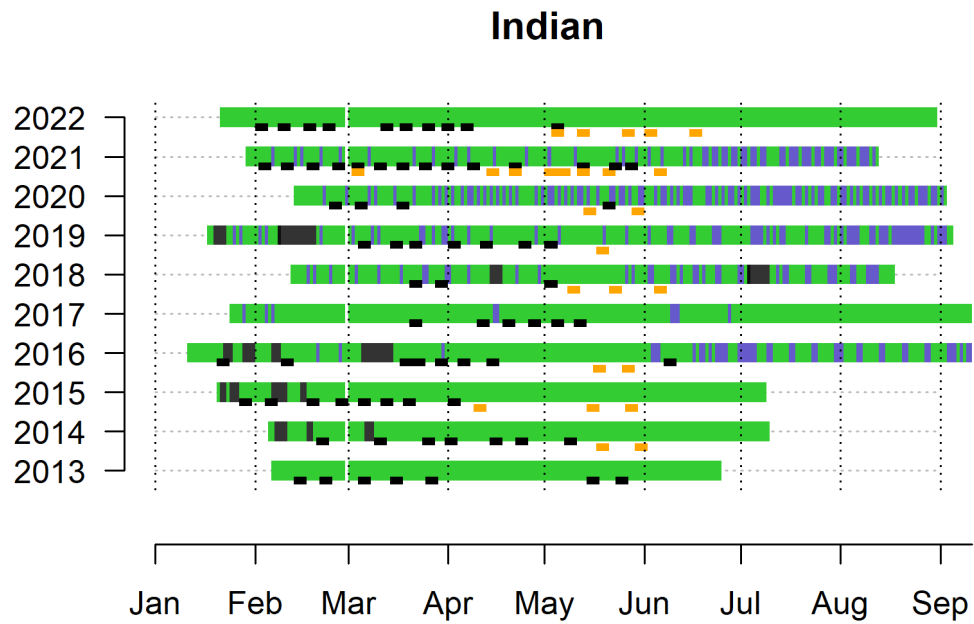


Figure 6. Little River smolt trap fishing effort by year, 2012-2022. Green are days fishing, blue is day fishing but trap not checked, and black are days not fishing. Black horizontal bars underneath the multicolored bars represent the four days including and immediately following efficiency trials.

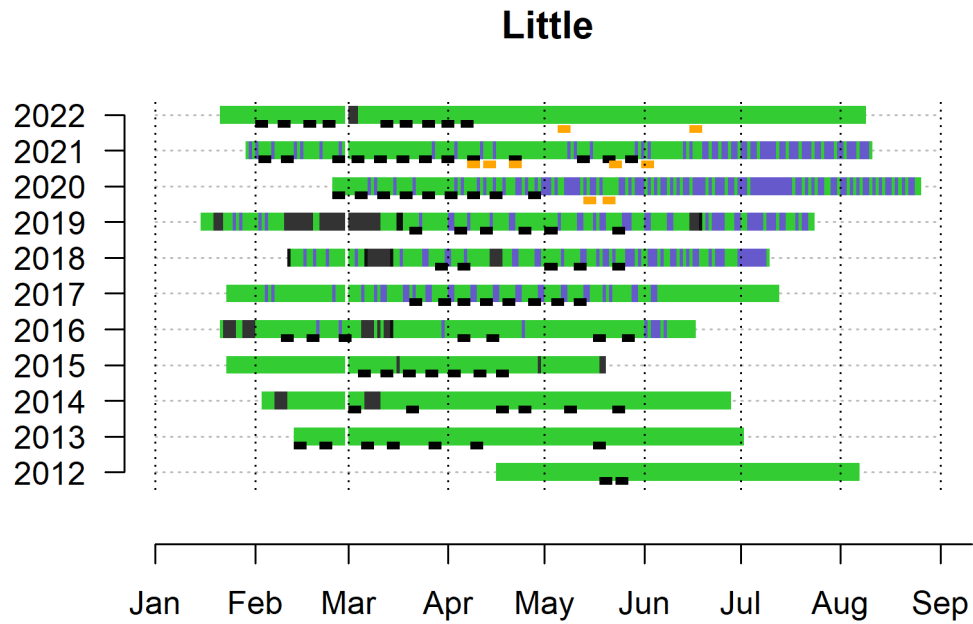


Figure 7. Elwha River flows (cfs) measured at the McDonald Gage Site, September 15, 2021 to February 1, 2022 (top-Chinook salmon incubation period) and January 29, 2022 to August 2, 2022 (bottom-smolt outmigration period).

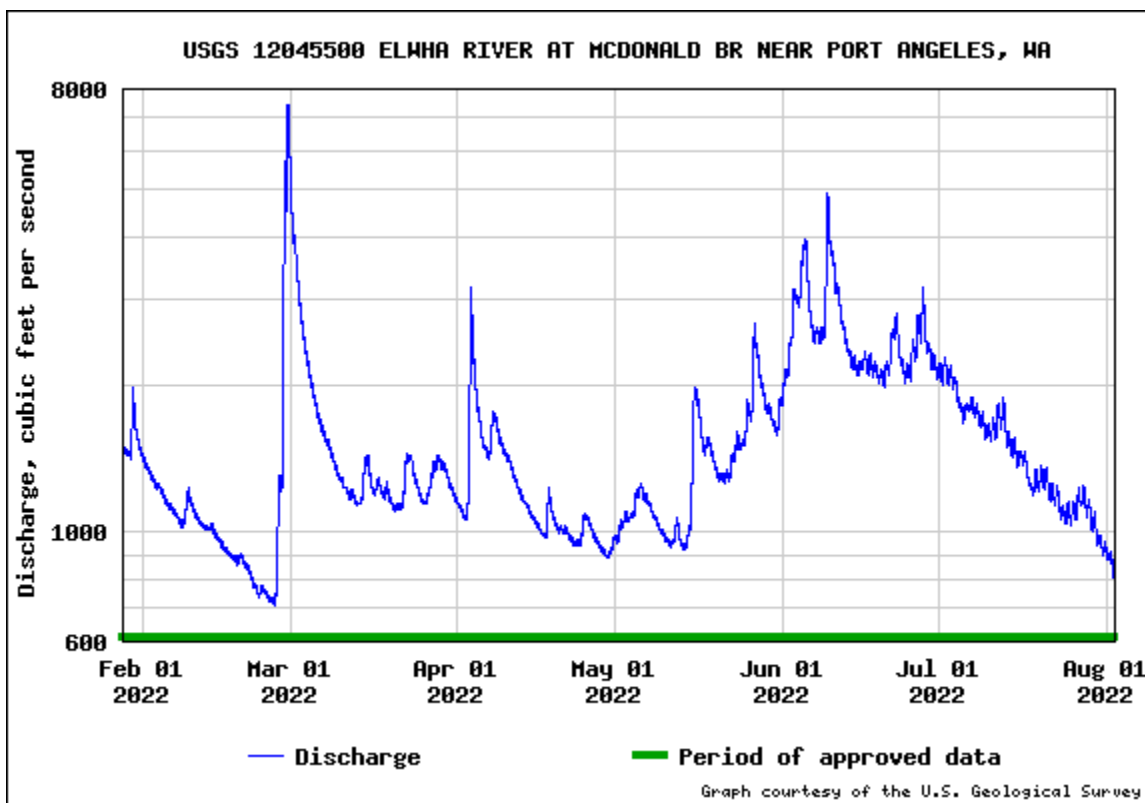
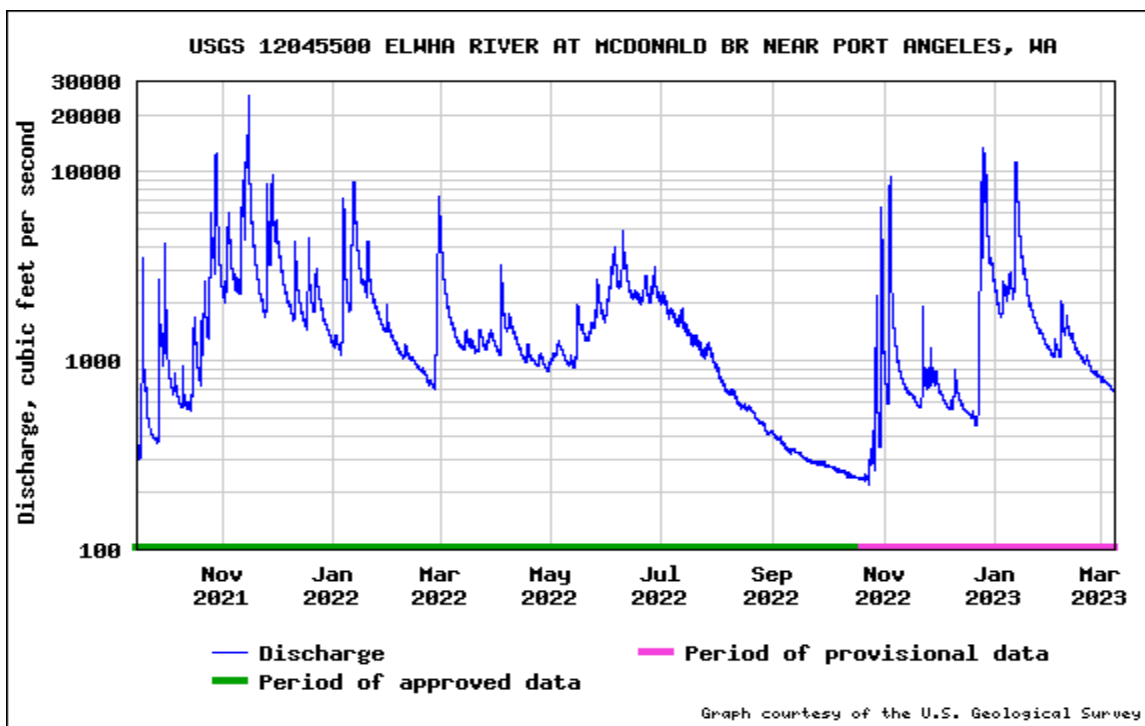


Figure 8. Elwha subyearling Chinook abundance and productivity (2005-2022).

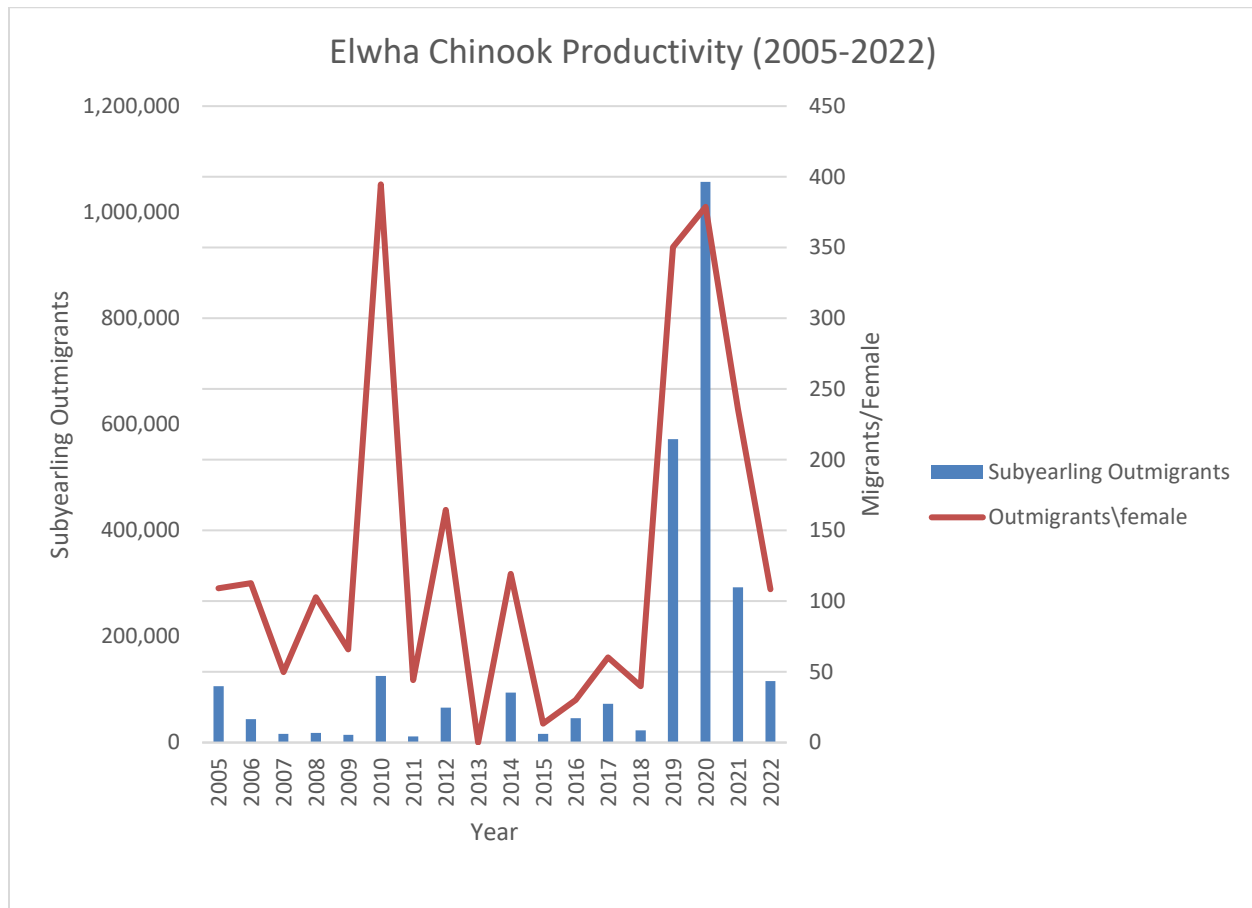


Figure 9. Pacific Lamprey captures at the Indian Creek Smolt trap (top) and sculpin (bottom) at the mainstem Elwha trap, 2006-2022.

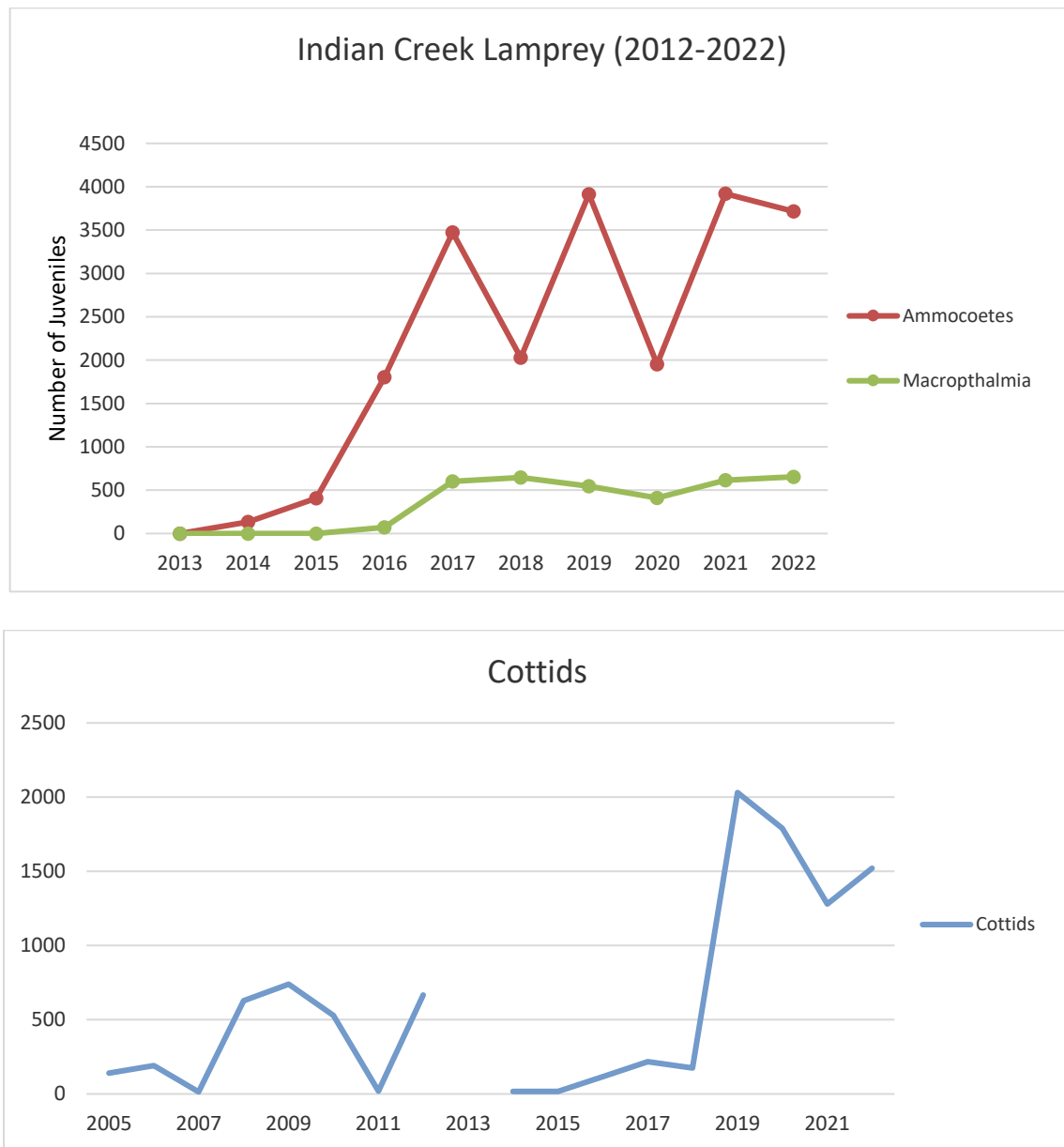


Figure 10. Egg to outmigrant survival rate for Elwha Chinook salmon (2005-2022).

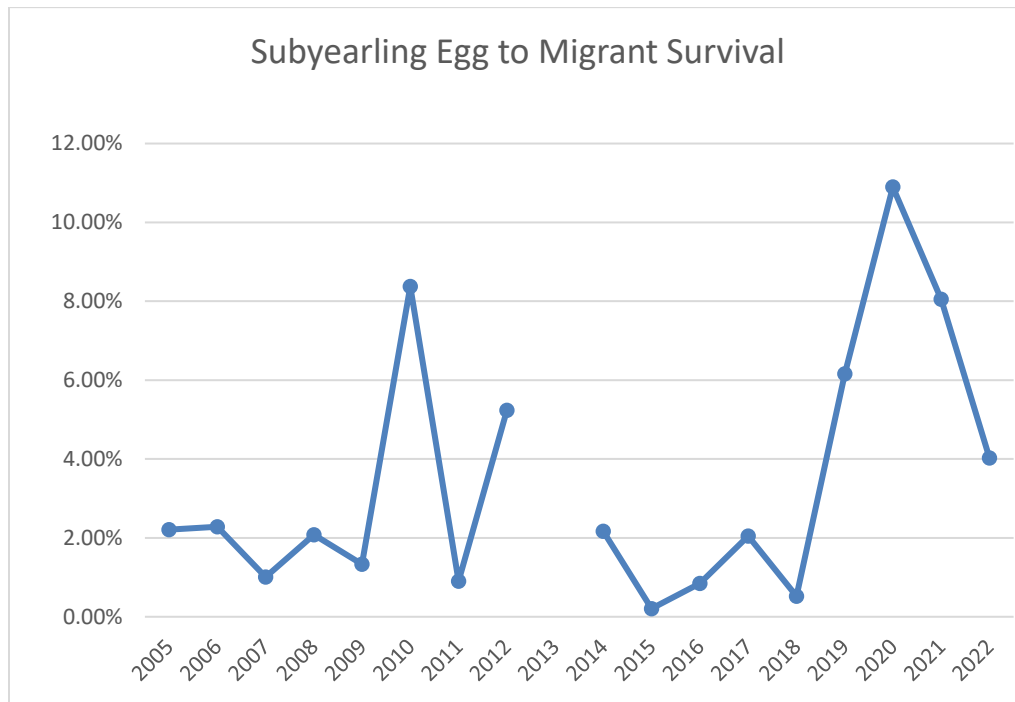


Figure 11. Chinook outmigrant timing and sizes for the Elwha River screw trap during the period when length data was available (2016-2022). The three vertical lines represent three dates that could be used to separate fry and parr migrants. The horizontal line at 45mm represent a common cutoff used to separate fry and parr. The dotted lines at 80mm and June 1st provide references for assessing changes in growth over time.

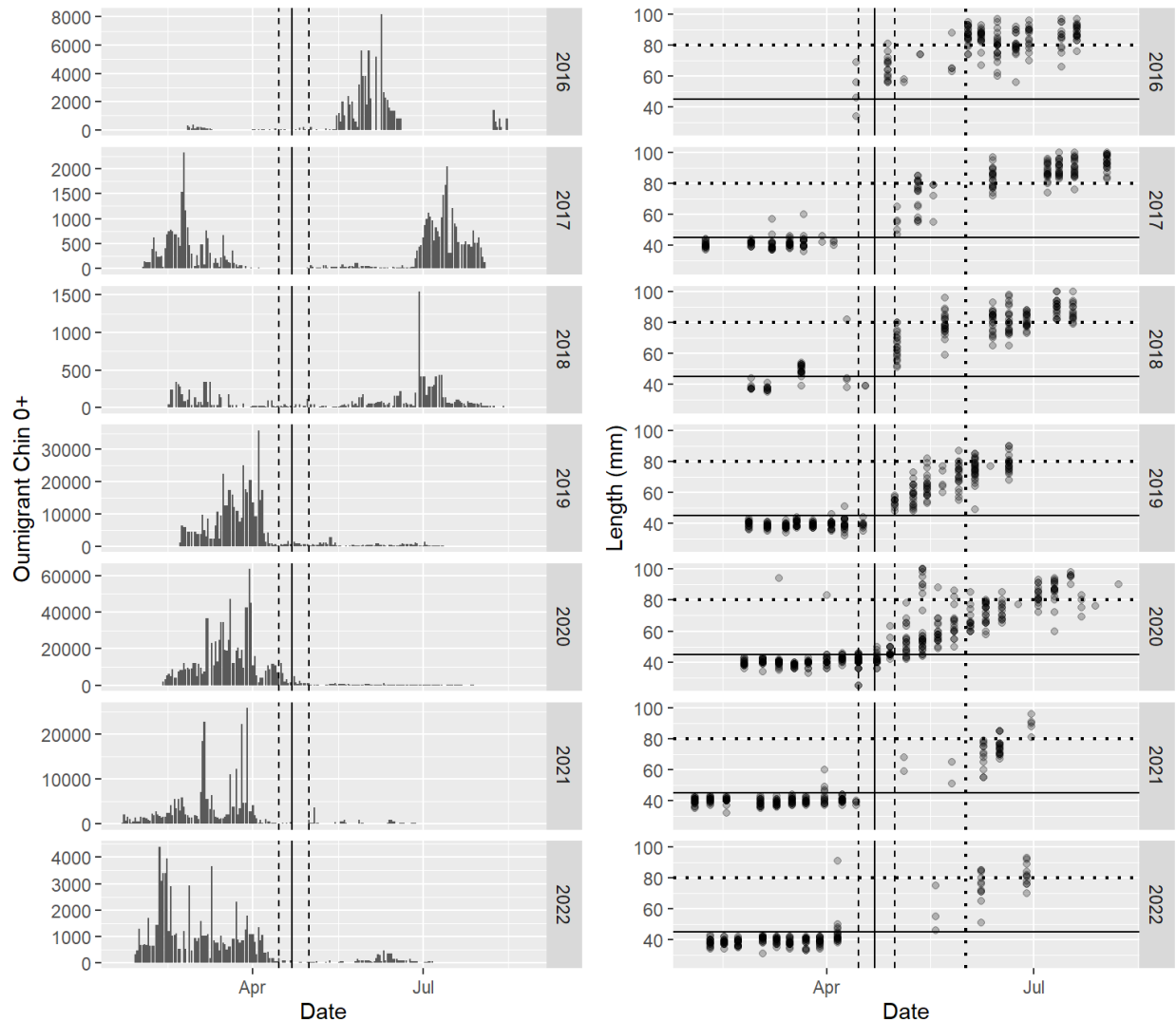


Figure 12. Chinook subyearling productivity for Indian Creek and Little River (2013-2022).

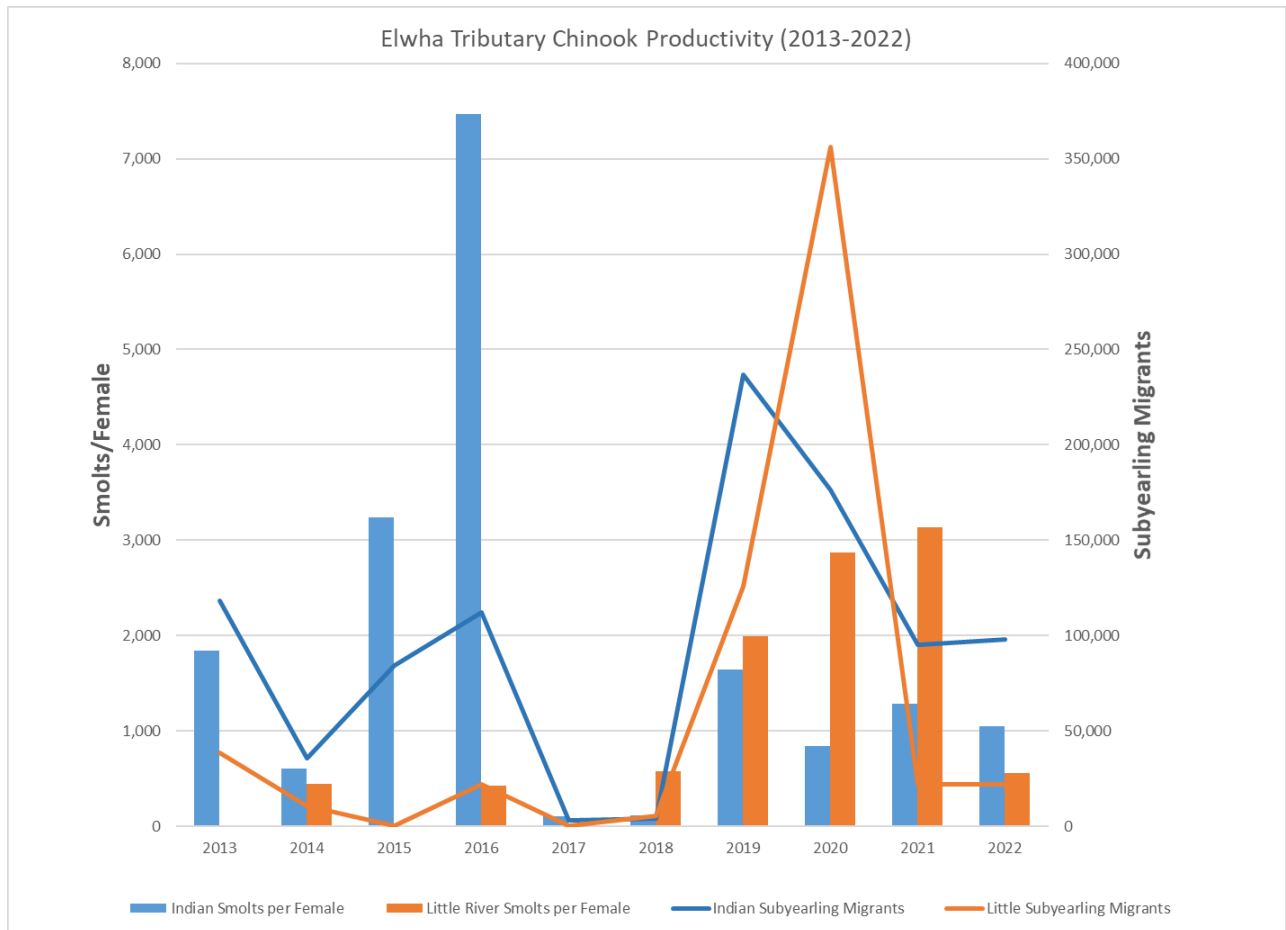


Figure 13. Estimated Steelhead and Coho smolt production for Indian Creek and Little River (2012-2022).

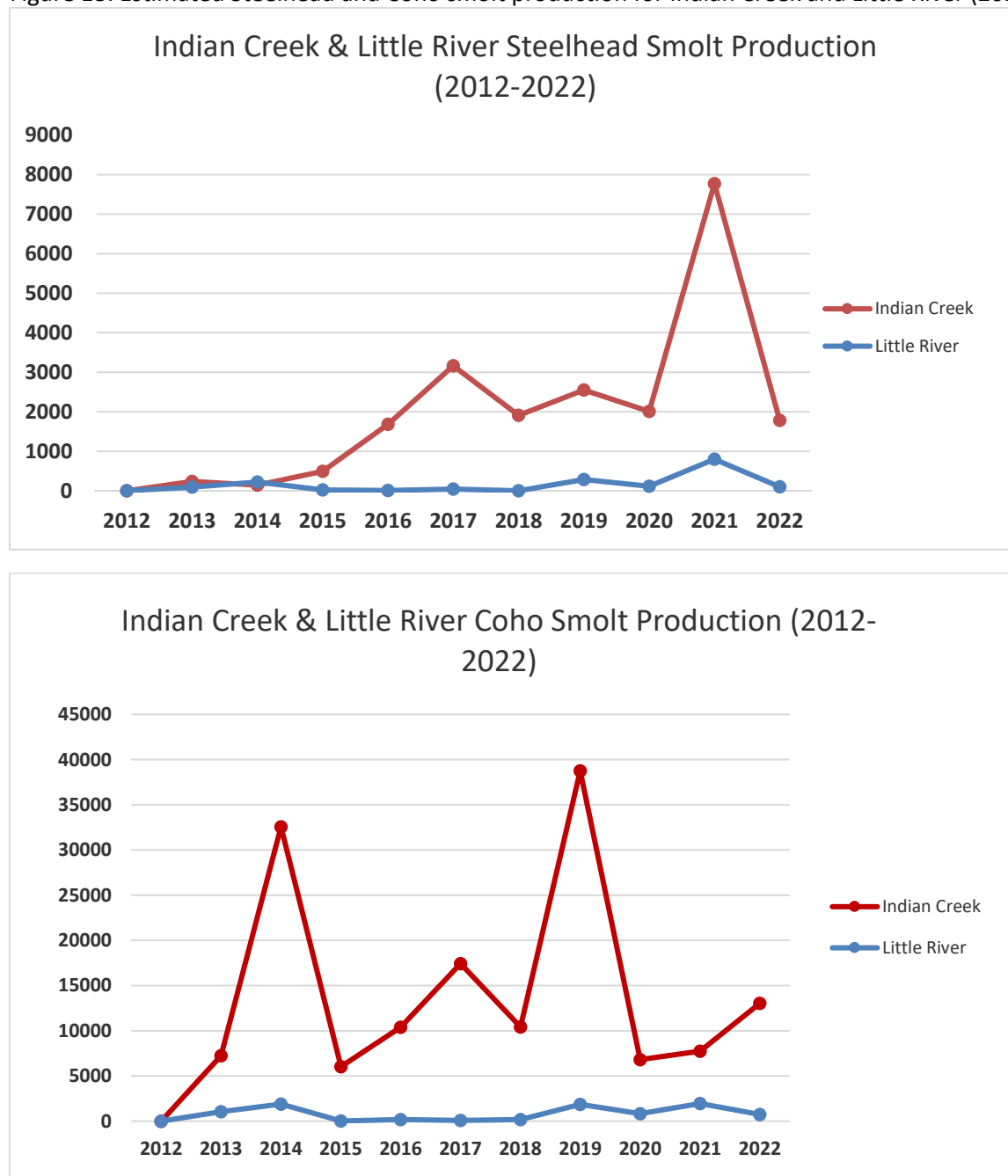


Figure 14. Estimated Pink and Chum salmon outmigration for the Elwha River (2006-2022).

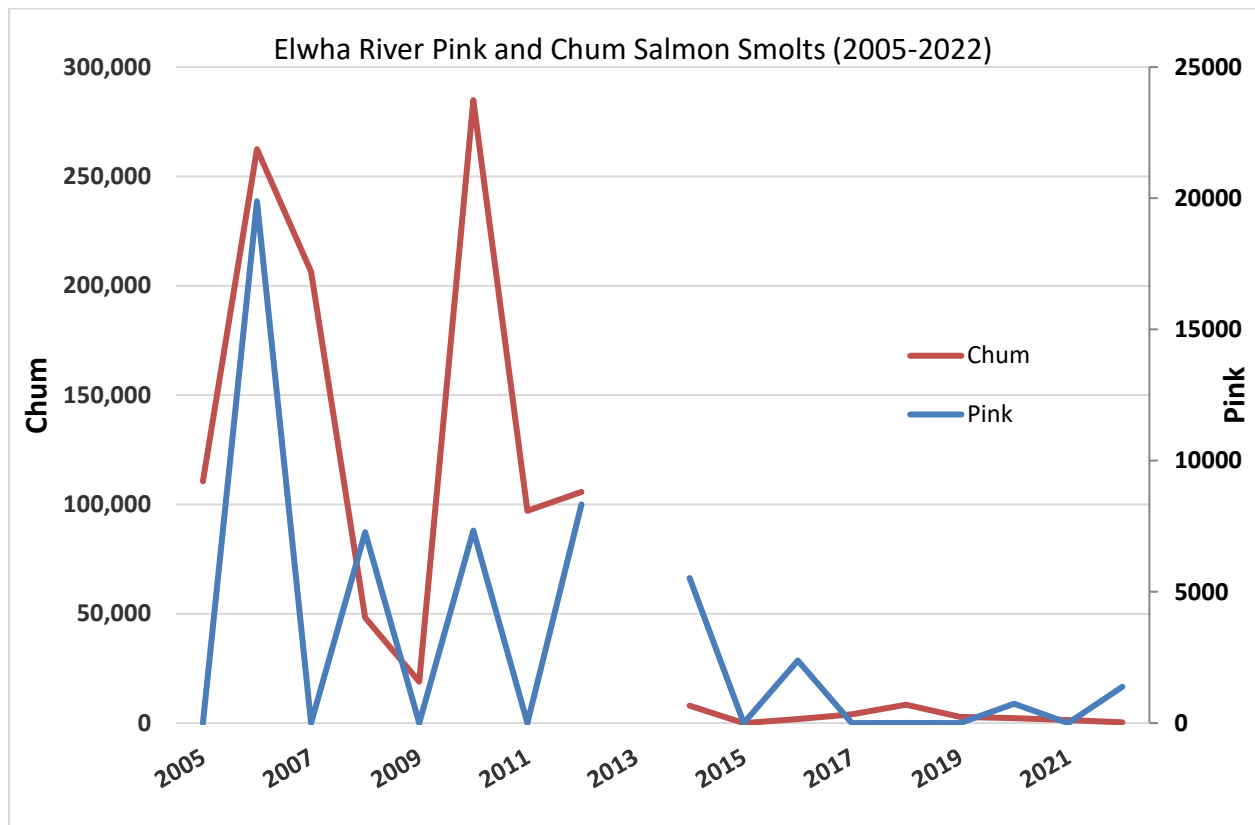
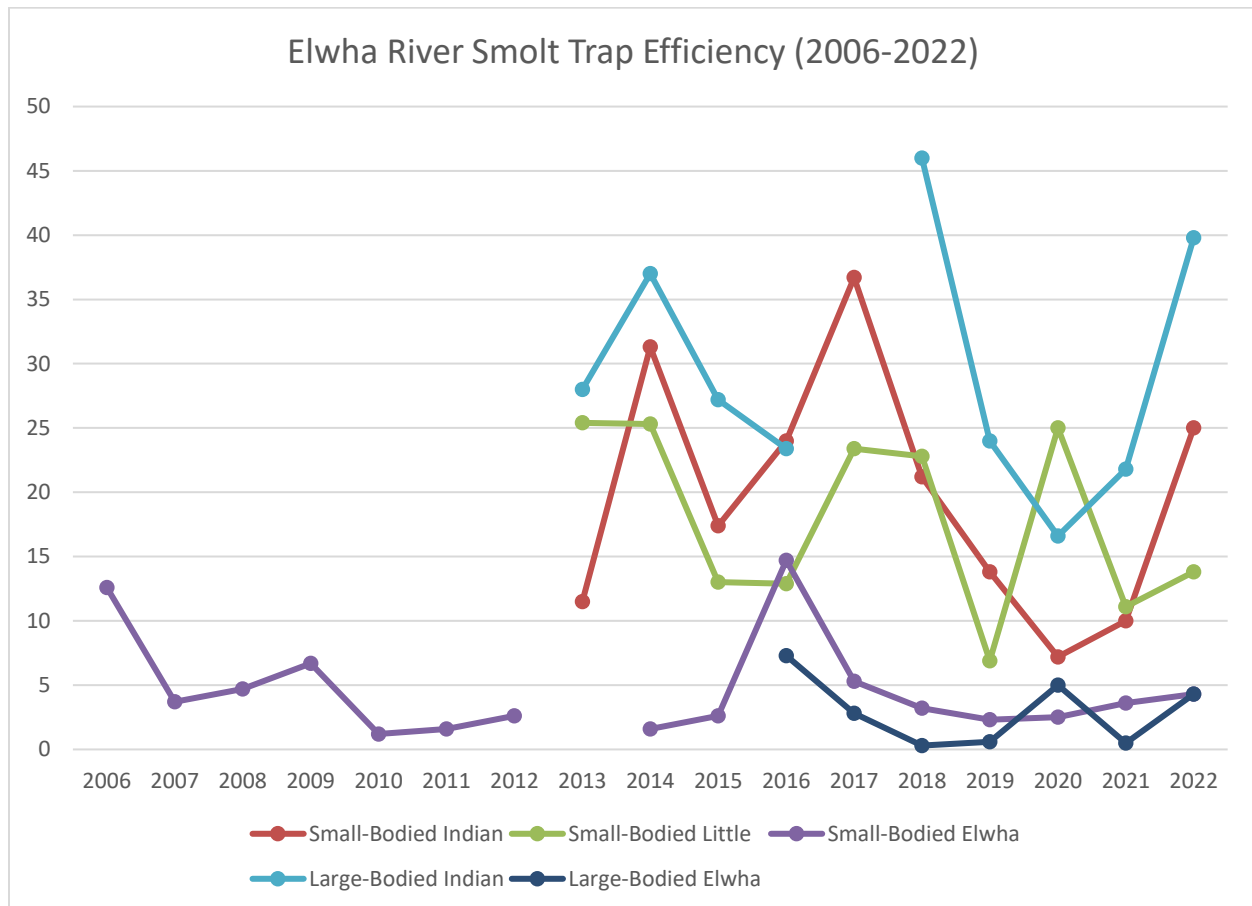
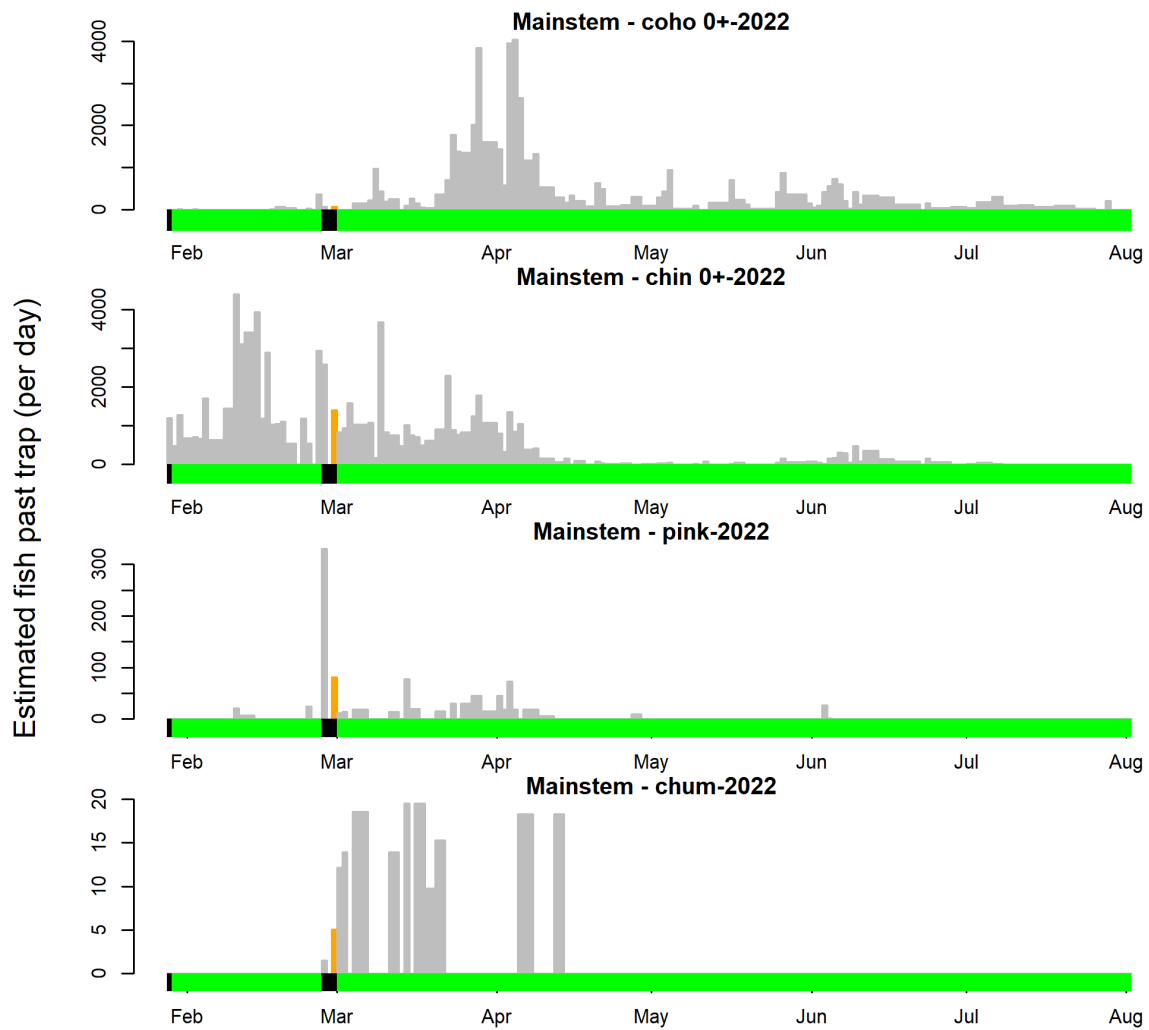


Figure 15. Trap Efficiency for small-bodied and large-bodied smolts for Elwha River (8' Screw), Little River and Indian Creek (2006-2022).

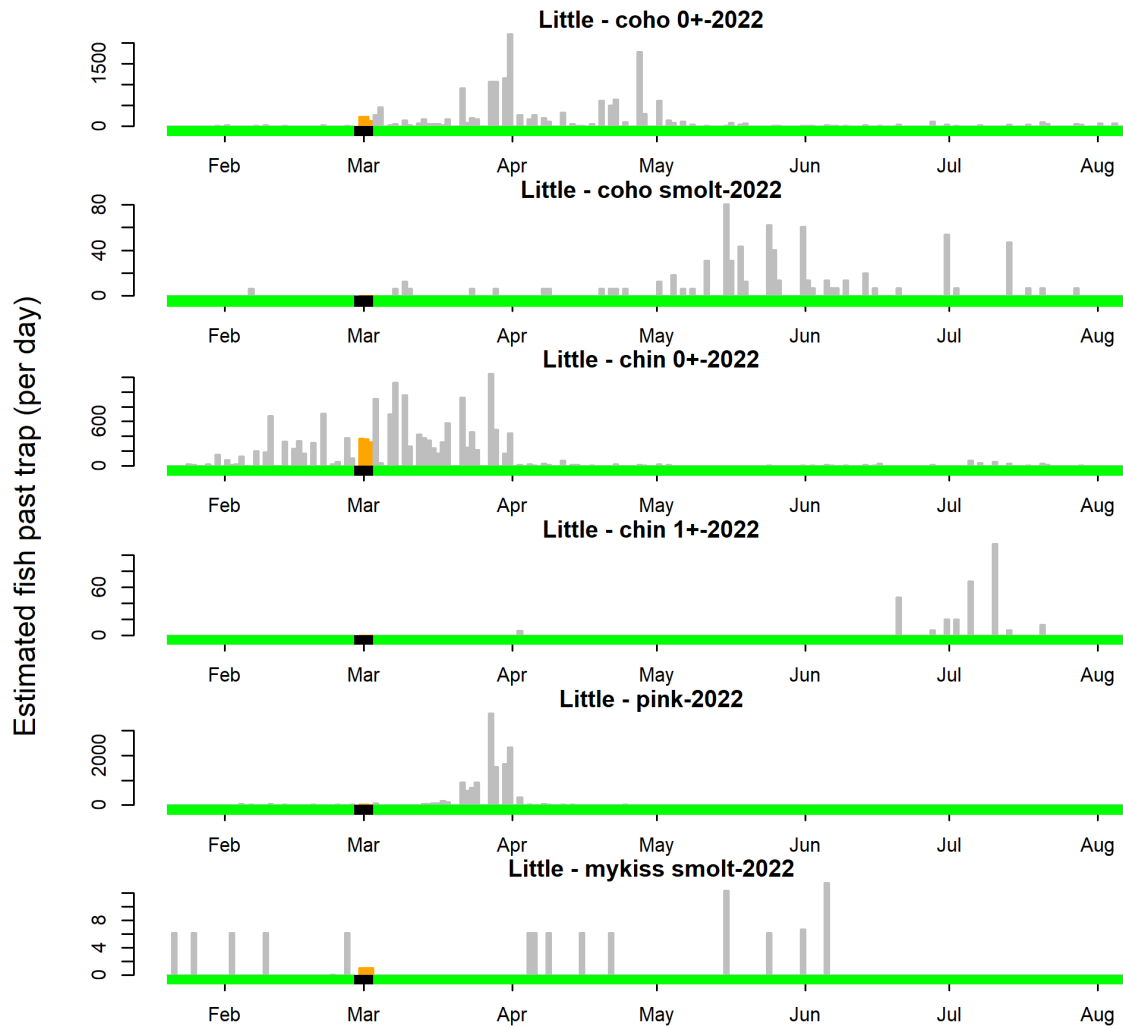


Appendix A.

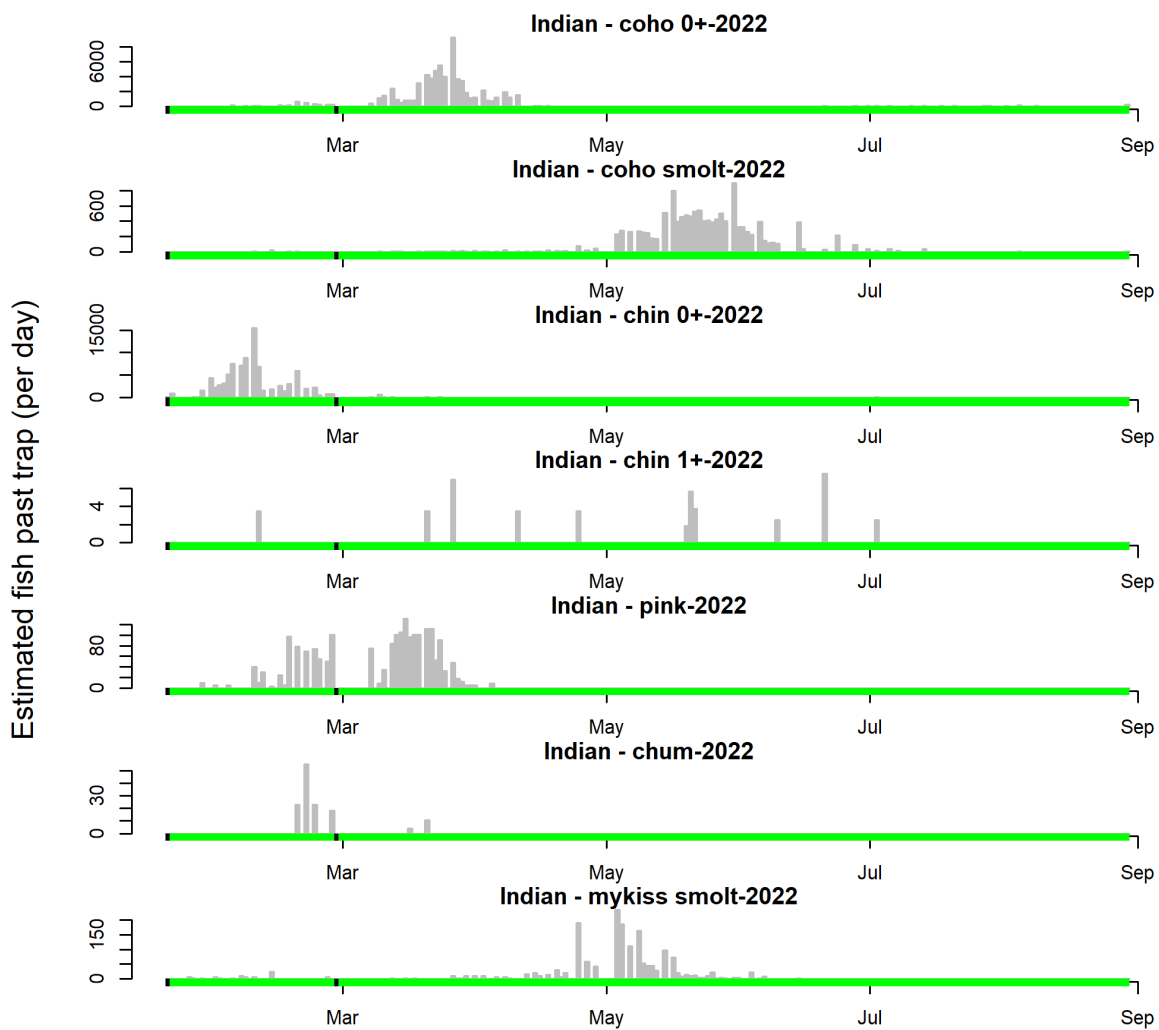
Estimated number of 0+ Coho, Coho smolts, 0+ Chinook, Pink and Chum outmigrants at the mainstem Elwha trap site by day during 2022.



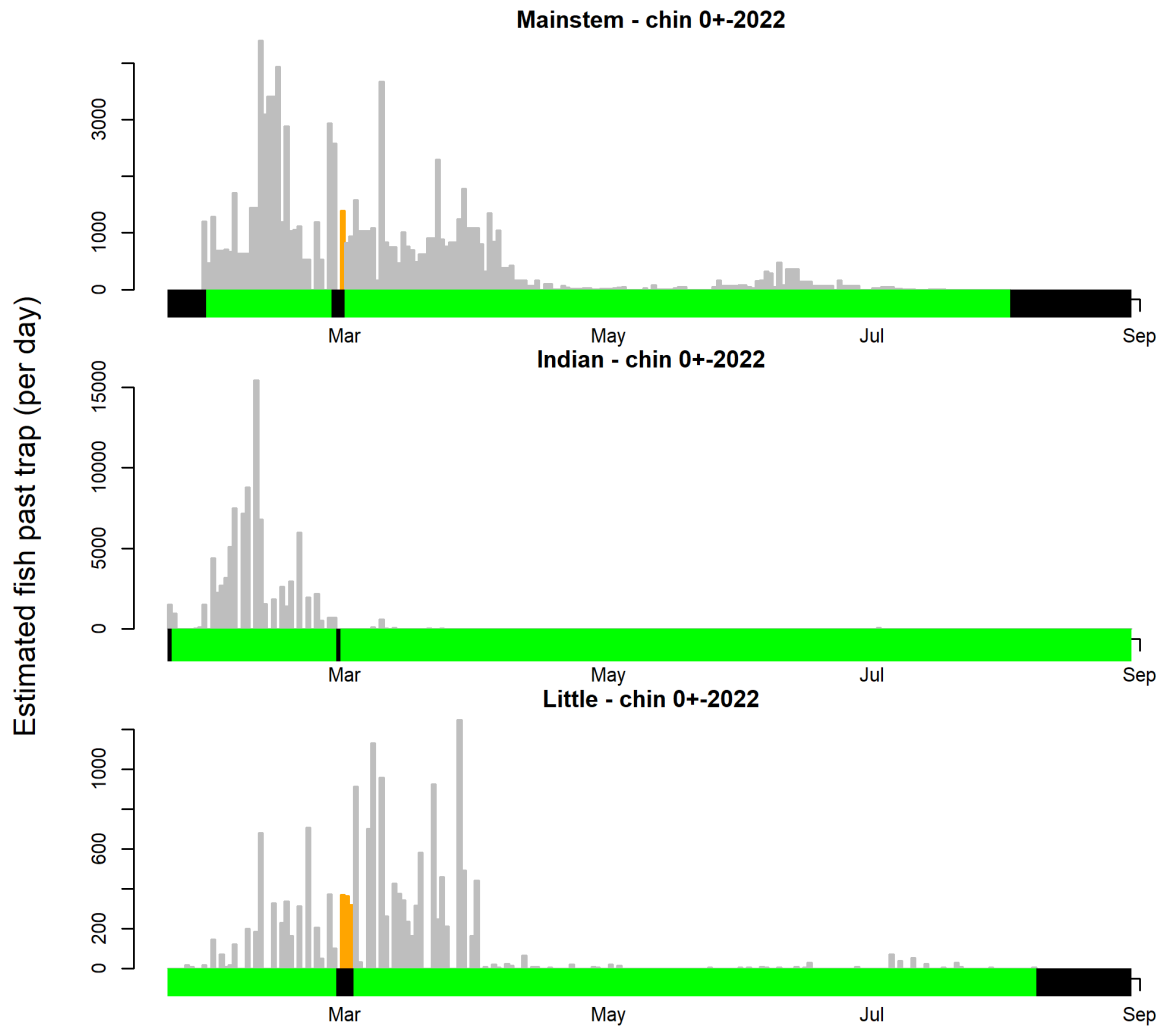
Estimated number of 0+ Coho, Coho smolts, 0+ Chinook, 1+ Chinook, Pink and Steelhead outmigrants at the Little River trap site by day during 2022.



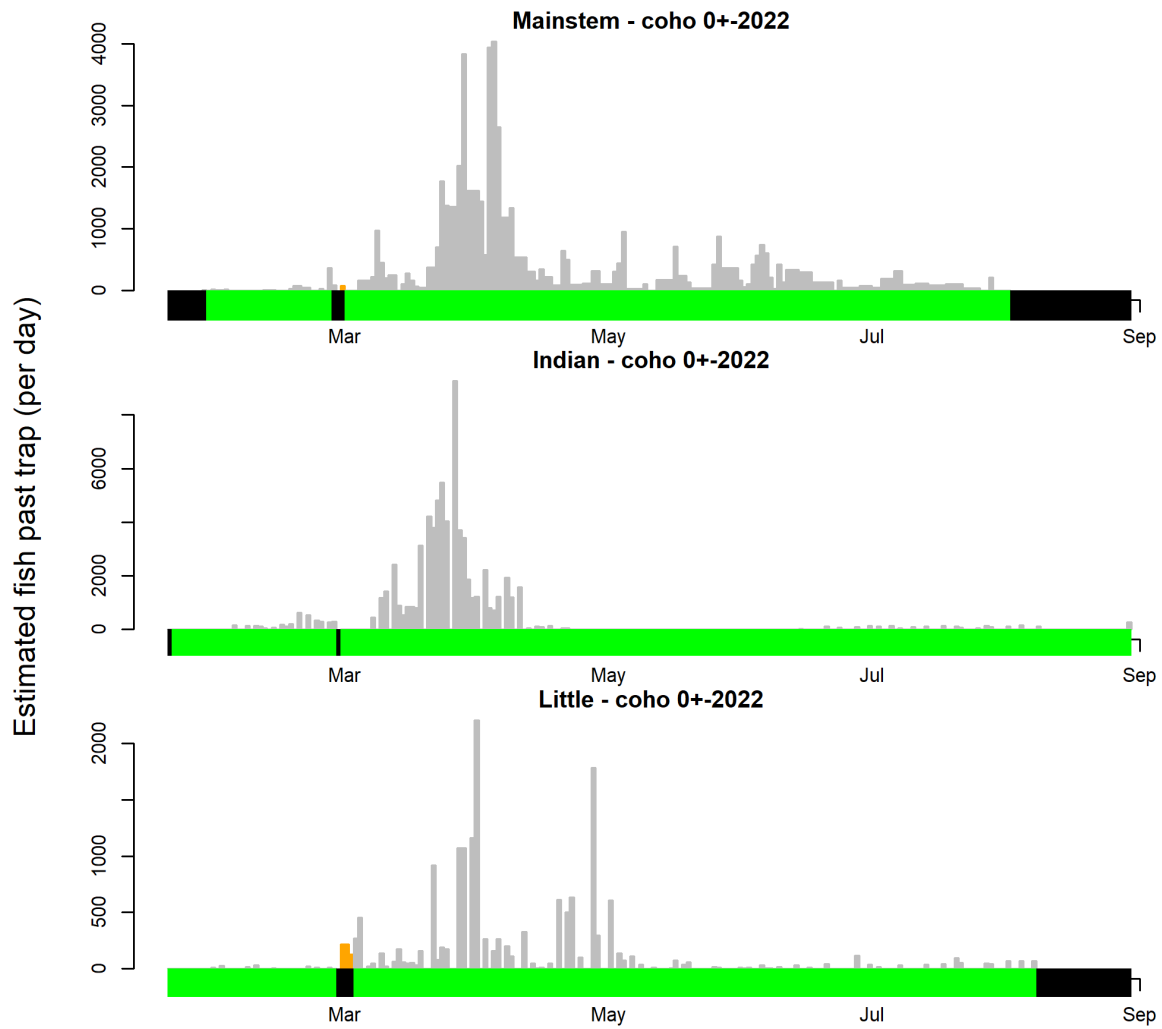
Estimated number of 0+ Coho, Coho smolts, 0+ Chinook, 1+ Chinook, Pink, Chum and Steelhead outmigrants at the Indian Creek trap site by day during 2022.



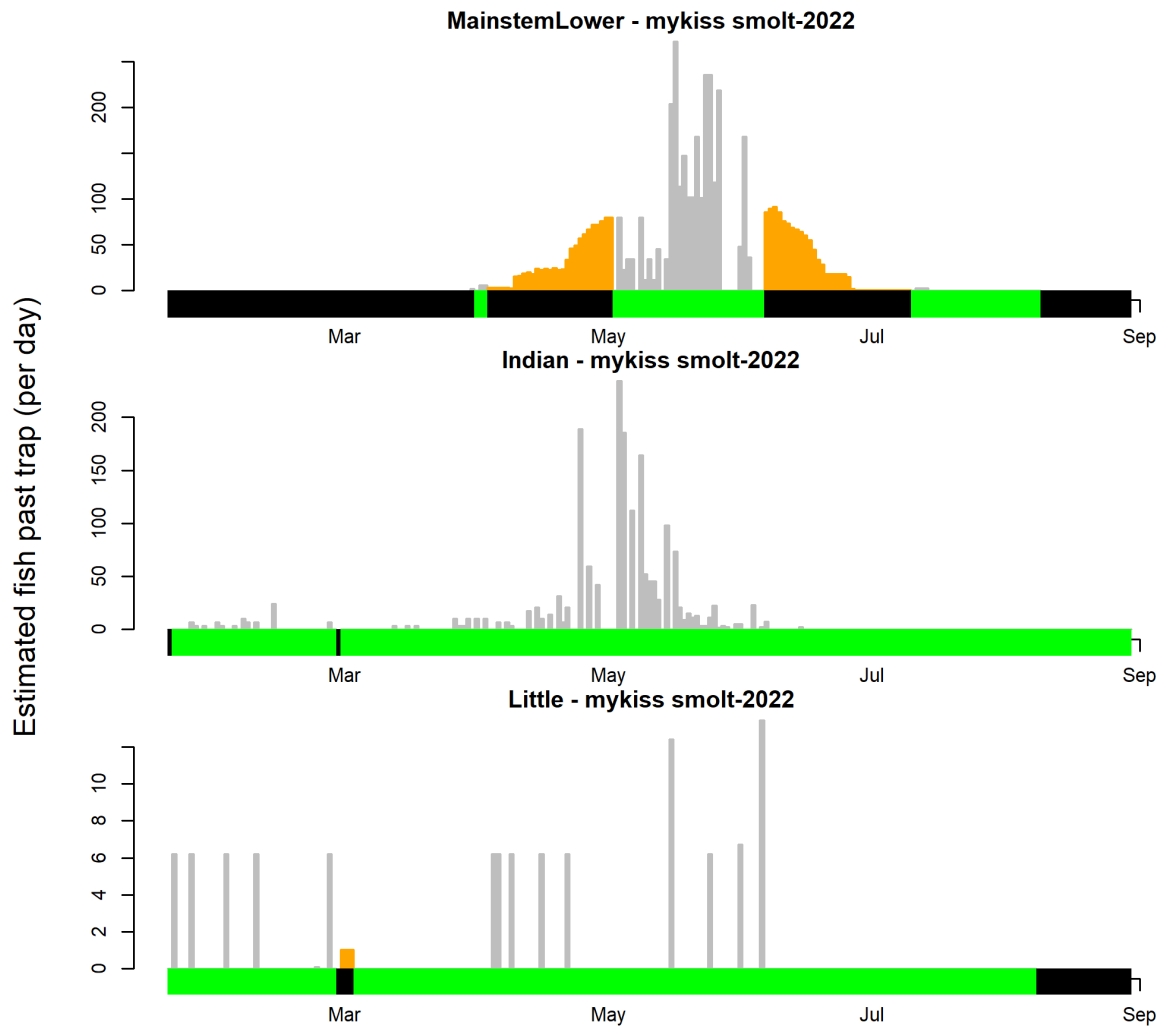
Estimated number of 0+ Chinook outmigrants at Indian, Little and mainstem Elwha trap sites by day during 2022.



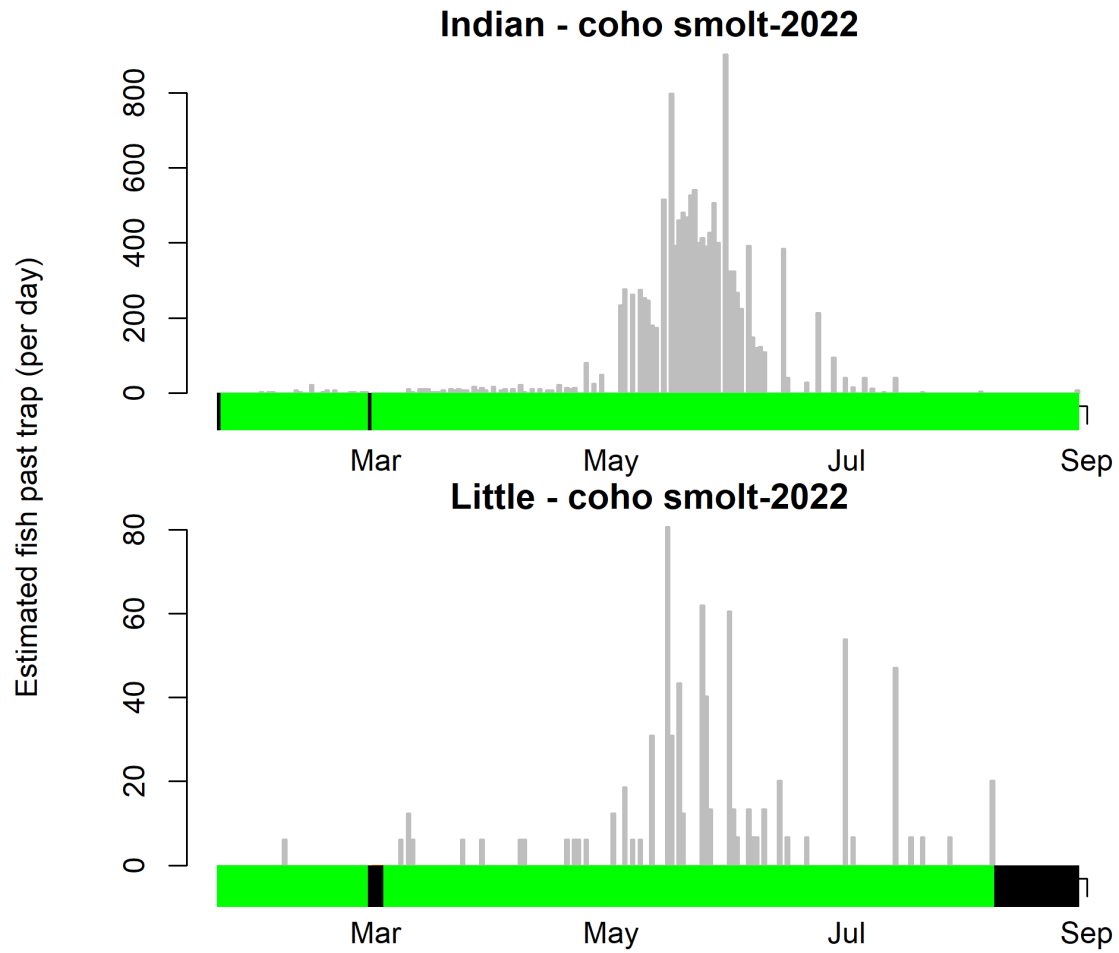
Estimated number Coho 0+ outmigrants at the Indian Creek, Little River and Elwha mainstem trap sites by day during 2022.



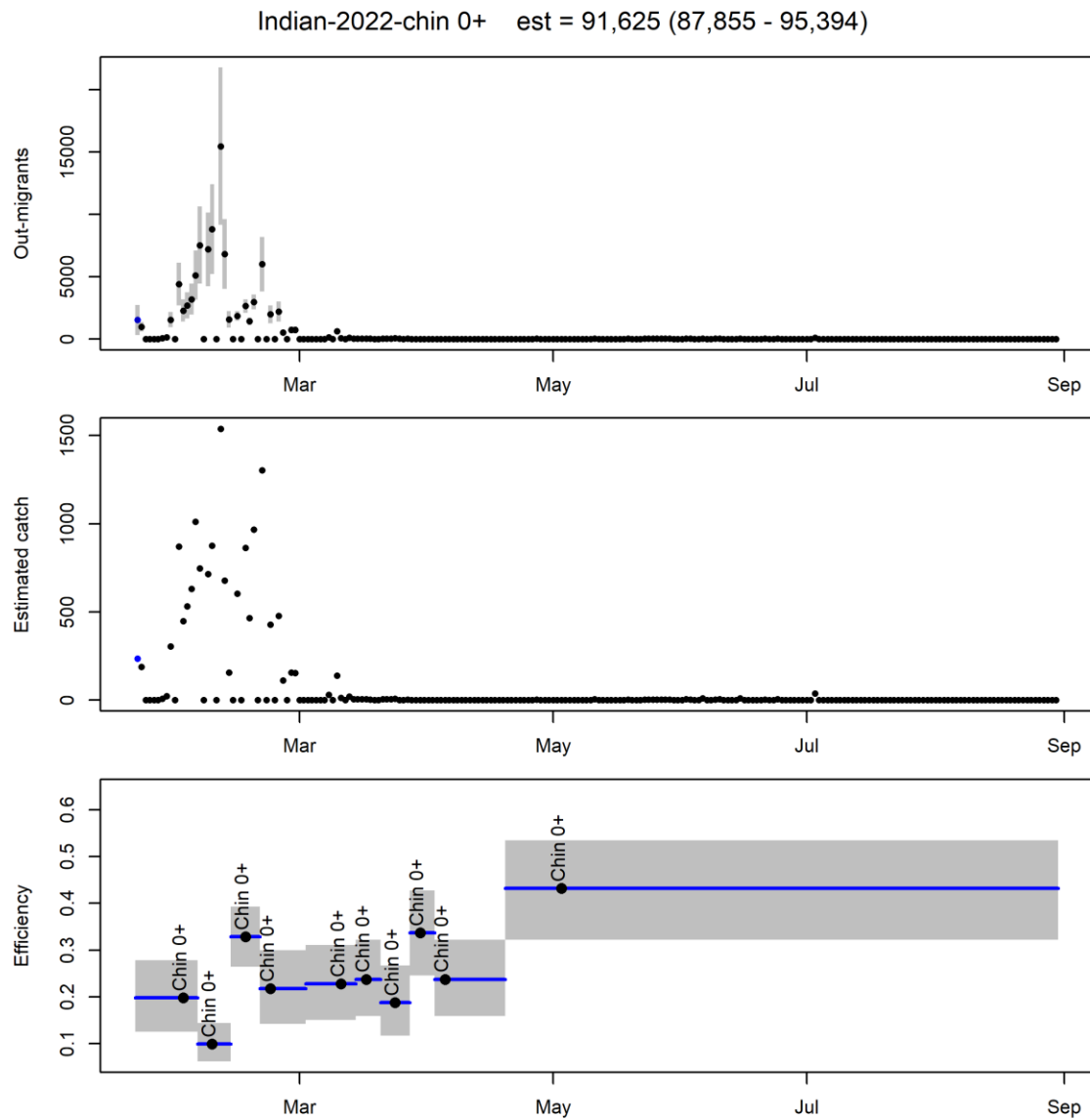
Estimated number Steelhead outmigrants at the Indian Creek, Little River and Elwha mainstem trap sites by day during 2022.

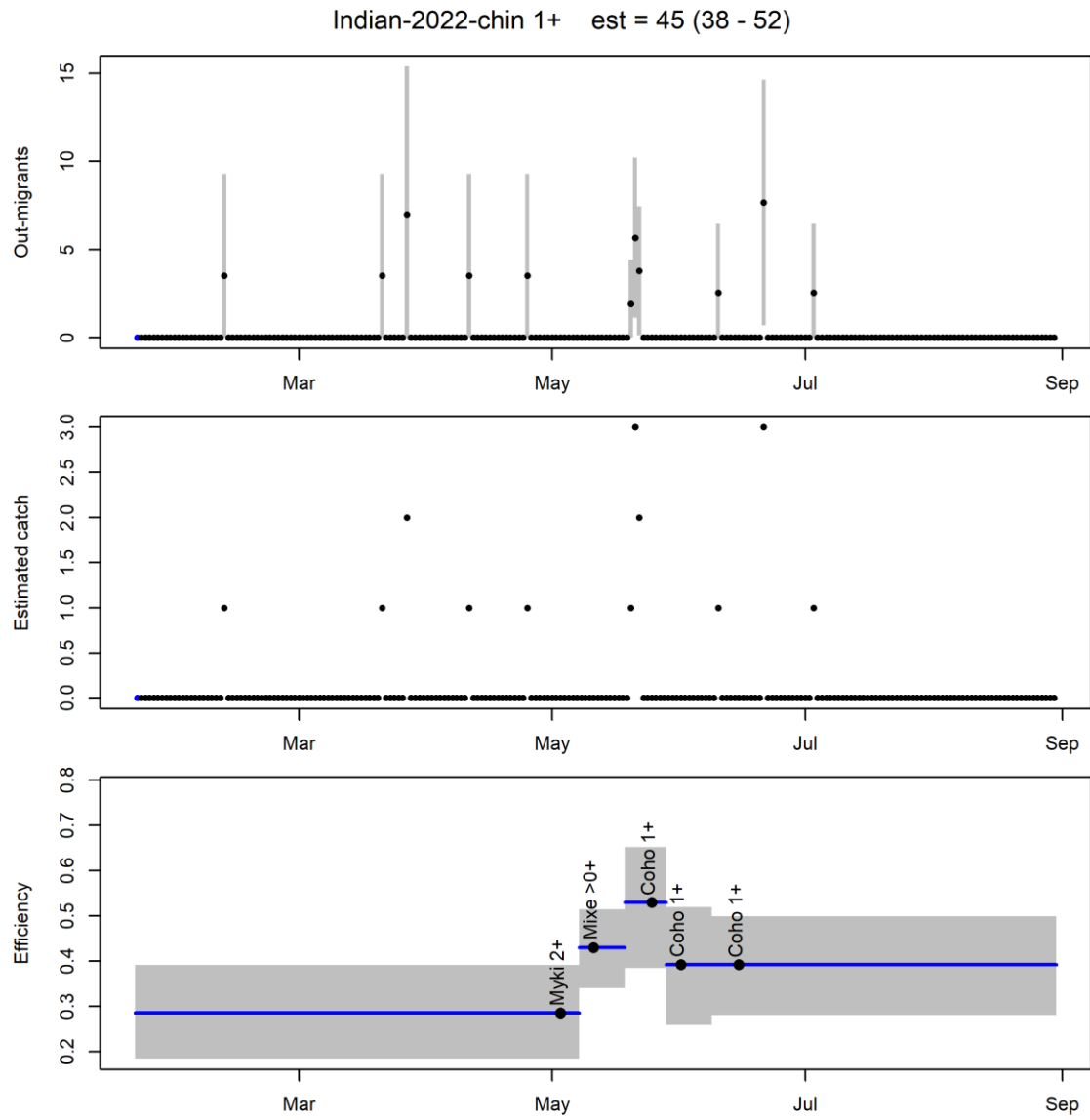


Estimated number of Coho outmigrants at Indian Creek and Little River trap sites by day during 2022.

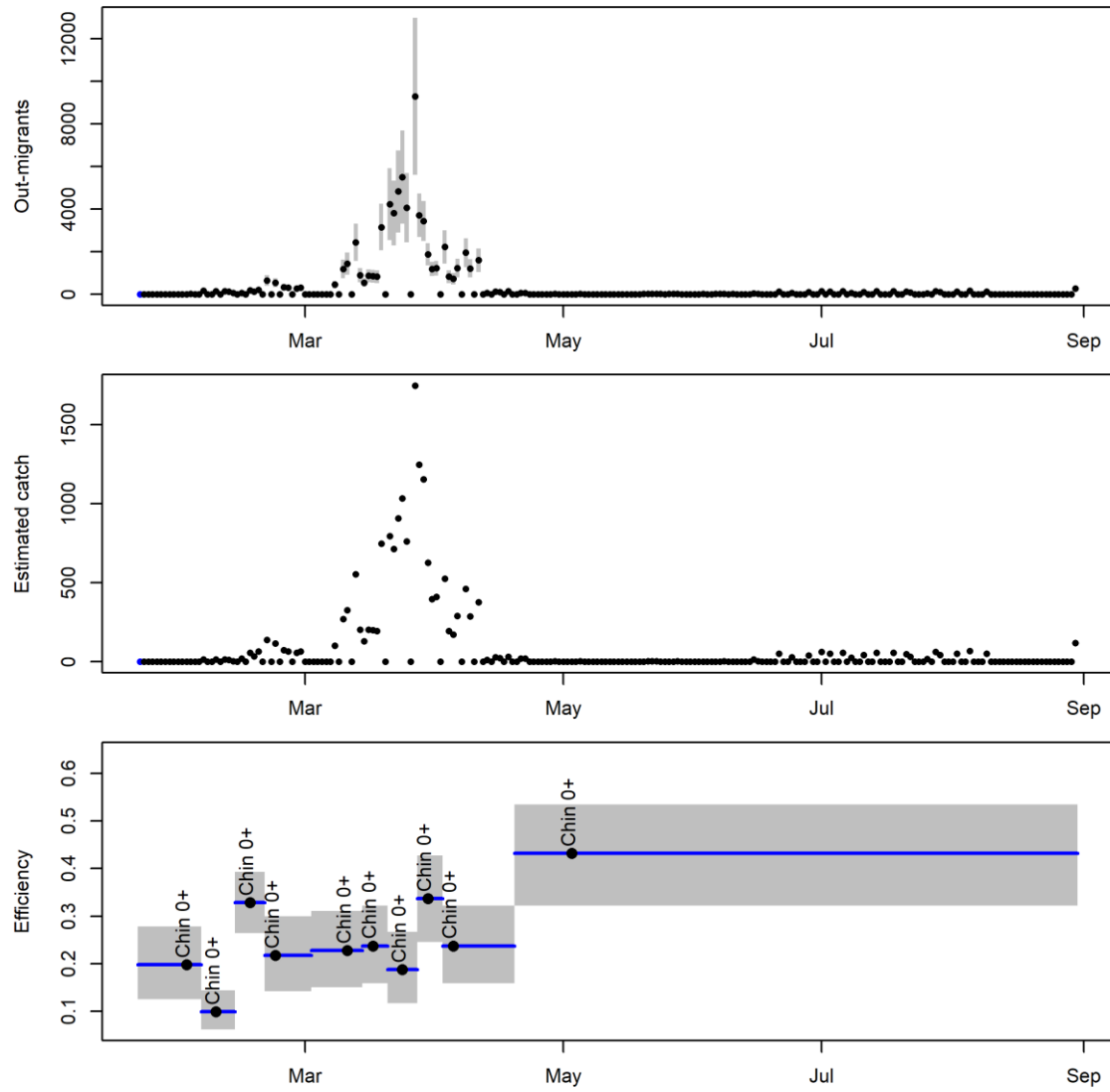


Appendix B. Plots of outmigrants, estimated catch and expansion factor by species and trap site for the 2022 smolt trapping season. Top panel: Points are outmigrants by day, with 50% confidence intervals in gray. Orange points are for days no fishing and blue points are for days that were partially fished (<24hours fished). Middle panel: Catch. Same color scheme as above. Third panel: Black lines are efficiency with gray rectangles representing 50% confidence intervals. The black points represent the release dates.

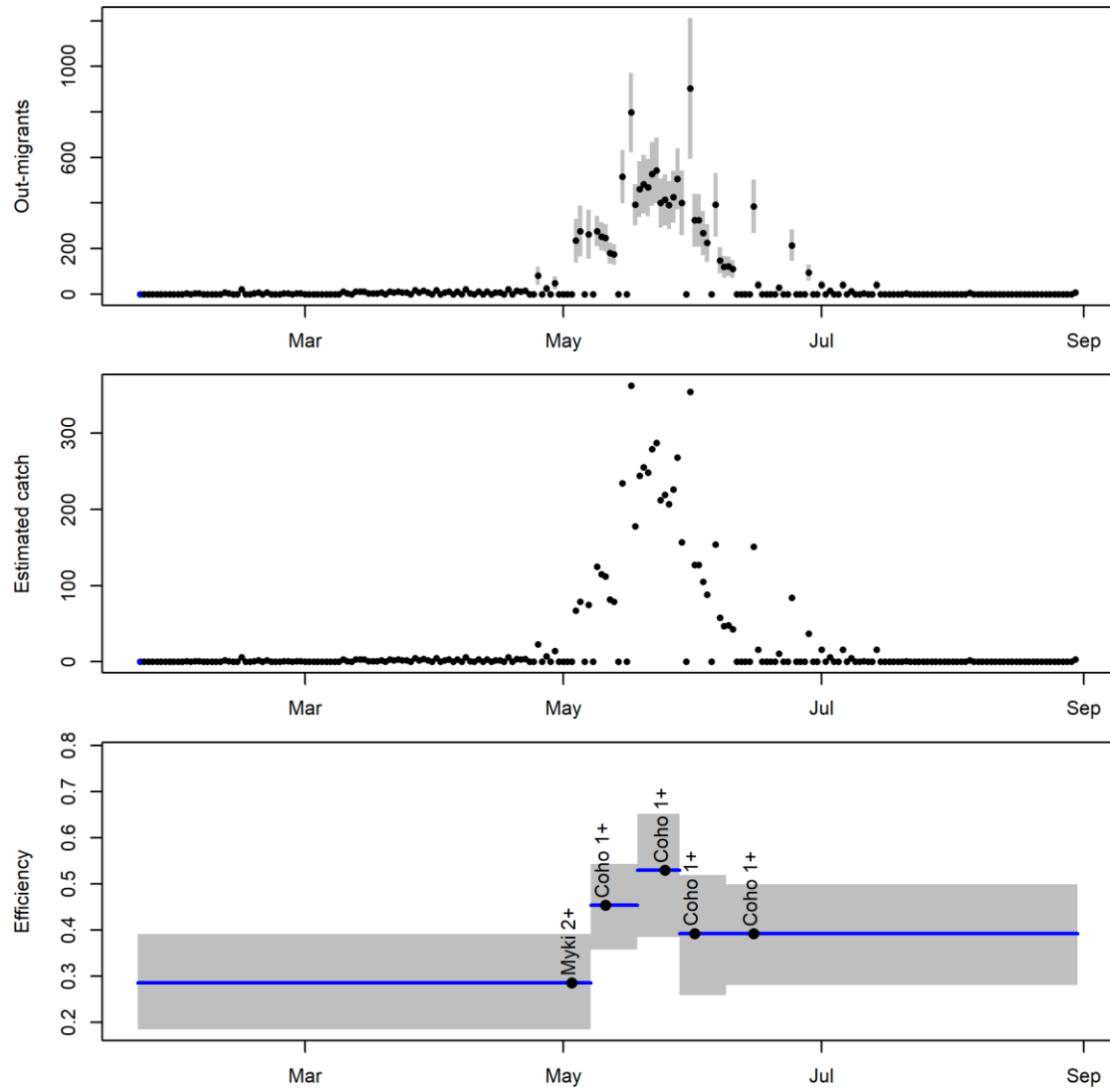




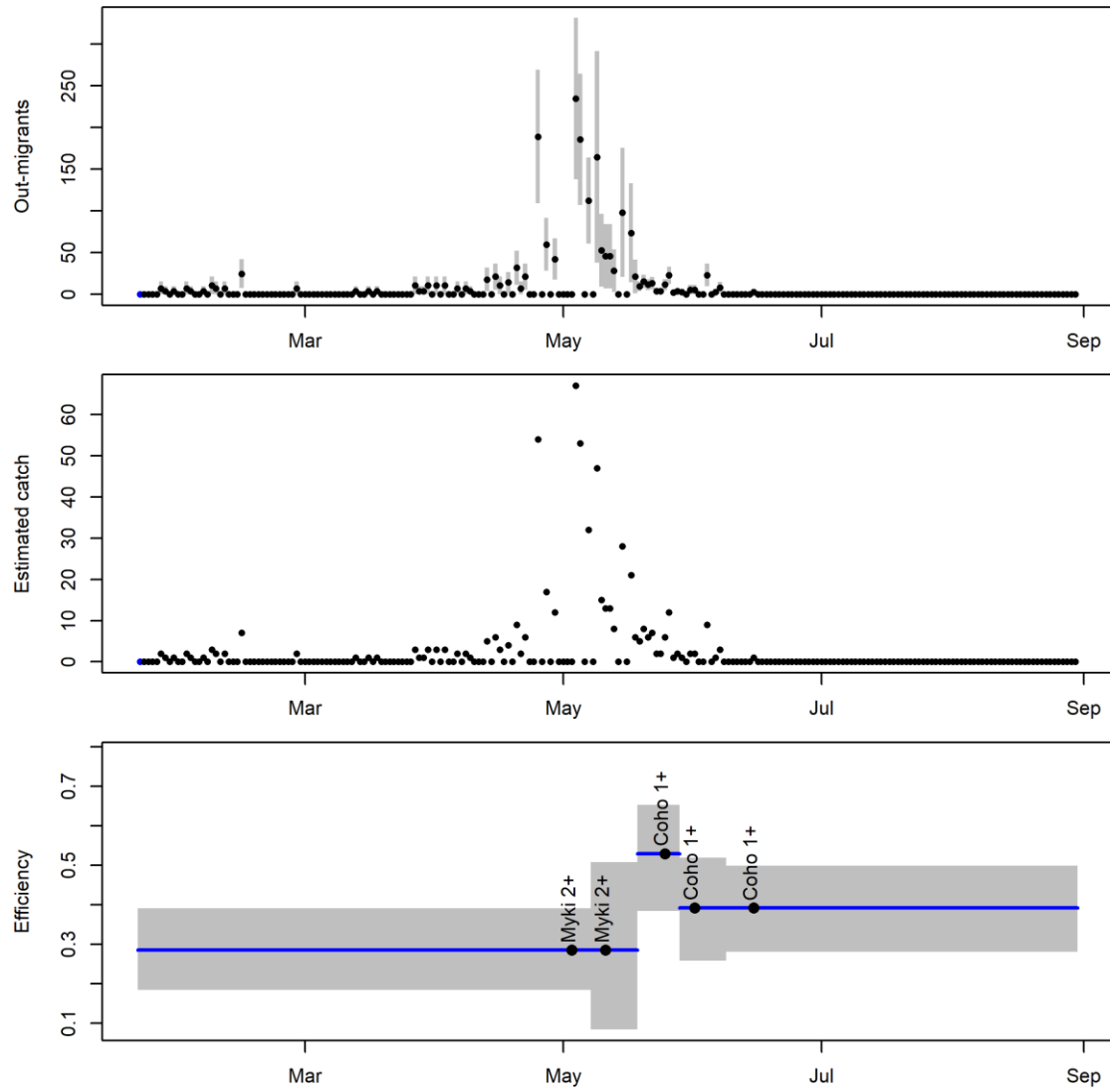
Indian-2022-coho 0+ est = 67,497 (64,228 - 70,767)



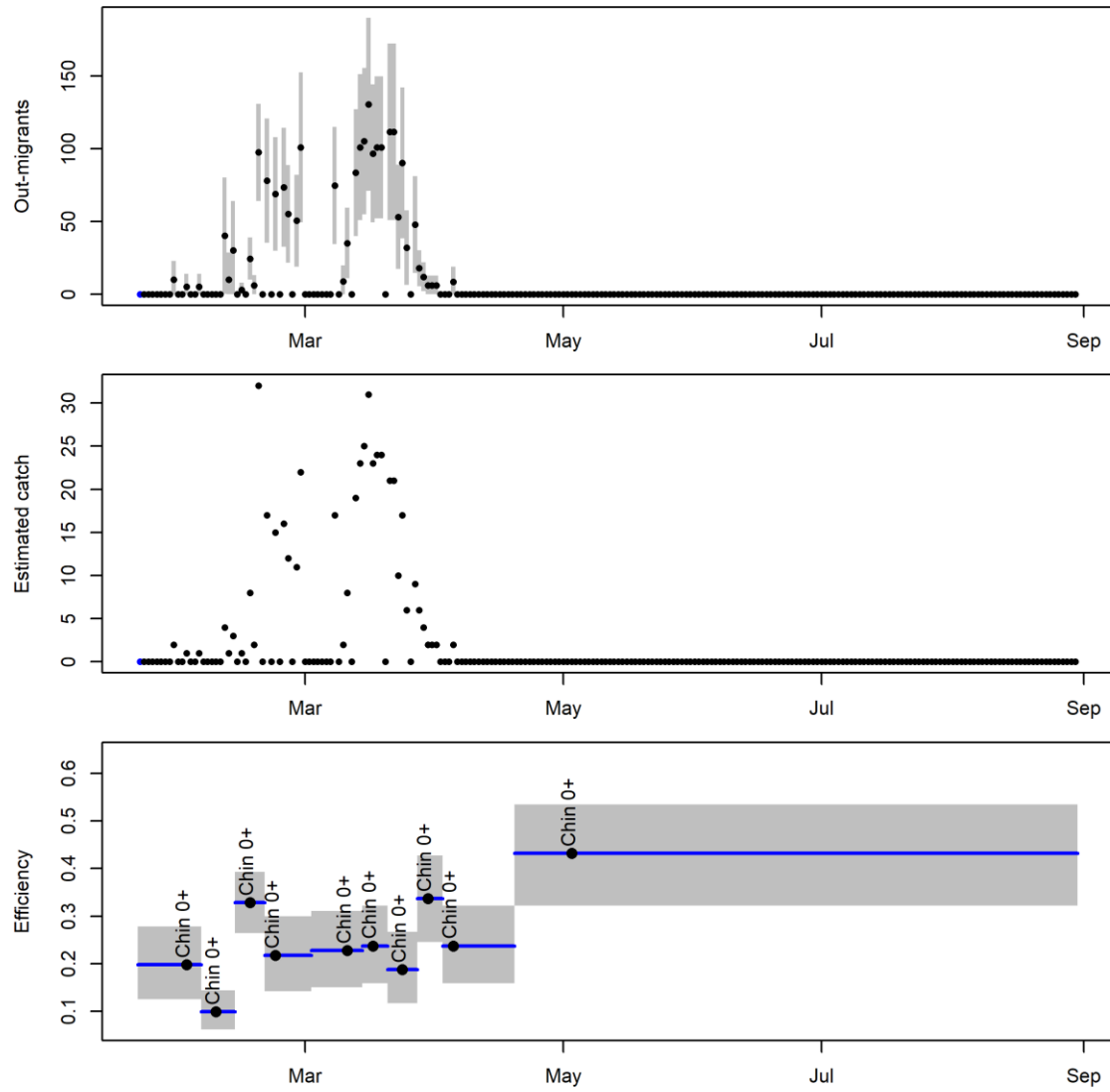
Indian-2022-coho smolt est = 13,038 (12,424 - 13,652)



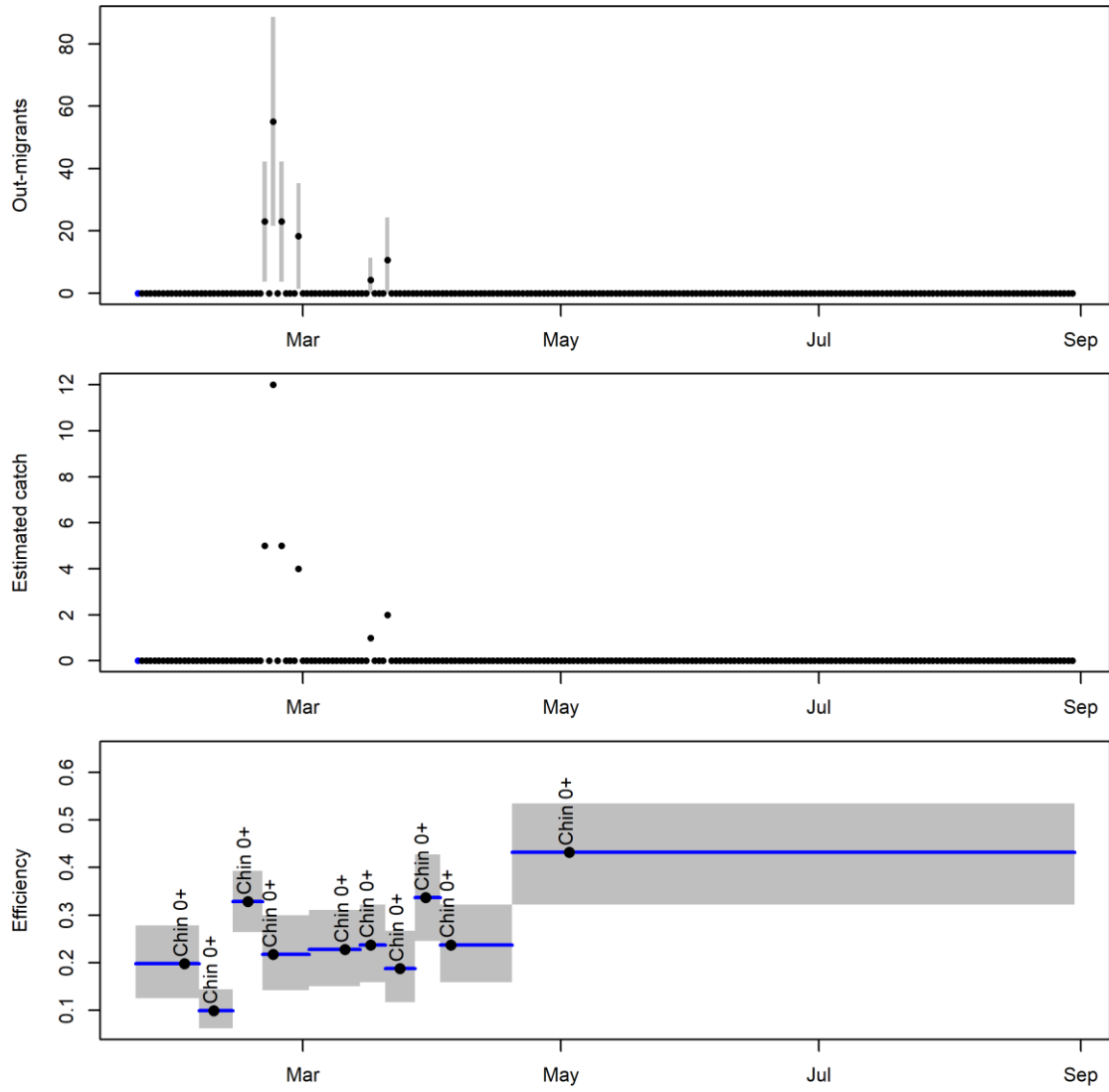
Indian-2022-mykiss smolt est = 1,779 (1,582 - 1,977)



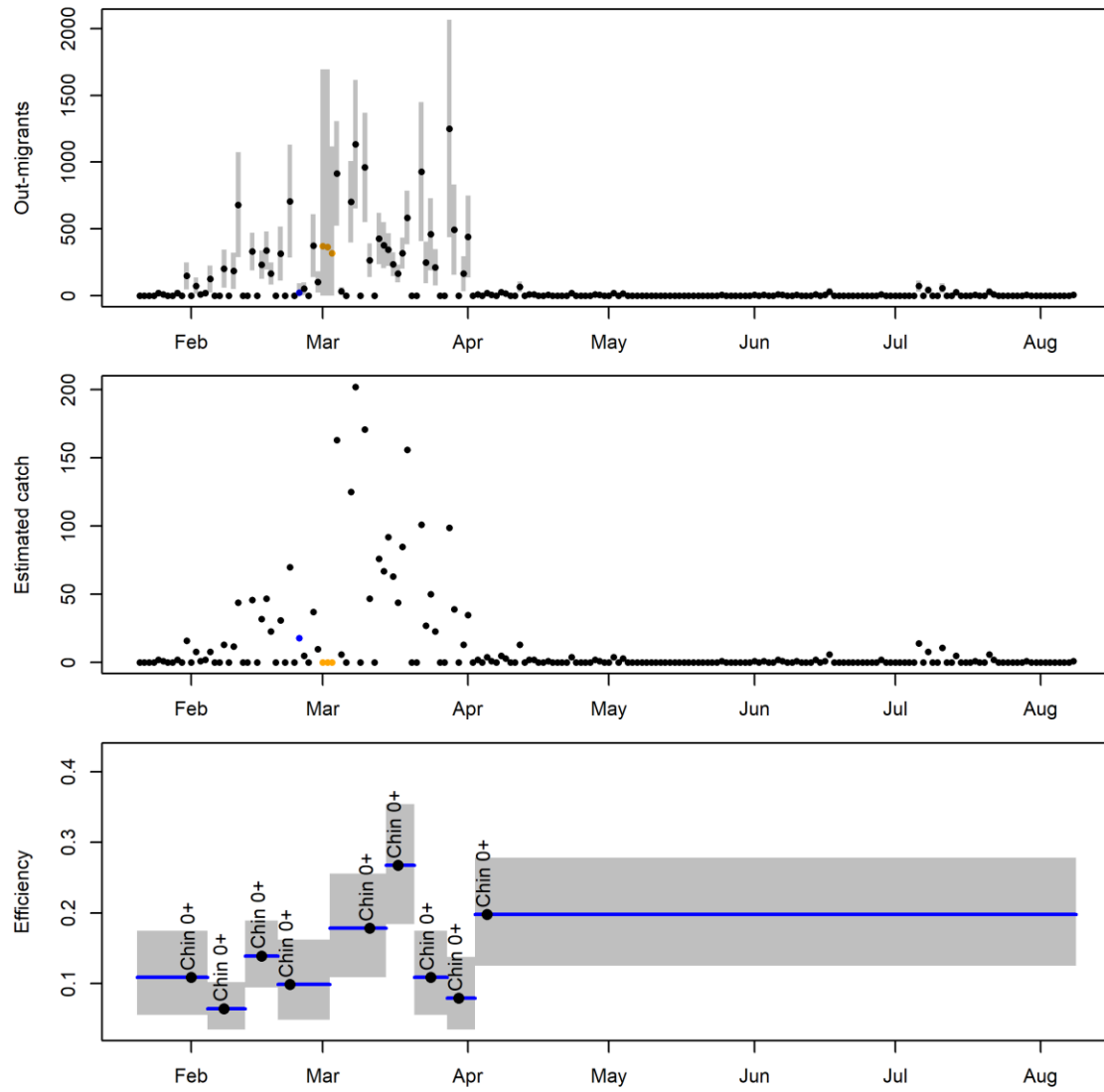
Indian-2022-pink est = 1,998 (1,871 - 2,126)



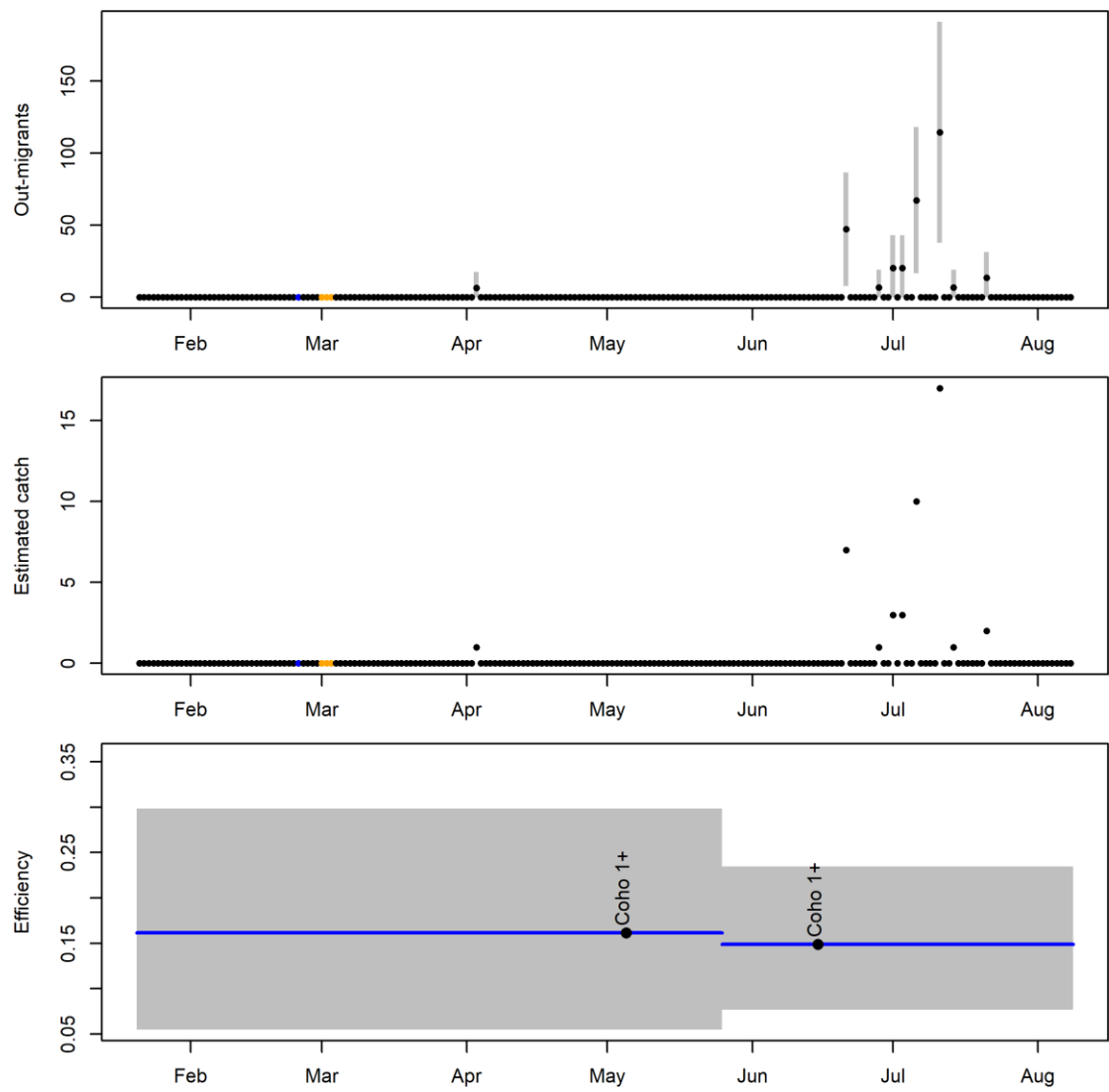
Indian-2022-chum est = 134 (115 - 154)



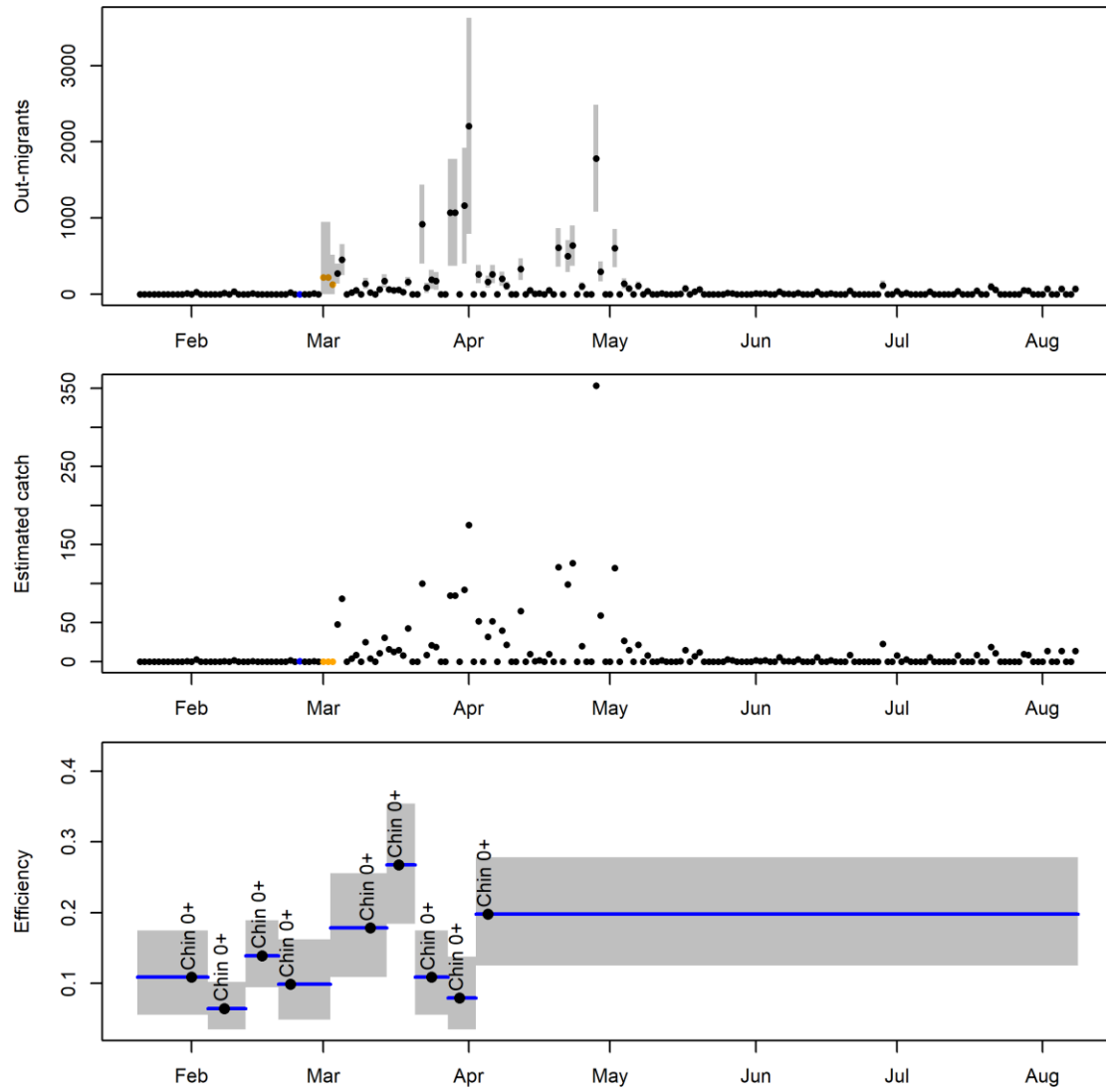
Little-2022-chin 0+ est = 16,577 (15,255 - 17,899)

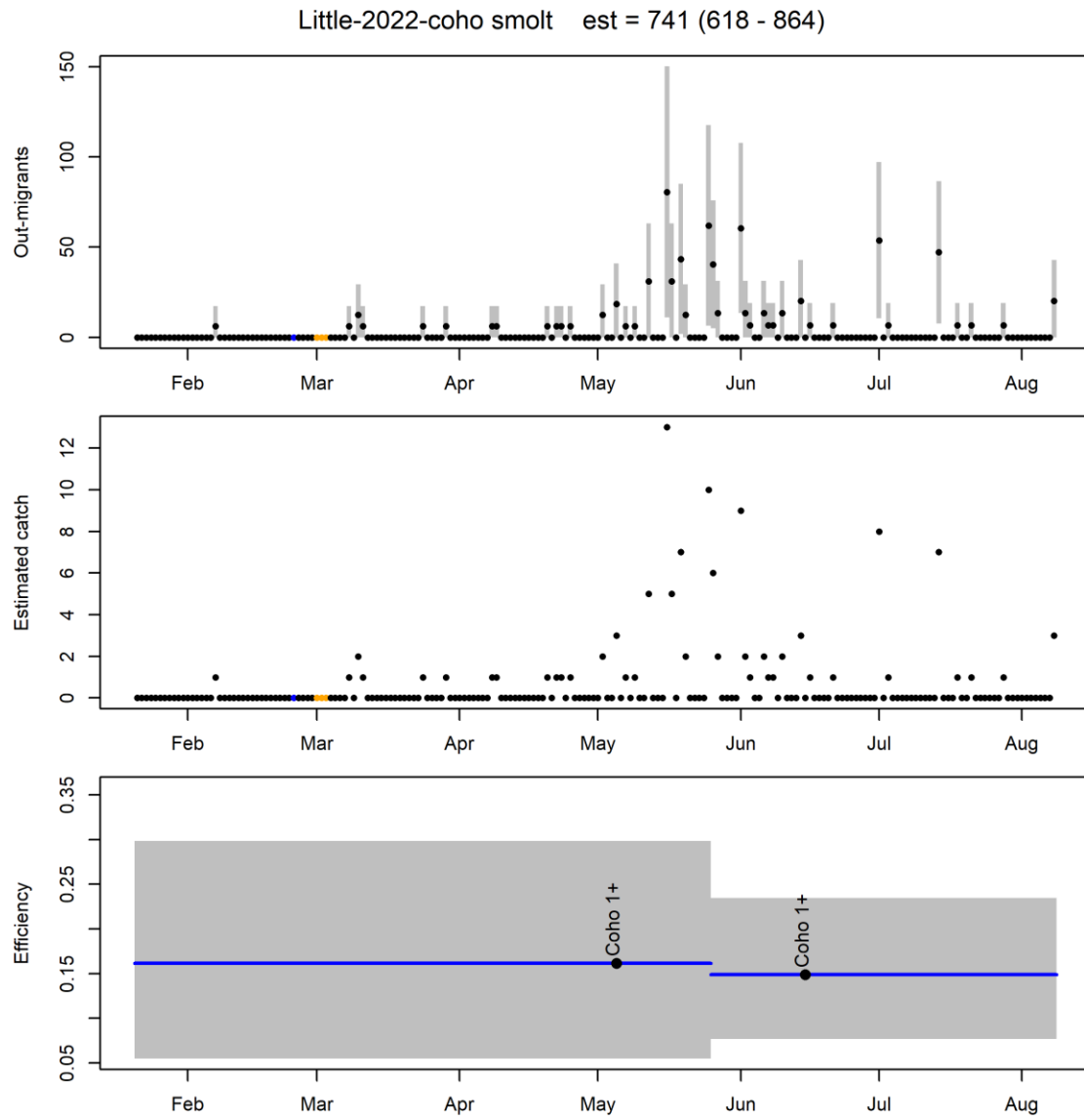


Little-2022-chin 1+ est = 302 (243 - 362)

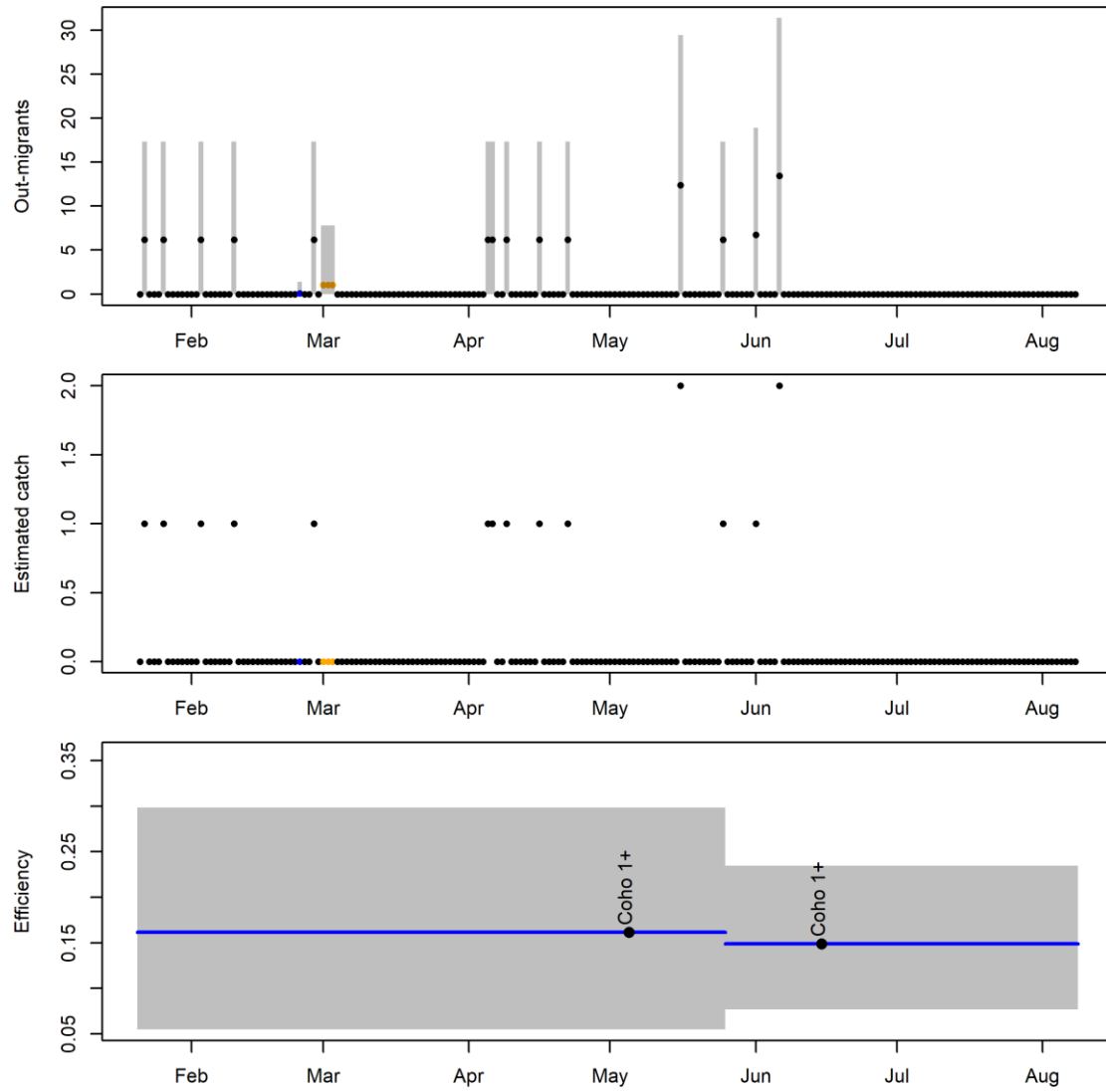


Little-2022-coho 0+ est = 16,599 (14,961 - 18,237)

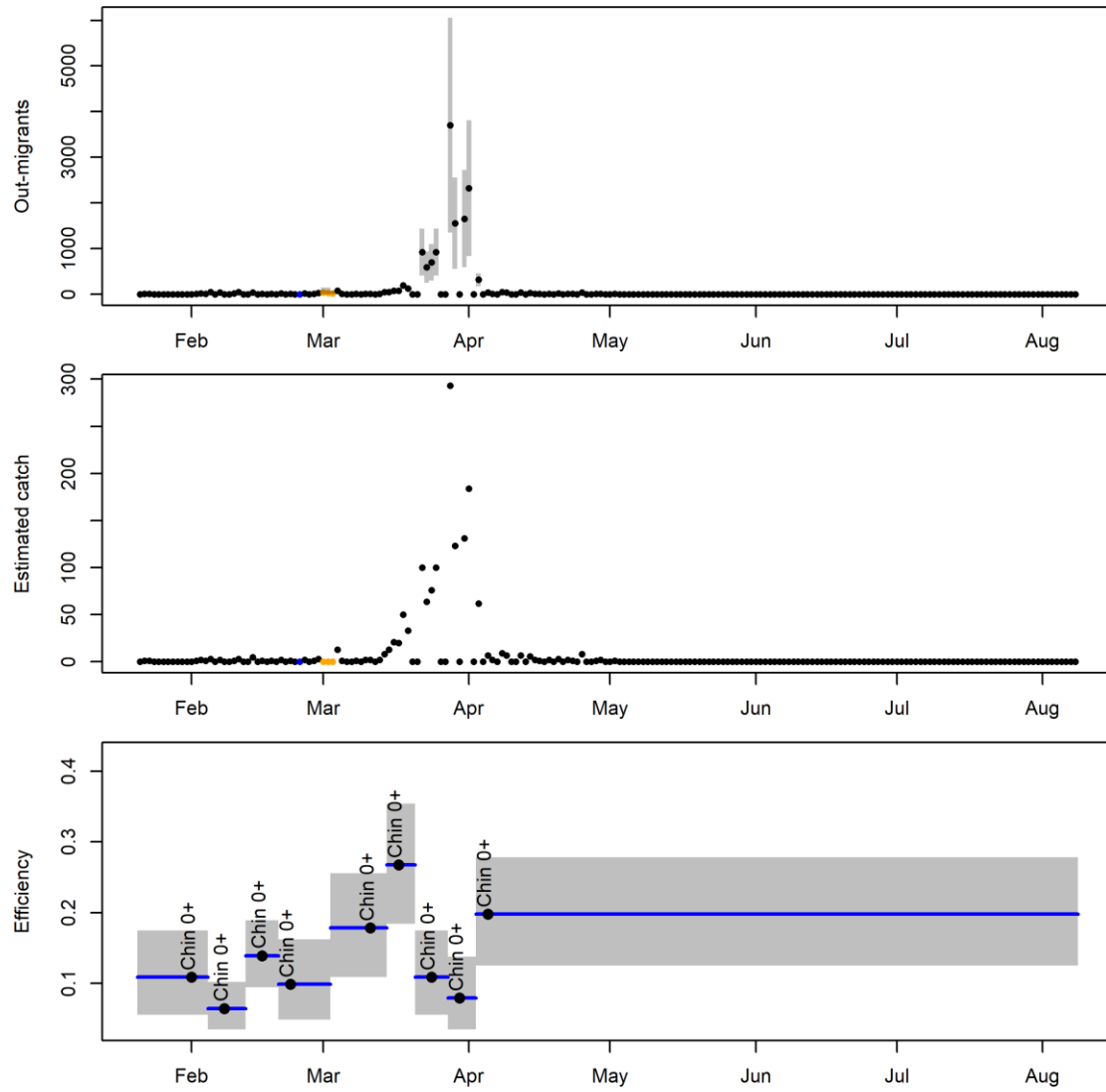




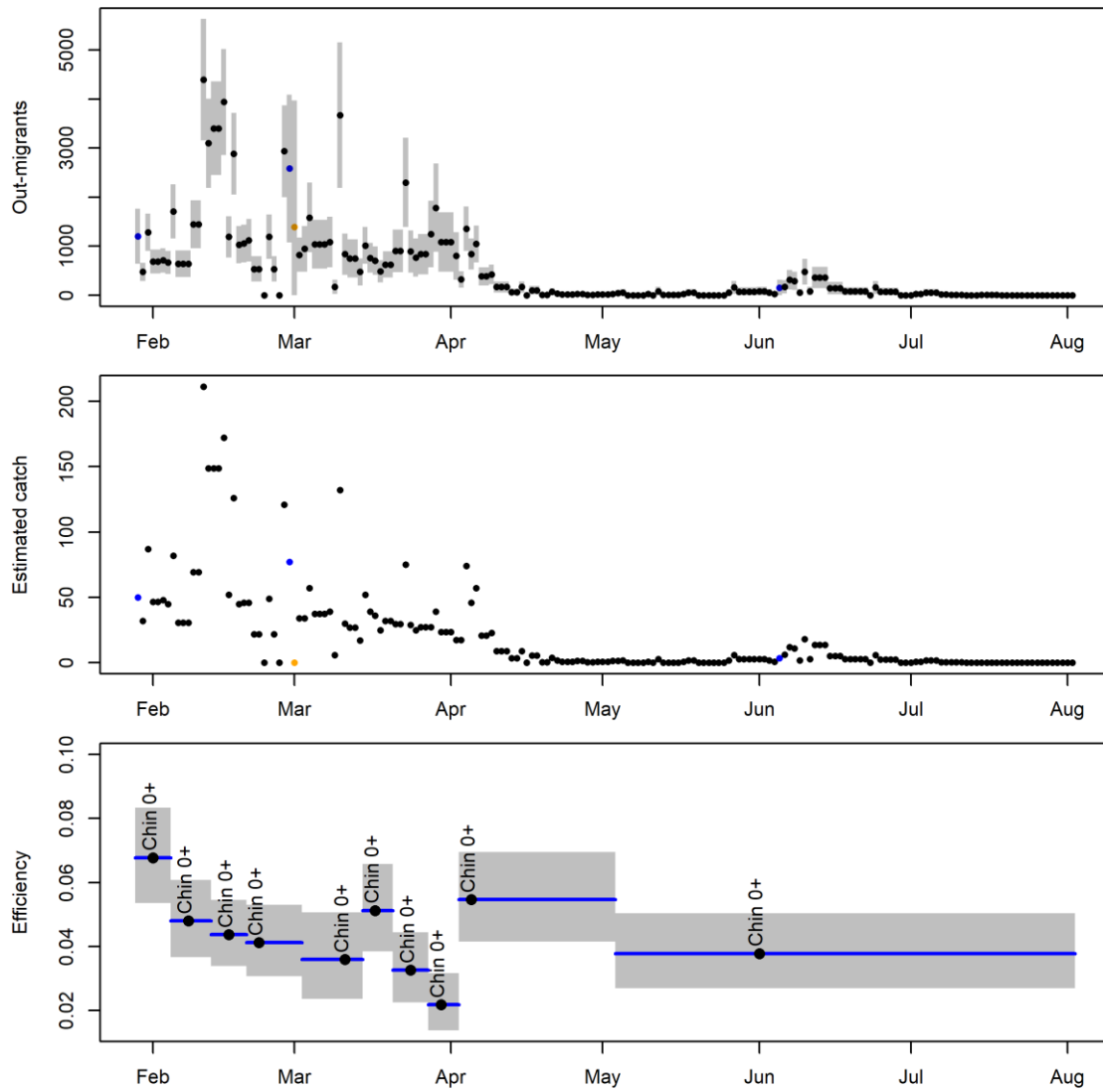
Little-2022-mykiss smolt est = 104 (78 - 130)

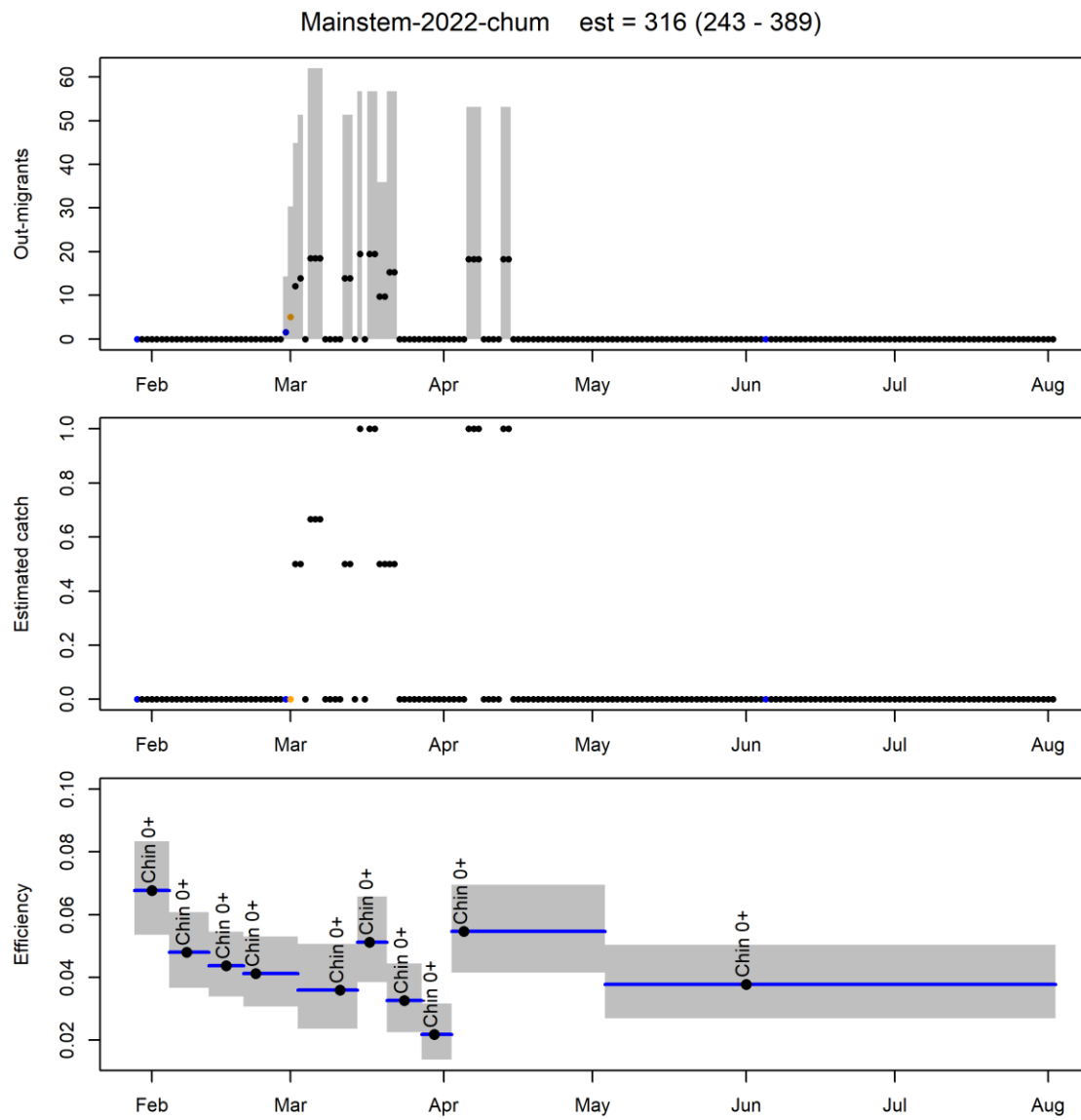


Little-2022-pink est = 14,065 (11,975 - 16,154)

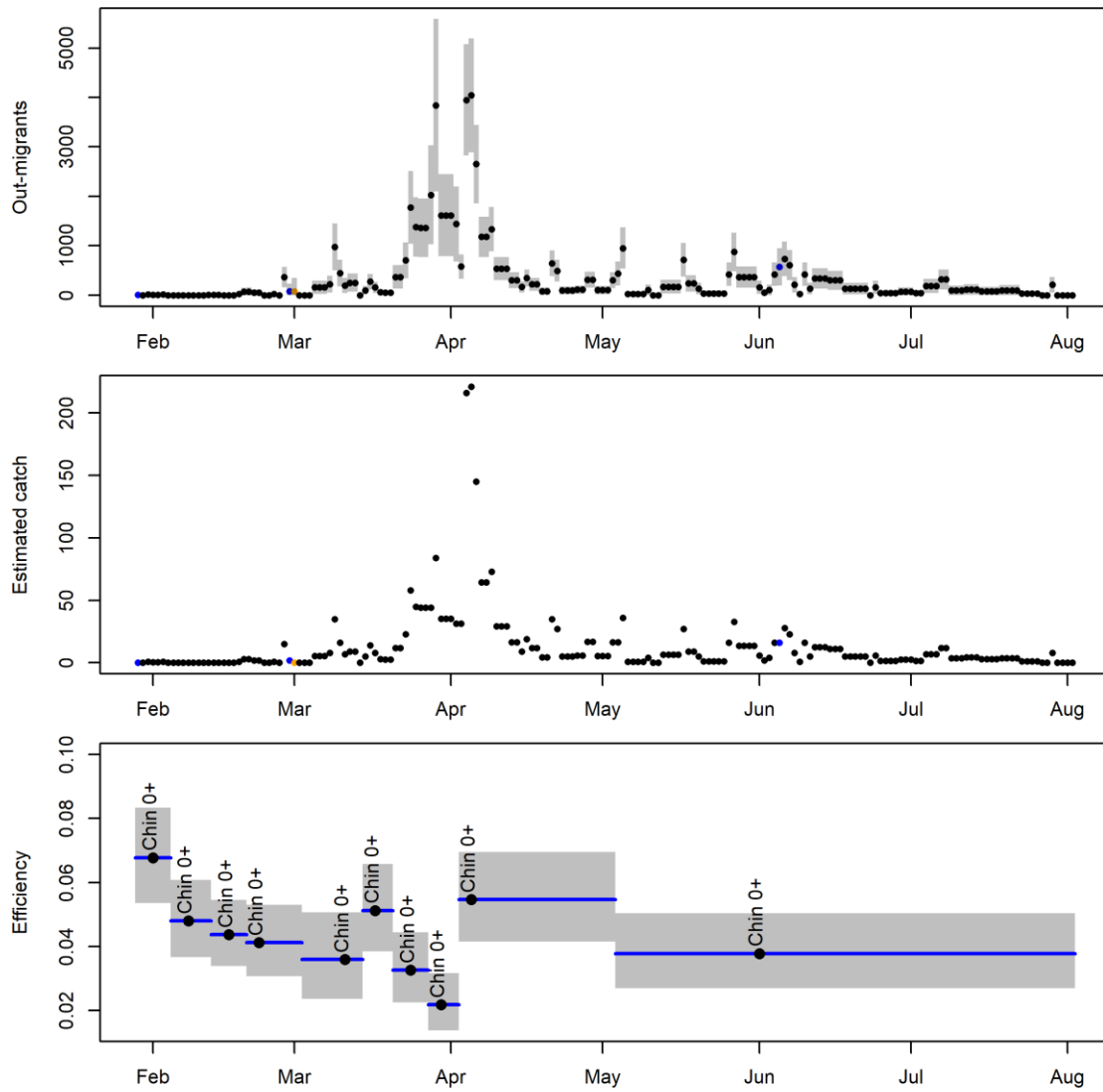


Mainstem-2022-chin 0+ est = 91,640 (87,841 - 95,439)

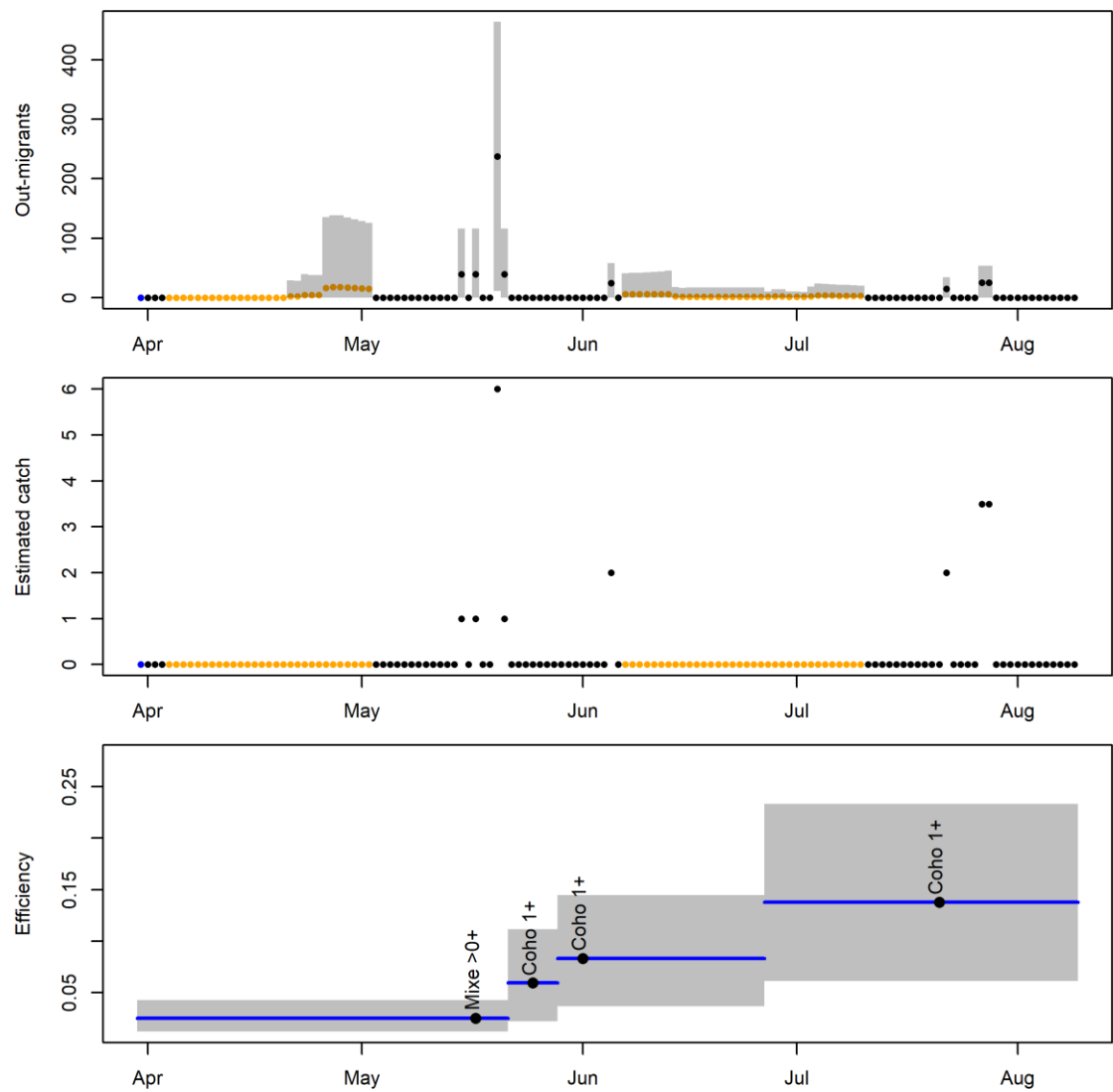




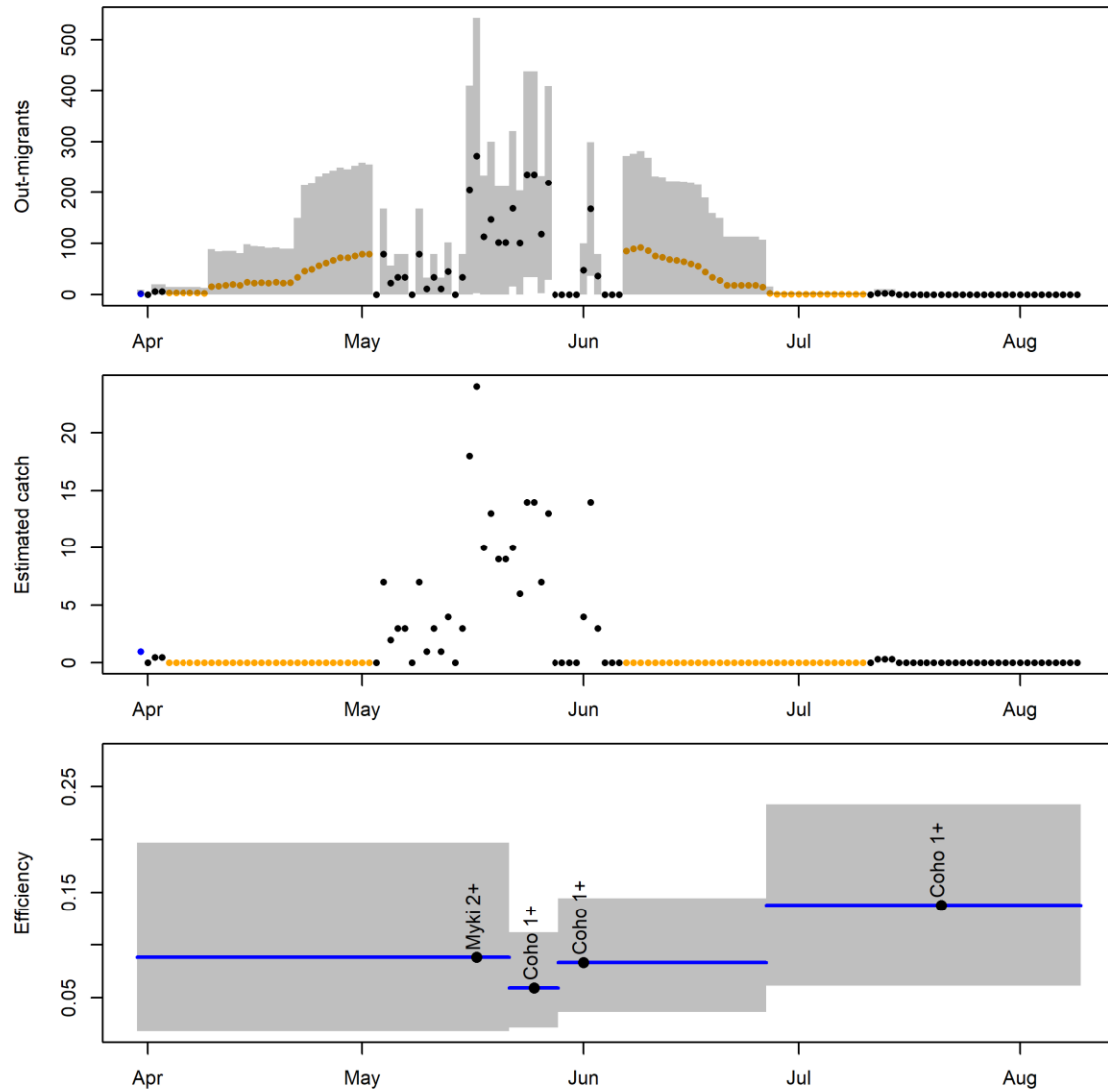
Mainstem-2022-coho 0+ est = 60,992 (57,127 - 64,857)



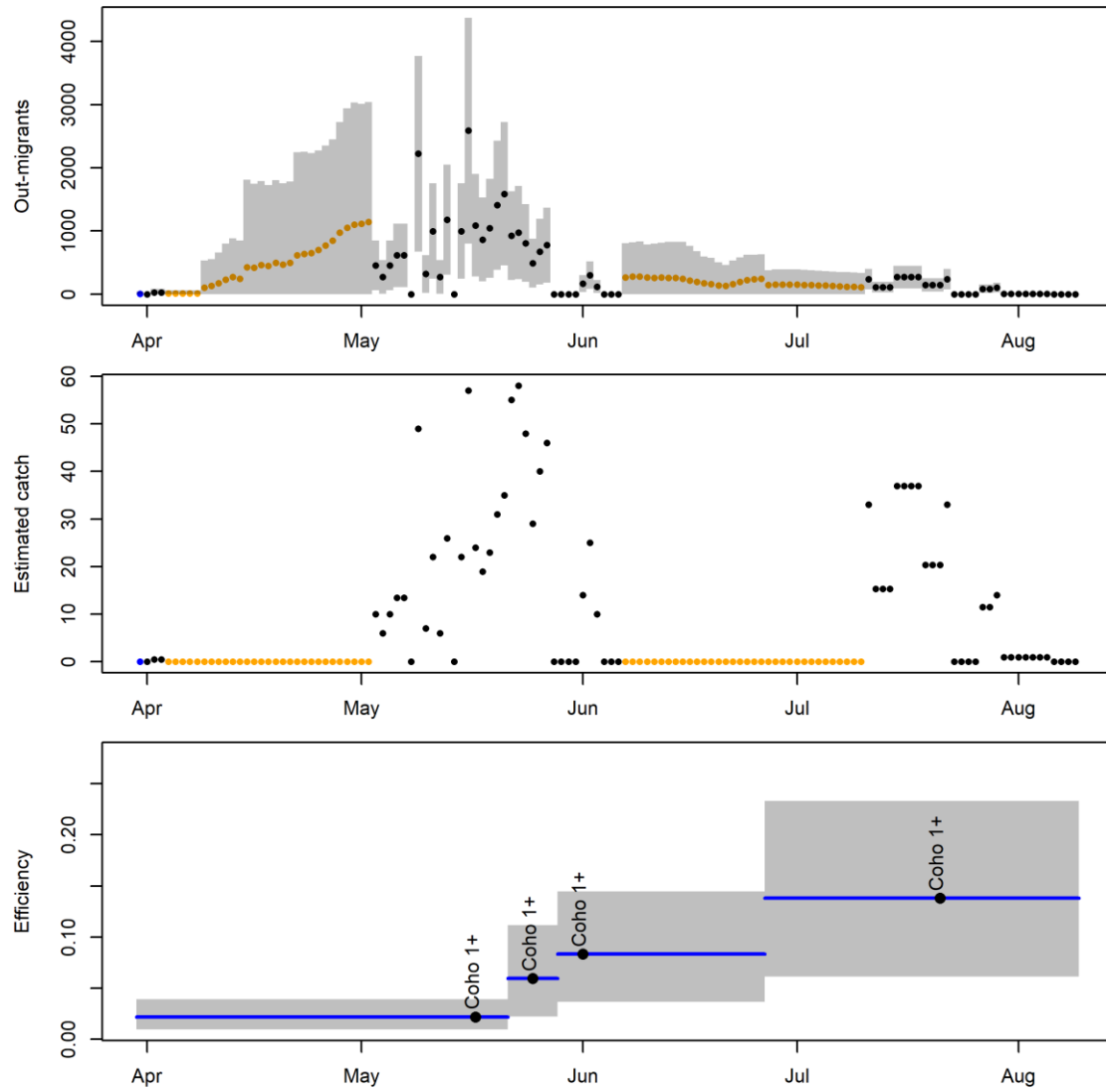
MainstemLower-2022-chin 1+ est = 670 (497 - 843)



MainstemLower-2022-mykiss smolt est = 4,741 (3,830 - 5,652)



MainstemLower-2022-coho 1+ est = 45,278 (37,731 - 52,825)



Appendix C: Analysis Details

Using the Lincoln-Peterson estimator we can estimate the total fish that passed the trap by summing the catch for each efficiency trial period and expanding these sums using the efficiency trials. For each efficiency trial period we multiply the summed catch, C_i , times the number of releases, S_i , divided by the number of recaptures, R_i .

$$O = \sum_{i=1}^n \frac{C_i S_i}{R_i}$$

However, this produces a biased estimate. If we assume that the marked fish are not part of the population of interest (e.g. using hatchery fish in the efficiency trials), a less biased estimate is (Carlson et al. 1998),

$$O = \sum_{i=1}^n \frac{C_i (S_i + 1)}{R_i + 1}$$

An approximately unbiased estimator of the variance of the out-migrants estimator (Carlson et al. 1998) is,

$$V(O) = \sum_{i=1}^n \frac{(S_i + 1)(C_i + R_i + 1)(S_i)(S_i - R_i)C_i}{(R_i + 1)^2(R_i + 2)}$$

which can be used to produce an approximate 95% confidence interval,

$$O \pm 1.96\sqrt{V(O)}$$

If there are periods of time when the trap is not fishing due to in-river conditions or other logistical constraints the estimator and approximate estimator variance are modified to account for periods with missing catch.

To fill in all or some of the catch for day, d , $\hat{C}_d$, we use observed daily catch rates within k days of the missing date.

$$\hat{C}_d = C_d + (1 - p_d) \text{avg} \left(\frac{C_i}{p_i} \right) \quad , \quad i \in (d - k) \text{ to } (d + k) \text{ where } C_i \neq \text{NA}$$

here the C_i 's are the total catch in a day and p_i is the proportion of the day that the trap was operational. Only days with catch data that are within k days of the missing day are used.

The variance of this estimate is,

$$V(\hat{C}_d) = \frac{\sum (C_i - \hat{C}_d)^2}{n(n-1)}$$

Summing over the days within an efficiency period we can get period specific variance estimates.

$$V(\hat{C}_p) = \sum_{d=1}^{N_p} V(\hat{C}_d)$$

These can be used to calculate the total variance of the estimator as (see Weinheimer et al. 2011),

$$V(O) = \sum_{p=1}^n \left(V(\hat{C}_p) \frac{(S_p + 1)(S_p R_p + 3S_p + 2)}{(R_p + 1)^2 (R_p + 2)} + \frac{C_p (S_p + 1) S_i (C_p + R_p + 1) (S_p - R_p)}{(R_p + 1)^2 (R_p + 2)} \right)$$

R code

Here are the R functions used to generate the estimate and the variance of the estimator.

```
## Carlson estimator modified to account for missing days (Weinheimer et al. 2011)
##
## @param x A list containing nDays = number of days fished, hoursFished = the number of hours the trap was fishing each day, catch = the number of fish captured on that day, ePeriod = the efficiency trial assigned to that day, releaseSize = the number of fish released for each efficiency trial, recaps = the number of fish recaptured for each efficiency trial.
## @param k The number of days on each side of a date to use for filling. So the window width is 2k+1.
##
## @return The estimated number of fish that past the trap between the first and last day of trapping.
## @export
##
## @examples estimate <- estFunc2(x)
estFunc <- function(x,k=4){
  ## fill in missing catch using adjacent days with catch
  n <- x$nDays # number of days
  ind <- x$hoursFished < 24 # days that need to have catch filled
  indF <- x$hoursFished > 0 # days with some catch (used for filling)
  missingCatch <- rep(0,n) # a vector to store the filled in catch data
  p <- x$hoursFished/24 # proportion of day fished
```

```

rawCatch <- x$catch # store the raw catch data
rawCatch[x$hoursFished == 0] <- 0 # set catch to zero for days with hoursFished = 0
# Now iterate over the days with missing data and
# create extra catch based on adjacent days
for(i in which(ind)){
  # use days with data that are within k days
  indC <- indF & abs(1:n-i)<=k
  # create extra catch for the missing hours (could be the total day)
  missingCatch[i] <- (1-p[i])*mean(rawCatch[indC]/p[indC])
}
# add the imputed data to the existing catch data
# and aggregate to the efficiency period
tmp <- aggregate(missingCatch+rawCatch,list(ePer=x$ePeriod),sum)
Ci <- tmp$x
names(Ci) <- tmp$ePer
# expand the catch data using the efficiency trials and sum
sum(Ci[x$ePeriodE]*(x$releaseSize+1)/(x$recaps+1))
}

#' A function to calculate the variance of the Carlson estimator
#'   modified to account for missing days (Weinheimer et al. 2011)
#'   It combines uncertainty from filling the catch series with uncertainty from the expansion
#'
#' @param x A list containing nDays = number of days fished, hoursFished = the number of hours the trap was fishing each day, catch = the number of fish captured on that day, ePeriod = the efficiency trial assigned to that day, releaseSize = the number of fish released for each efficiency trial, recaps = the number of fish recaptured for each efficiency trial.
#' @param k The number of days on each side of a date to use for filling. So the window width is 2k+1.
#'
#' @return The variance of the estimator
#' @export
#'
#' @examples estVar <- varFunc(x)
varFunc <- function(x,k=4){
  ## fill in missing catch using adjacent days with catch
  n <- x$nDays # number of days
  ind <- x$hoursFished < 24 # days that need to have catch filled
  indF <- x$hoursFished > 0 # days with some catch (used for filling)
  missingCatch <- rep(0,n) # a vector to store the filled in catch data
  varC <- rep(0,n) # a vector to store the variances related to filling

```

```

p <- x$hoursFished/24 # proportion of day fished
rawCatch <- x$catch # store the raw catch data
rawCatch[x$hoursFished == 0] <- 0 # set catch to zero for days with hoursFi
shed = 0
# Now iterate over the days with missing data and
# create extra catch based on adjacent days
for(i in which(ind)){
  # use days with data that are within k days
  indC <- indF & abs(1:n-i)<=k
  # create extra catch for the missing hours (could be the total day)
  missingCatch[i] <- (1-p[i])*mean(rawCatch[indC]/p[indC])
  # calculate the variance associated with filling
  varC[i] <- (1-p[i])^2*var(rawCatch[indC]/p[indC])
}

# add the imputed data to the existing catch data
# and aggregate to the efficiency period
tmp <- aggregate(missingCatch+rawCatch,list(ePer=x$ePeriod),sum)
Ci <- tmp$x
names(Ci) <- tmp$ePer
# aggregate the daily variances to the efficiency period
tmp <- aggregate(varC,list(ePer=x$ePeriod),sum)
Vp <- tmp$x
names(Vp) <- tmp$ePer

# use the formulas from Kris Ryding's appendix and Carlson's paper
fillVar <- sum(Vp[x$ePeriodE]*(x$releaseSize+1)*(x$releaseSize*x$recaps + 3
*x$releaseSize +2)/((x$recaps+1)^2 * (x$recaps+2)))
expandVar <- sum((x$releaseSize+1)*(Ci[x$ePeriodE]+x$recaps+1)*(x$releaseSi
ze-x$recaps)*Ci[x$ePeriodE]/
((x$recaps+1)^2 * (x$recaps+2)))

# combine to give the total variance
fillVar + expandVar
}

```