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2020 Elwha River Smolt Enumeration Project Report

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Pursuant to a settlement between the National Park Service and Lower Elwha
Klallam Tribe

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Executive Summary

Smolt enumeration monitoring was conducted on the mainstem Elwha River and in two tributaries, Little River and Indian Creek, during the 2020 outmigration season. This represents the fifth year of monitoring during the post dam removal period, and the 15th consecutive year of smolt monitoring on the Elwha River. For the second consecutive year, the mainstem trap was fished above both hatcheries and no fishing days were missed. In 2020, we generated watershed production estimates, credible intervals (CI), and coefficient of variation (CV) estimates for the greatest number of species/life histories including: Chinook salmon (0+ and 1+), Coho salmon (0+ and 1+), Pink salmon, and Chum salmon. Because of catchability issues we did not estimate steelhead smolt outmigration in 2020. We estimate a total of 1,057,329 Chinook salmon subyearling outmigrants for the Elwha River in 2020. This is the largest estimate in our monitoring history, and eclipses the pre-project average (2006-2012) by a factor of twenty two. The 2020 estimate of 5,259 was also the highest measured to date for yearling Chinook salmon (1+) smolts. For Coho salmon we estimated a total outmigration of 8,470 (range 6,863-10,616), which is a decrease of 87% from 2019. Production of Chum salmon and Pink salmon remains very low 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 impacts from dam removal.

At the tributary sites, smolt trapping was continuous and we fished 100% of potential fishing days. For Indian Creek we estimated Coho salmon (ages 0+, 1+ and smolts), Chinook salmon (0+), Pink salmon and Steelhead smolts. For Little River we produced estimates for Coho salmon (ages 0+, 1+, and smolts) and Chinook salmon (0+ and 1+), Chum salmon, Pink salmon, and Steelhead. We estimated 304,062 0+ Chinook salmon from in 2020. We estimate an additional 51,725 Chinook salmon 0+ smolts downstream of the Little River trap in 2020. The combined estimate of 356,327 is the highest to date since trapping was initiated. We estimated 148 1+ Coho, 838 Coho smolts and 114 Steelhead smolts from Little River in 2020. For the first time, there was a measurable production of Pink and Chum salmon from Little River. We estimated a total of 4,465 and 1,686 Pink and Chum salmon smolts, respectively. For Indian Creek, we estimated at total outmigration of 112,226 (71,527-184,611) Chinook salmon 0+ smolts. We estimate an additional 69,192 smolts were produced from below the trap for a grand total of 181,418 Chinook 0+ smolts. Coho salmon smolts were estimated at 6,819 the second lowest to date. In contrast, the estimated number of Steelhead smolts was 2,008 the third highest since the project began. 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 2020. A total of 44 ammocoetes were captured at Little River suggesting that the early stages of recolonization have initiated.

Introduction

Removal of two mainstem hydroelectric dams on the Elwha River was completed between 2011 and 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 attempted 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 guidance in the hatchery biological opinions for the Elwha hatchery operations) provides quantitative performance targets that could be used to affect 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 including: 1) preservation, 2) recolonization, 3) local adaptation, and 4) viable natural population. 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 factors 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 populations. Most importantly the National Park Service (NPS) submitted a Chinook and Steelhead Monitoring Plan pursuant to paragraph 6 of the Terms and Conditions and Reasonable and Prudent Measures sections within the July 2, 2012, National Marine Fisheries Service (NMFS) Biological Opinion for the Elwha River Restoration Project (as amended by letter dated November 30, 2012, from NMFS to ONP). 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 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 parameters such as the timing and size at outmigration. The Lower Elwha Klallam Tribe (LEKT) established a smolt enumeration program on the Elwha River beginning in 2006. During the pre-dam removal period (2006-2011) the tribe 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 0.3. Funding of trap operations during this period was provided by the Pacific Coast Salmon Recovery Fund (NOAA). This effort has resulted in estimates of pre-project (dam removal) production for the aforementioned species. Estimation of larger sized Coho salmon smolts and Steelhead smolts has historically been more problematic because of their relative 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.

The 2020 trapping season represents the fifth year of main stem Elwha monitoring following dam removal and the fifteenth year in total. The beginning of the post-dam removal period is a significant project benchmark and metrics associated with smolt outmigration will be 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 and tidal 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 (2016-2020). 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 zero by mid to late June, likely 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).

During the dam-removal period (2011-2014), sediment and debris entrained in the river negatively affected trapping operations. Conditions were so poor in 2013 that trapping operations were discontinued as sediment and small organic debris overwhelmed the trap box and unacceptable level of fish mortality occurred. The changes in fishing conditions forced changes in both trap size and mainstem location during the dam removal period. River conditions have steadily improved since 2015 and LEKT was able to reoccupy the lower river site using the larger 8' screw. 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.

Changes in stream channel morphology during the dam removal period have not only affected the mainstem fishing site, 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. 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. Thus the LEKT was forced to use 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 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.

The LEKT established tributary smolt monitoring sites on Little River in 2012 and Indian Creek in 2013. Because of the lack of access to the lowest portions of each drainage, we used county road bridge crossings in each tributary for trap deployment. For Little River, we used the bridge crossing on Hot Springs Road located at Rkm 0.2. For Indian Creek, we used the bridge crossing on 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. 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 this site effectively (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. We partially resolved this issue by motorizing the screw in 2018 and 2019 using batteries and solar panels. In 2020, we fabricated an entirely new trap for Little River. The location of the traps over time within the Elwha watershed is depicted in Figure 3.

Daily Operations-2020

In 2020, LEKT commenced trapping operations in the mainstem on February 13 and ceased trapping efforts on July 25 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 were able to fish the mainstem trap for 194 of the 194 (100%) total fishing days in the 2020 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.

At Indian Creek, trapping commenced on February 13 and ceased operations on September 2, for a total of 202 out of 202 (100%) potential fishing days. At Little River trapping was initiated on February 25 and was concluded on August 25 for a total of 181 of 182 (99%) possible fishing days; a record for most days fished. For both tributary sites, the traps were fished continuously. The tributary fishing effort by year is summarized in Figure 5. In 2020, LEKT installed a fence weir 400 m downstream from the Lake Sutherland outlet to determine smolt outmigration from the lake. This replaced a fyke net fishing operation conducted in 2018-2019; the fyke net had been plagued by debris and flow issues that made it difficult to continuously sample outgoing smolts. The fence weir was installed on April 17 and removed on June 10, and was operational for 49 of 55 possible fishing days (89%).

Field Methods

Because of the coronavirus pandemic it was uncertain if trapping operations would be conducted in 2020. However after assessing the risks, we determined that trapping could be conducted safely and an individual employee was assigned to an individual trap. Employees drove separate vehicles to each work site and the trapping operation was successfully completed. 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 utilize plexiglass fish viewers to facilitate fish identification.

A weekly subsample of all species 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 multiple mark recapture tests at all three trap sites. 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 marking we used Bismarck Brown dye which gives the fish a distinctive mark that is readily recognizable by trap personnel. This is a non-toxic 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.

On the tributaries, weekly to biweekly samples of 50 to 450 fish, representative of the species migrating at any given time (i.e. 0+ Chinook salmon, 0+ Coho salmon, and 1+ Coho salmon smolts), were marked and released approximately 100 meters upstream of the trap site. 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 site. The majority of tests utilized small-bodied 0+ Chinook salmon, which were abundant at both tributary sites in 2020. A total of ten and eleven recapture trials were completed for Indian Creek and Little River, respectively. Recapture rates averaged 6.3% at Indian Creek and 24.8% at Little River.

For Indian Creek, efficiencies were much lower from the beginning of March to the beginning of May. We believe this was due to a damaged gasket in the trap box that was discovered after the season. Lower flows before and after this period likely prevented the fish from accessing this escape route resulting in higher efficiencies. Because the hole was relatively small we believe that the estimated efficiencies during the March to May period were not representative of what larger bodied coho smolt and steelhead smolt were experiencing. We therefore averaged all of the efficiencies outside of the period and multiplied this rate times 50

(resulting in 7 captures) to create faux efficiency data that likely was more representative of the efficiency for the 1+ bodied fish. This efficiency was used for the 1+ fish during this period in Indian Creek (Coho 1+, Coho smolt, and Steelhead smolt).

For the mainstem trap efficiency trials we primarily used 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 378-1,000 marked 0+ Chinook. Two additional tests were conducted using large-bodied 1+ Coho salmon obtained from Indian Creek. All of the trials were successfully completed and resulted in similar recapture rates (0.9-6.0%) for an average of 2.4%. Fish were released approximately 1000 meters above the mainstem trap.

Data Analysis

The sum of daily catch data along with efficiency trials were used to estimate total numbers for the season. To incorporate uncertainty due to periods of missing data and expansion based on trap efficiency we applied a flexible Bayesian model (Appendix A). Daily passage was assumed to follow a negative binomial distribution with a mean constrained to change smoothly with time (a random walk). Catch was modeled as a binomial distribution where the probability of capture was estimated from regular efficiency trials. Period specific efficiencies were assumed to be independent due to observed temporal trends in efficiency for some traps. We summarize the results with the median and 95% credible 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). Additional information on production estimation is provided in Appendix A.

Results

Smolt trapping on the Elwha River was successfully completed at all sites despite the challenges presented by the coronavirus pandemic. Additionally, moving the trap upstream of the hatchery outfalls has eliminated hatchery release impacts. Similar to the last four seasons, the 2020 trapping season was not significantly interrupted by sediment or small woody debris at the mainstem site. River conditions appear to have, in large part, stabilized following dam removal. During the incubation season flows were benign with only a peak flow of 12,300 cfs. The highest flow of the winter 2019-20 occurred in early February, which delayed the deployment of the mainstem trap by two weeks. Flow conditions were moderate during the 2020 trapping season, resulting in no lost days due to high flow (Figure 6).

Catch rates for several species remained relatively low, while others increased dramatically on the mainstem Elwha River in 2020. In 2020, estimates were made for a record number of species and life histories. We produced estimates for Chinook salmon (0+ and 1+), Coho salmon (0+ and 1+), Chum and Pink salmon, at the mainstem site (Table 2). For the fifth consecutive year we generated estimates for larger-bodied Coho salmon (1+) because of improved capture rates. Additionally, estimates for 1+ Chinook salmon were made for the mainstem and Little River. In 2020, 0+ Chinook salmon were the most numerous species captured in the mainstem trap with a total of 20,427 captured. We estimated a total 0+ Chinook salmon smolt outmigration of 952,442 to the trap. Using the number of Chinook salmon redds (563) counted upstream of the trap in 2019, we calculated that each redd produced an average of 632 smolts. In order to account for the number of Chinook salmon redds constructed below the trap (221) we used the average Chinook salmon smolts/redd value to account for an additional 104,887 0+ Chinook salmon. Therefore the total 0+ Chinook salmon estimate for the Elwha River in 2020 is 1,057,329. In addition, we estimated the production of 1+ 5,259 Chinook salmon, 20,470 0+ Coho salmon, 8,470 1+ Coho salmon, and 1,600 Steelhead for the Elwha River in 2020. Low numbers of Chum salmon were encountered in 2020, resulting in an estimated total outmigration of 1,483 smolts. Small numbers of Pink salmon (18) were captured at the mainstem site in 2020, however, we were able to estimate a total outmigration of 736. Total catch, estimated catch and production estimates for the mainstem trap in 2020 are summarized in Table 2.

We estimated adult and juvenile Chinook salmon abundance in the Elwha River, Indian Creek and Little River over the period of record using outmigration estimates along with annual redd counts (2005-2020) and SONAR escapement estimates (2011-2020). 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 (2016-2020) natural Chinook salmon estimates remained low through 2018 but increased dramatically for the 2019 (571,817) and 2020 (1,057,329) outmigration years. As a result, the post-dam removal average has increased to 442,838 subyearling Chinook salmon outmigrants (Table 3). Trends in Chinook salmon sub-yearling abundance over time are summarized in Figure 7.

We assessed Chinook salmon productivity by calculating the number of smolts produced per female over the period of record (2005-2020). In general the productivity of Elwha Chinook salmon has been low over the period of record. During the pre-dam removal period (2005-2011), productivity averaged 130 (range 44-395) smolts/female. During dam removal Chinook salmon smolts/female productivity 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 increased dramatically to 309 smolts/female. The 2020 outmigration year was the second highest on record (312 smolts/female) and increased the post-project average to 150 smolts/female (range 13-312). 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). Trends in Chinook salmon sub-yearling productivity over time are summarized in Figure 8.

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) prior to dam removal. Up until dam removal, the river had moderately 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.

The 2020 tributary trapping season was the most successful to date. Both sites were fished continuously with no breaks in fishing operations due to elevated streamflow in early spring. The new trap on Little River performed well, even after snowmelt and we fished a record of 183 days. With the exception of a decrease in Coho smolts, production estimates for Indian Creek continue to be high for a number of species. We generated estimates for 0+ Chinook salmon (181,418), 1+Chinook salmon (276), 0+ Coho salmon (3,303), Coho salmon 1+ (528), Coho smolts (6,819) Pink salmon (219) and Steelhead (2,008) at Indian Creek (Table 4). Only 8 Chum salmon smolts were captured in 2020 and no estimate was generated.

In 2020 we installed a fence weir downstream of the outlet of Lake Sutherland in an attempt to estimate the production of Coho salmon from Lake Sutherland. Because the Sutherland Coho smolts were extremely fragile and subject to severe scale loss during handling, we decided not to conduct trap efficiency tests in 2020. However we did capture a total of 213 1+ Coho salmon smolts, 66 Cutthroat trout, 18 resident Cutthroat adults, and 944 Prickly Sculpins. An additional 400-500 Coho salmon smolts that were reluctant to enter the trap, were passed through the trap site by removing a trap panel on May 29. Of particular interest was the large size observed for Coho smolts emigrating from Lake Sutherland with several individuals over 300 mm (average fork length/weight = 252 mm/156.7 gms). Also of interest was what appeared to be a downstream migration of adult resident Cutthroat trout from Lake Sutherland

to habitats in Indian Creek. These fish were 300-400 mm and gravid. At the same time we noted an upstream migration of numerous 1+ Cutthroat trout parr, apparently trying to migrate to the lake.

In Little River, species-specific estimates were generated for 0+ Chinook salmon, 1+ Chinook salmon, 0+ Coho salmon, 1+ Coho salmon, Coho smolts, Pink salmon, Chum salmon and Steelhead (Table 5). This is the greatest number of species estimated since trapping was initiated in 2012. The estimate of 356,327 Chinook 0+ is the highest to date. A record number of Chinook salmon redds (124) were observed in Little River in 2019. Chinook salmon yearlings were also encountered and generated an estimate of 276. For Coho salmon we estimated a total of 23,758, 148 and 838 for 0+ fry, 1+ parr and smolts, respectively. In 2020, we were able to estimate the number of Chum (1,686) and Pink salmon (4,465) produced in Little River for the first time. Finally, we estimated the number of Steelhead produced from Little River at 284. For all trap sites we plotted estimated catch and expansion factors for all species in 2020 (Appendix D).

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, Brook trout, plus all non-salmonids (Table 6). 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 rainbow 0+, 1+ and 2+ age classes that were captured at Indian Creek and Little River in 2020. Only three Cutthroat smolts were captured at Indian Creek. Three bull trout were captured in Little River and 4 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 15 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 decline of reddsideshiner (*Richardsonius balteatus*) encountered at Indian Creek. In 2020, Pacific lamprey captures remained strong at Indian Creek (Figure 9) and were the highest to date on the mainstem trap (Table 6). Two adult lamprey were encountered at Little River, one of which was a dwarf. For sculpin the number of encounters were generally less than 600/year during the pre-dam removal period. That number dropped precipitously during dam removal but has rebounded to over 2,000 in 2020 (Figure 9). In 2020 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.

Discussion

Smolt trapping on the Elwha was initiated in 2006. The period from 2006-2011 represents pre-dam removal conditions when anadromy was limited to the lower 7.9 kilometers below the dams and hatchery production dominated salmon returns for Chinook salmon, Coho salmon, and to a lesser extent Steelhead. Dam removal was initiated in 2011 and smolt outmigration estimation continued through the dam removal period. The period between 2012 and 2015 represents the production of salmonids during dam-removal period. Mainstem smolt trapping efforts during the dam removal period were challenging and in 2013 trapping operations were abandoned during peak sediment transport. Lost fishing days is a primary and direct effect of the annual increases in sediment and debris transport during the dam removal time period. During 2014 we were only able to fish the mainstem site <50% of the days. From 2015-2020 we have been able to fish the mainstem trap for a total of 155 of 166 days (93%), 142 of 171 days (83%), 111 of 182 days (61%), 140 of 181 days (77%), 158 of 159 (99%), and 195 of 195 days (100%), respectively. The 2016-2020 seasons represent the first five years of post-dam removal data and provides a benchmark to assess the state of early recovery. We believe that the we have passed the worst of the sediment impacts from dam removal on smolt trapping operations because sediment loads are now at or below what was estimated prior to the initiation of dam removal (Ritchie et al. 2018)

The outmigration estimates for Elwha 0+ Chinook salmon smolts in 2020 was 1,057,329; the highest number over the period of record. This impressive total is greater than the annual estimates from many other Puget Sound Rivers. For example, the Dungeness, Green and Nisqually Rivers have averaged 51,968, 418,123, and 146,641 Chinook subyearling smolts for the period from 1999-2018 (Unpublished Data, WDFW). In contrast, the Skagit River, the most 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.

The Elwha estimate is also conservative in that trapping operations were delayed by 3-4 weeks due to due to a storm which generated the largest flow of the winter of 2019-2020 (17,200 cfs). The 2020 estimate is nearly twice the number produced in 2019 and twenty-two times the average for the period from 2006 to 2018 (Table 3). In 2019, adult Chinook salmon escapement to the Elwha River was in excess of 7,000 salmon, and the largest numbers of redds since dam removal (1,672) were enumerated during spawning ground surveys (McHenry et al. 2020). Those eggs were subjected to a very benign flow year with minimal peak flows during the incubation period. 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. A negative correlation between peak flows and Chinook salmon survival has been reported in Puget Sound (Greene et al. 2005). 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. 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).

The large number of Chinook salmon outmigrants in 2020, while encouraging, will need to survive the remainder of their life history in order to produce significant numbers of 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 9). For Puget Sound Chinook salmon, size at outmigration may be related to survival to adulthood. Using otolith analysis, Campbell & Claiborne (2018) has 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 intact in northern Puget Sound and severely degraded in South Puget Sound.

The estimated number of 0+ Chinook salmon produced from both Indian Creek (181,418) and Little River (356,327) was significant, and the Little River production was the most since trapping commenced in 2012. The estimate for Indian Creek is likely an underestimate because when the trap was removed for maintenance it was discovered that the gasket between the trap box and clean-out wheel was degraded and likely leaking fish. Both systems experienced record numbers of Chinook salmon spawning during 2019, with 216 and 124 redds counted in Indian Creek and Little River, respectively. Since Elwha Dam was removed in 2014, Little River has had three of eight 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 10). In 2020, we estimate productivity at 2,874 smolts/female and 844 smolts/female for Little River and Indian Creek respectively.

We compared the total outmigration estimates between tributaries and found some noticeable differences in abundance and timing (Appendix 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. 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 and 2020 at both sites. In 2020 we estimated the total outmigration of 0+ Coho salmon at 3,303 and 23,758 for Indian Creek and Little River, respectively. The consistently higher number 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 6,819 fish, which is the second lowest since monitoring began in 2013. Only 838 Coho smolts were produced at Little River in 2020. These low numbers reflect low abundance of adults in the 2018 brood year. When few redds were observed on tributary surveys (McHenry et al. 2020).

Steelhead smolt production in the Elwha River has generally increased since the LEKT was able to generate its first production estimates from 2015-2019. Prior to 2015 we encountered so few Steelhead smolts (less than 50/year) that we were unable to generate an estimate. In 2020 we captured only 47 individual steelhead smolts. The 2020 estimate of 1,600 represents a reduction of 91% from the 2019 estimate of 17,648. However, the low estimate was judged to be an artifact of catchability issues surrounding Steelhead smolts and as a result there is no mainstem estimate for 2020. Steelhead are capable of avoiding capture in screw traps and even escaping if caught. Other Puget Sound smolt trapping programs struggle with Steelhead estimation in some years (Personal Communication, Joe Anderson, WDFW). To date, LEKT has conducted no trap testing using Steelhead smolts. Increasing these trials could provide additional insights into Steelhead catchability on the Elwha.

Production of Steelhead smolts from Indian Creek has seen an increasing trend over time, from 85 in 2013 to 2,008 in 2020 (Figure 11). The general increase in Steelhead smolt numbers in the mainstem Elwha and Indian Creek suggests rebuilding is ongoing. Little River Steelhead smolt numbers have been consistently low and show no rebuilding trend (Figure 11). This is despite the moderate number of Steelhead redds that are observed in annual redd surveys (McMillan et al. 2019). 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 could have colonized these habitats following dam removal in 2013. These outmigrants were likely the progeny of resident rainbow trout populations that have 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 varied over time since dam removal. The mainstem site increased dramatically in 2019 (69,874), but declined to 8,470 in 2020. The reduction may be attributed to a very weak adult cohort in 2018. Indian Creek also had a dramatic reduction in Coho production in 2020 and a record low 6,819 smolts were produced. Indian Creek has consistently produced larger numbers of 1+ Coho salmon smolt outmigrants relative to Little River over the period of monitoring (Figure 11). The larger numbers of Coho salmon 1+ 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 2018-2020 has determined that Sutherland is producing Coho smolts that on average are very large. To date, we have not been able to enumerate a production number for Sutherland.

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 2020 Elwha Chum salmon estimate was 2,210 fish; 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 2020 we estimated a total outmigration of 736 smolts. For years in which we caught enough Pink salmon smolts to generate a mainstem production estimate, the trend shows a steady decline (Figure 12). Before 2019, neither tributary had been colonized by significant numbers of returning adult Chum or Pink salmon. In 2019, small numbers of Pink salmon were observed in both Indian Creek and Little River. The progeny of those fish spawned and resulted in the first estimated smolt production from the tributaries with 219 and 4,465 for Indian Creek and Little River, respectively.

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 Chum salmon and Pink salmon to both Little River and Indian Creek 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 yards of sediment stored behind the dams. Historically abundant, Pink and Chum salmon returned tons of marine derived nutrients to the Elwha River. Those nutrients contributed to aquatic food webs that supported other Pacific salmon of the Elwha.

Smolt trapping operations have documented several ecologically significant events that suggest the “reawakening” of anadromy or natural recolonization 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 recolonization 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 no signal of recovery to date. The Elwha Fisheries Recovery Plan (Ward et al. 2008) indicates that for Sockeye salmon natural recovery is the preferred means of rebuilding this stock. 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 from the West Coast Vancouver Island and the other half were from northern regions including the Stikine River (Quinn et al. 2021).

Based on seven 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 (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 Indian Creek, 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 were related to low gradient and lake dampened hydrologic conditions that reduced scour and allowed small bodied fish to survive. Spring spawning is not unusual for cutthroat trout and has also been documented for populations in adjacent Lake Crescent.

Recolonization is successfully occurring for Pacific Lamprey in Indian Creek, where adult were first documented in 2013 and subsequently again in later years at the smolt trap. These adults were the early colonizers to Indian Creek. Ammocoetes (juveniles) were first encountered at Indian Creek in 2013, one year following the initial recolonization event by adults in 2012. Lamprey appear to be expanding rapidly in Indian Creek (Figure 13). 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 a new record of 3,914 were captured. In 2020 we had a raw catch of 1,954 ammocoetes. 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 2018-2020, the total number of macrophthalmia was 649, 546 and 441, respectively. In 2020 we report that Pacific lamprey have begun the recolonization of Little River. We captured one adult lamprey and 44 ammocoetes during trapping operations.

We have strived to keep the aforementioned sources of uncertainty low in order to stay within a coefficient of variation of 15% or less. However, maintaining in-stream infrastructure in a large rain-on-snow and snow dominated hydrology, relatively steep gradient river continuously for up to 7-8 months is very 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 large portions of the fishing season were lost due to river conditions, mechanical breakdowns and hatchery releases, no days of fishing were lost in on the mainstem Elwha in 2020. The overall abundance of NOR fish is also increasing and as a result more fish are being captured. The net effect of this is a reduction in the Coefficient of Variation. In 2020, we achieved the lowest Coefficient of Variation (CV) values since the project

was initiated for the mainstem. The CV for mainstem trapping estimates ranged from 11% (Chinook 0+, Coho 1+) to 31% (Pink salmon) and averaged 17% for all species.

In 2020 the CV was at or near the 15% threshold for 3 of 7 species/life histories estimated at the mainstem site. We expect the CV values to continue to improve over time as populations expand and catch rates rise. During the pre-dam removal period (2005-2011) our annual CV on the mainstem Elwha ranged from 5.5% to 28%, with two of seven years exceeding the 15% threshold. With continuous fishing in 2020 we were able to complete eleven trap efficiency tests on the mainstem. Two of these used Coho 1+ and the other nine used Chinook 0+. The lack of large-bodied trap efficiency tests introduces the greatest amount of uncertainty to the mainstem estimates and requires improvement.

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 three of seven species/life histories and averaged 19.5%, a 46% reduction of 2019. Little River estimated CV was 8% for 0+ Coho salmon and 59% for 1+ Coho salmon, while Steelhead was 22%. Indian Creek CV's were variable and ranged from 14% for 0+ Coho smolts to 94% for Pink salmon. For all species the CV for the Indian Creek site was 39%.

Recommendations

The long term future of the lower mainstem trap site has been threatened by the dynamic nature of the river in the vicinity of the trap site over the last several years. Changes in channel position now limit our ability to launch the trap from the terminus of Lower Elwha Road. Additionally, overflow channels that could erode the road to the point that it is no longer accessible to vehicles continually threaten Lower Elwha Road. Based on our experiences conducting smolt trapping on the Elwha River during the dam removal period we will implement the following changes for 2021 operations. For the mainstem Elwha River trapping effort we will continue the trapping operations at the upstream site at Rkm 4.0 just downstream of Elwha River Road bridge. This is the only reliable road access point in the lower river and places the trap further upstream than desired, but offers the advantage of being above both Elwha River hatcheries.

The problem of low catch rates for larger sized smolts at the mainstem trap will be partially addressed by maximizing fishing time. The new trap location results in fewer lost days from hatchery releases. It will also increase the precision of fish identification, particularly for 0+ Chinook salmon. 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. The majority of mainstem trap efficiency tests on the Elwha River have historically relied on small-bodied hatchery produced smolts including Chinook

salmon (0+), Chum salmon (0+) and Coho salmon (0+) (Figure 14). These sized fish are generally available and were convenient to use for trap efficiency tests. In recent years we added trap tests using larger sized hatchery and natural origin smolts including 1+ Coho salmon, and 1+ Chinook salmon. We will continue calibrating the trap using both small- and large-bodied smolts in future years. Alternatively, we will use larger sized smolts collected at the tributary sites to provide animals for mark-recapture evaluations on the mainstem. 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. All other trapping operations, including timing and daily trap inspections are anticipated to remain unchanged.

We will continue to refine our estimation approach in an attempt 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 2019 we employed a battery powered motor to power the screw with some success. In 2020, we deployed a new trap to the site. This trap performed well and we were able to successfully fish into August. On Indian Creek, we will continue our efforts to quantify the production of fish directly from Lake Sutherland. In 2019 we used a fyke net to capture emigrating smolts just below the outlet of the lake. The fyke net was difficult to maintain and was constantly clogged with algae and other debris from the lake. In 2020 we installed a fence weir 0.3 miles downstream from the lake outlet. This improved overall catch rates and eliminated maintenance associated with the fyke net. Our goal in 2021 will be to estimate production out of Lake Sutherland.

Our final recommendation is to add a fourth smolt trap monitoring site just below Glines Canyon at the former location of the Glines Powerhouse. The purpose of this site is to measure the production of smolts occurring in the upper watershed which is currently in the early phases of recolonization. This action was planned for the 2018 outmigration season and LEKT

has a 5' screw ready to deploy. However, this has been delayed because the Olympic Hot Springs Road is currently closed one mile upstream of the ONP entrance due to the Elwha River reoccupying its floodplain and washing out the road. The lack of vehicle access precludes launching a trap at the Glines site, however an alternate site is available just downstream of the ONP entrance and may be used in lieu of the Glines Canyon location.

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Tables

Table 1. Results of mark-recapture tests for Elwha River, Indian Creek and Little River for the 2020 smolt outmigration season.

Site	Date	Species	Number	Recaptures	Percentage (%)
Elwha	2/25/20	Chinook 0+	378	16	4.2
Elwha	3/3/20	Chinook 0+	1,000	45	4.5
Elwha	3/10/20	Chinook 0+	1,000	13	1.3
Elwha	3/17/20	Chinook 0+	722	5	0.7
Elwha	3/24/20	Chinook 0+	1,000	19	1.9
Elwha	3/31/20	Chinook 0+	1,000	14	1.4
Elwha	4/6/20	Chinook 0+	565	17	3.0
Elwha	4/14/20	Chinook 0+	995	9	0.9
Elwha	4/21/20	Chinook 0+	343	8	2.3
Elwha	4/29/20	Chinook 0+	1,000	28	2.8
Elwha	5/5/20	Chinook 0+	1,000	28	2.8
Elwha	5/13/20	Chinook 0+	1,000	28	2.8
Elwha	5/13/20	Coho 1+	100	6	6.0
Elwha	5/19/20	Chinook 0+	1,000	33	3.3
Elwha	5/19/20	Coho 1+	100	4	4.0
<i>Elwha Average</i>			<i>11,203</i>	<i>273</i>	<i>2.4</i>
Little	2/25/20	Chinook 0+	456	69	15.1
Little	3/3/20	Chinook 0+	200	58	29.0
Little	3/10/20	Chinook 0+	201	72	35.8
Little	3/17/20	Chinook 0+	200	34	17.0
Little	3/24/20	Chinook 0+	300	58	19.3
Little	3/31/20	Chinook 0+	200	85	42.5
Little	4/7/20	Chinook 0+	100	29	29.0
Little	4/14/20	Chinook 0+	197	32	16.2
Little	4/26/20	Coho 0+	200	44	22.0
Little	5/13/20	Coho 1+	50	13	26.0
Little	5/19/20	Coho 1+	52	11	21.2
<i>Little Average</i>			<i>2,156</i>	<i>565</i>	<i>24.8</i>

Indian	2/24/20	Chinook 0+	42	5	11.9
Indian	3/3/20	Chinook 0+	200	10	5.0
Indian	3/16/20	Chinook 0+	200	5	2.5
Indian	3/24/20	Chinook 0+	200	1	0.5
Indian	3/31/20	Chinook 0+	200	0	0.0
Indian	4/7/20	Chinook 0+	100	0	0.0
Indian	4/14/20	Chinook 0+	200	0	0.0
Indian	5/13/20	Coho 1+	50	11	24.0
Indian	5/19/20	Chinook 0+	100	10	10.0
Indian	5/28/20	Coho 1+	53	6	11.3
<i>Indian</i>			<i>1,345</i>	<i>48</i>	<i>3.5</i>
<i>Average</i>					

Table 2. Total catch, estimated catch (missing catch estimated), average efficiency (weighting by efficiency period length) , days missed (trap not operational during species migration window), estimated outmigrants, 95% C.I., CV, and geometric CV for smolt outmigration from the mainstem Elwha River, 2020 outmigration year.

Species	Catch	Estimated Total Catch	Estimated Outmigrants	95% C.I.	CV	gCV
Chinook Salmon(0+)	20,247	21,049	952,442 ¹	757,417-1,123,995	0.11	0.11
Chinook Salmon(1+)	134	142	5,259	4,031-7,248	0.17	0.16
Coho Salmon(0+)	382	384	20,470	16,384-26,662	0.12	0.12
Coho Salmon(1+)	227	228	8,470	6,863-10,616	0.11	0.11
Chum Salmon	43	43	2,210	1,483-3,402	0.22	0.21
Pink Salmon	18	20	736	417-1,213	0.31	0.28
Steelhead	46	47	NE	NE	0.17	0.17

¹ Estimated number of smolts to the trap

Table 3. Estimated number of Chinook salmon subyearling outmigrants and productivity (smolts/female) for the Elwha River, Indian Creek and Little River (2005-2020).

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	14,290	251	10,628	443
2015	16,200	13	134,909	5,189	8	NE
Dam Removal Average	46,973	63				
2016	45,818	29	93,395	6,226	21,863	429
2017	73,152	60	3,024	108	3	NE
2018	23,236	43	3,916	112	5,205	578
2019	571,817 ²	309	236,523	1,643	125,585	1,993
2020	1,057,329	312	181,418	844	356,327	2,874
Post-Project Average	442,838	150				

² Total production estimate including estimate to the trap and additional production below the trap

Table 4. Total catch, estimated outmigrants, 95% Credible Interval (C.I.), Coefficient of Variation (CV) and geometric CV for smolt outmigration from Indian Creek, 2020 outmigration year.
NE=Not estimated.

Species	Total Catch	Estimated Total Catch	Estimated Outmigrants ³	95% C.I.	CV	gCV
Chinook Salmon(0+)	9,740	10,372	112,226	71,527-184,611	0.25	0.25
Chinook Salmon(1+)	9	NE	NE	NE	NE	NE
Coho Salmon(0+)	258	267	3,303	2,190-5,436	0.25	0.24
Coho Salmon(1+)	78	78	528	346-863	0.24	0.24
Coho Smolt	1,048	1,048	6,819	5,003-9,638	0.	0.
Pink Salmon(0+)	13	14	219	107-619	0.94	0.48
Chum Salmon(0+)	8	NE	NE	NE	NE	NE
Steelhead	343	343	2,008	1,286-3,687	0.29	0.27

³ Estimate to Trap.

Table 5. Total catch, estimated outmigrants, 95% Credible Interval (C.I.), Coefficient of Variation (CV) and geometric CV for smolt outmigration from Little River, 2020 outmigration year.

Species	Total Catch	Estimated Total Catch	Estimated Outmigrants ⁴	95% C.I.	CV	gCV
Chinook Salmon(0+)	67,355	67,820	304,602	274,970-339,770	0.05	0.05
Chinook Salmon(1+)	59	59	276	175-492	0.28	0.27
Coho Salmon(0+)	5,243	5,249	23,758	20,615-28,139	0.08	0.08
Coho Salmon(1+)	26	29	148	95-366	0.59	0.34
Coho Smolts	187	187	838	660-1,111	0.	0.
Pink Salmon(0+)	1,063	1,067	4,465	3,937-5,118	0.07	0.07
Chum Salmon(0+)	399	400	1,686	1,444-2,002	0.08	0.08
Steelhead	25	25	114	75-174	0.22	0.22

⁴ Estimate to Trap

Table 6. Total catch of miscellaneous fish encountered at Elwha River, Little River and Indian Creek smolt traps, 2020.

Site	0+ Trout	1+ Trout	2+ Trout	Bull Trout	Brook Trout	Cutthroat Trout (Smolts)	Cottids	Redside Shiner	Ammocoete	Macrothalamia	Adult Pacific Lamprey
Elwha	220	74	10	2	0	0	1,791	2	219	15	2
Little	90	348	28	3	0	0	22	0	44	0	2
Indian	124	482	154	4	15	3	81	1	1,954	411	7

Table 7. Summary of fishing effort for 2020 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	2/13/20	8/25/20	195	0	100
Little	2/25/20	8/25/20	183	0	100
Indian	2/13/20	9/2/20	203	0	100

Figures

Figure 1. Top Elwha River 8' rotary screw trap fishing at Rkm 4.0 during the post-project period.



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, 2005-2020. 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.

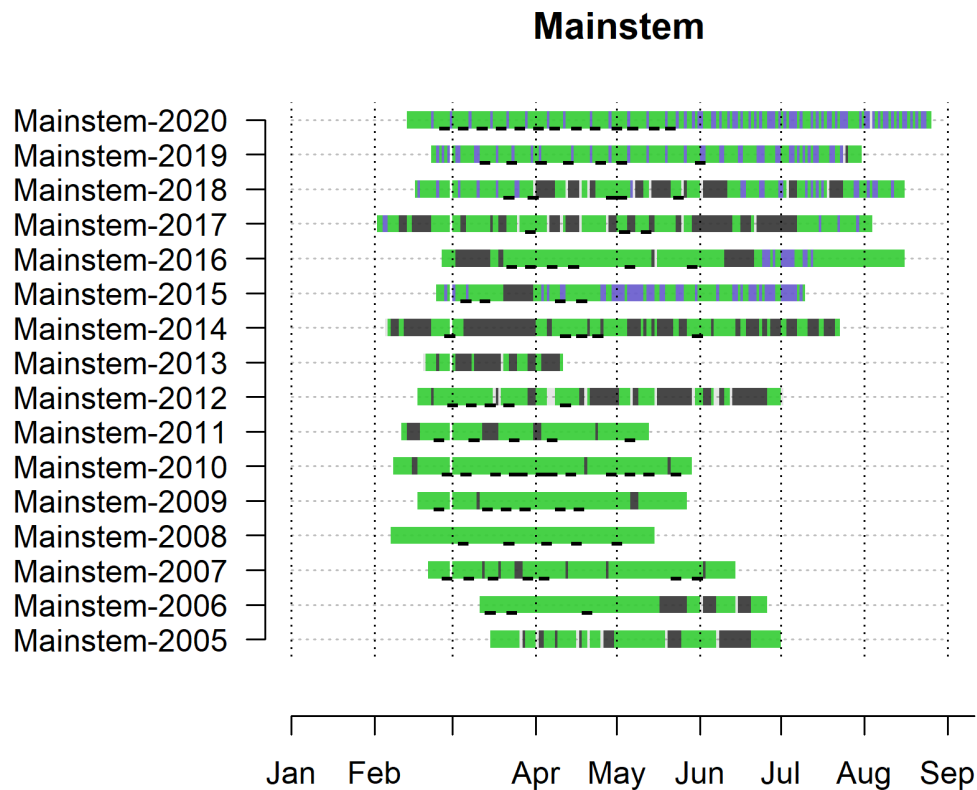


Figure 5. Little River and Indian Creek smolt trap fishing effort by year, 2012-2020. Green are days fishing, blue is day fishing but trap not checked, and black are days not fishing. Black horizontal bars underneath the multicolored bars represent the four days including and immediately following efficiency trials.

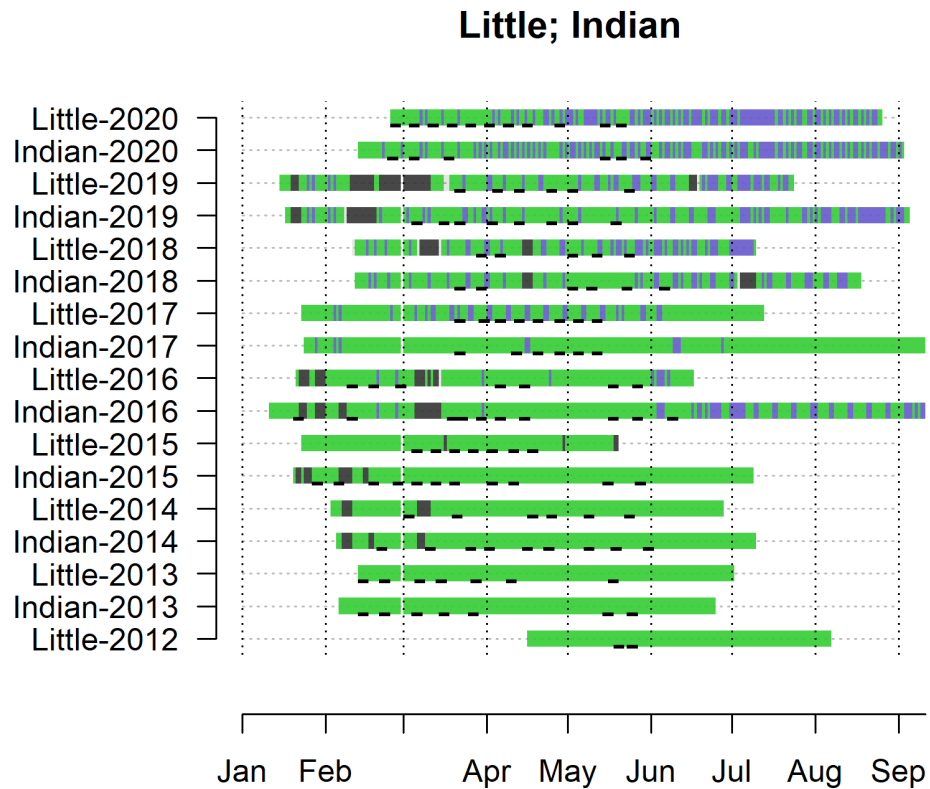


Figure 6. Elwha River flows (cfs) measured at the McDonald Gage Site, September 15, 2019 to February 1, 2020 (top-Chinook salmon incubation period) and February 13, 2020 to August 28, 2020 (bottom-smolt outmigration period).

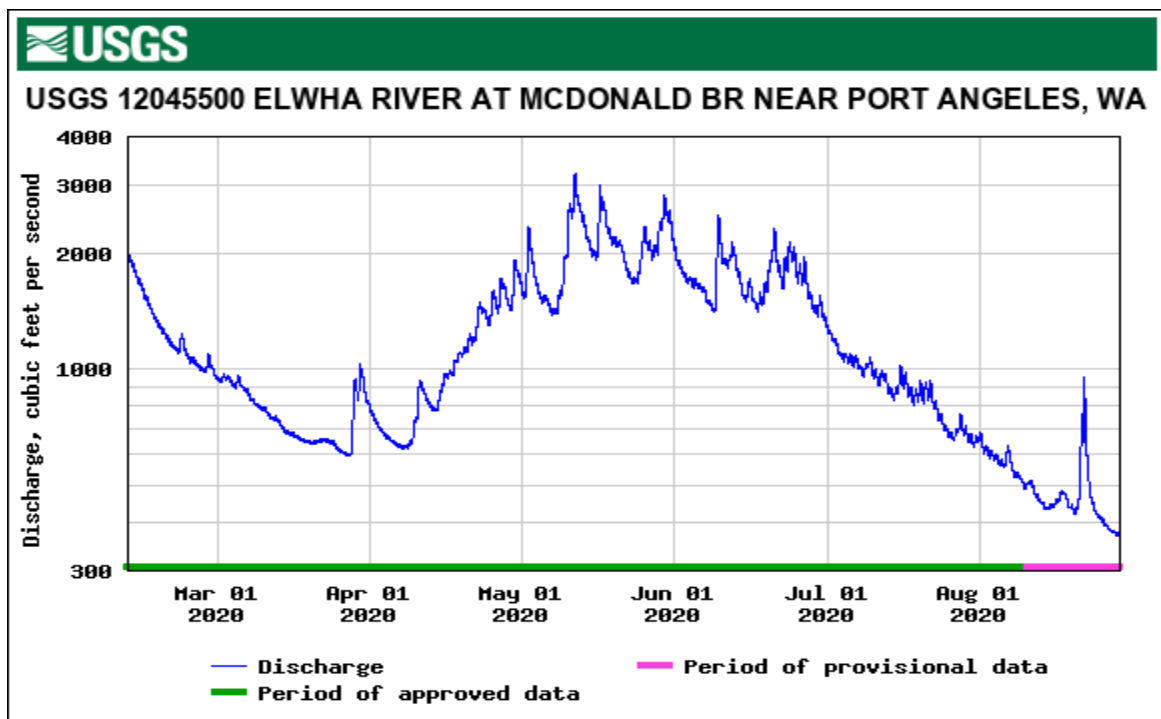
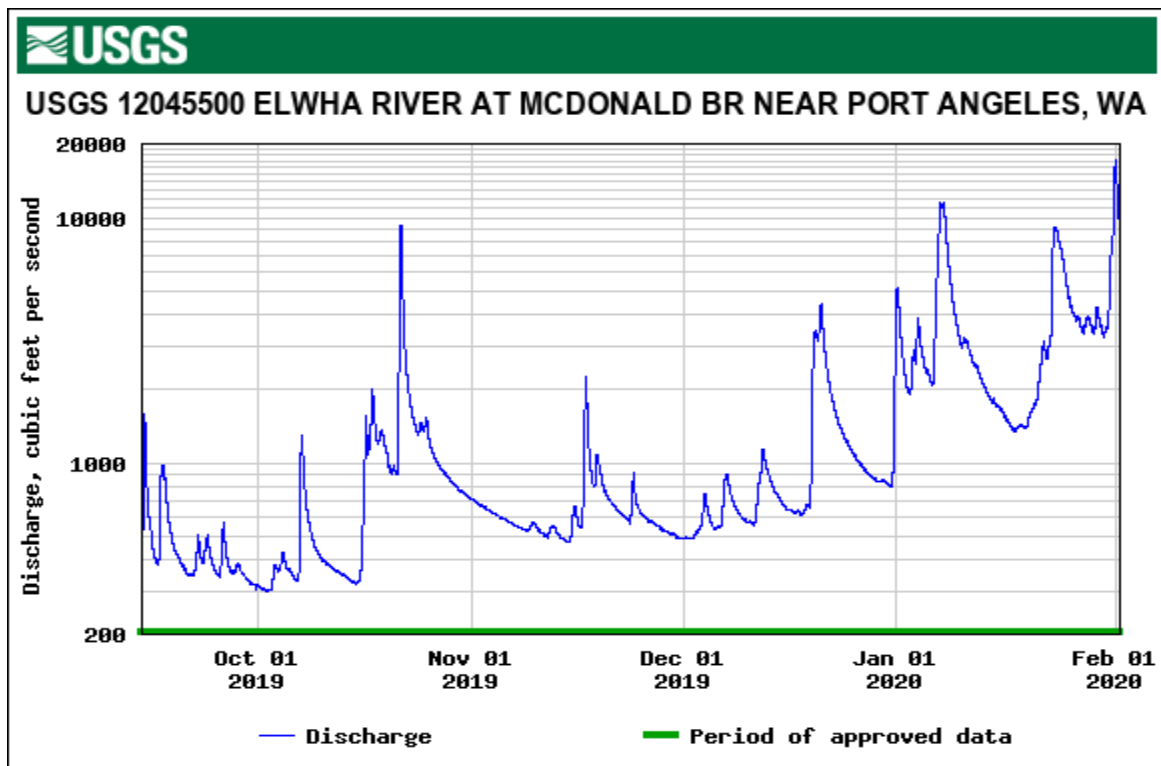


Figure 7. Elwha subyearling Chinook abundance and productivity (2006-2020).

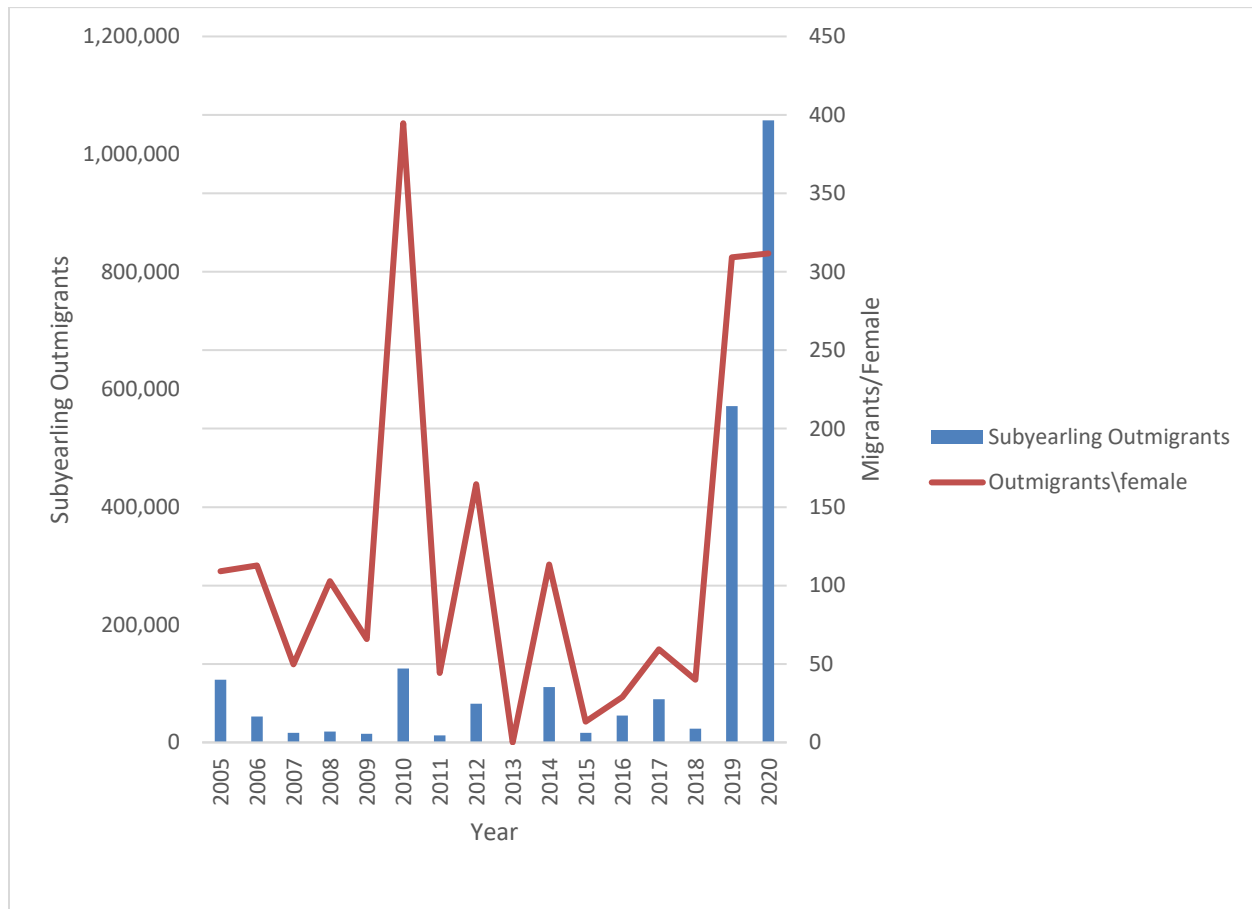


Figure 8. Length frequency distribution of Chinook 0+ smolts captured on the Elwha mainstem trap, 2020.

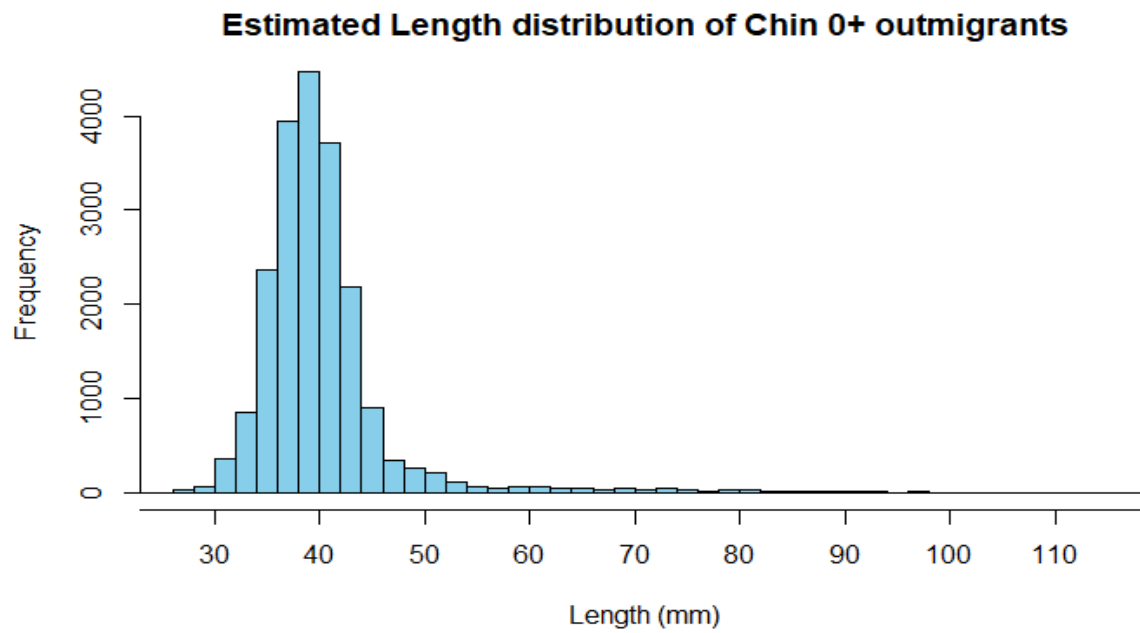


Figure 9. Chinook subyearling productivity for Indian Creek and Little River (2012-2020).

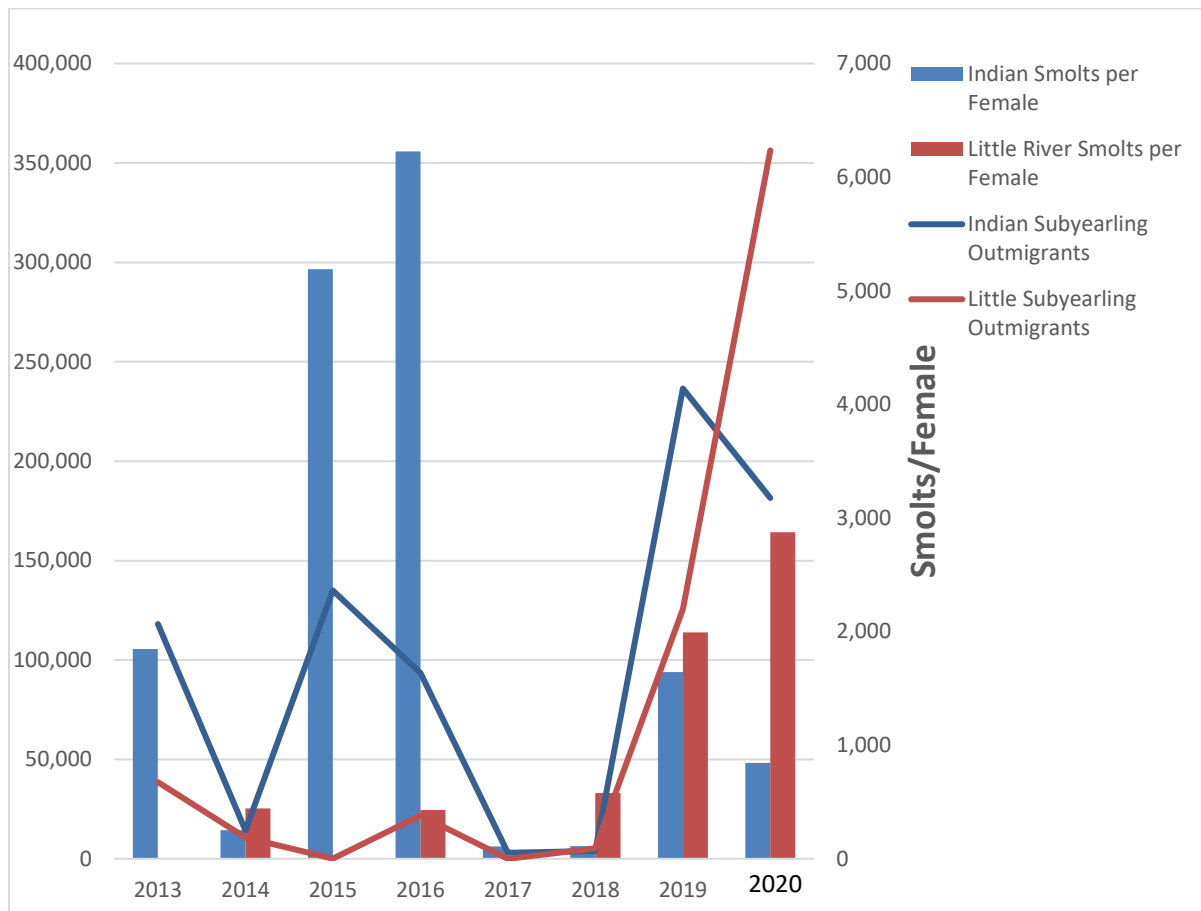


Figure 10. Estimated Steelhead and Coho smolt production for Indian Creek and Little River (2012-2020).

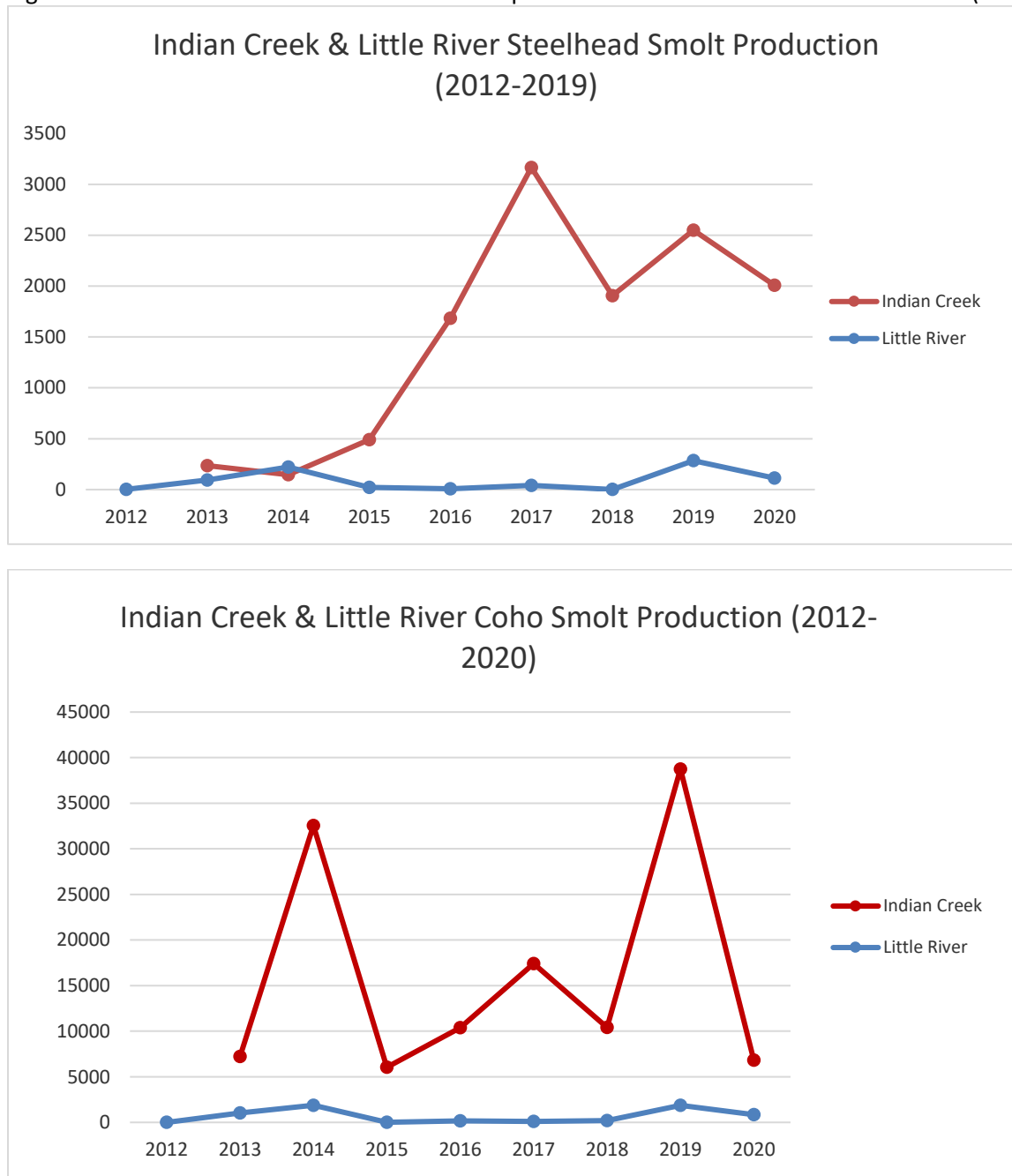


Figure 11. Estimated Pink and Chum salmon outmigration for the Elwha River (2006-2020).

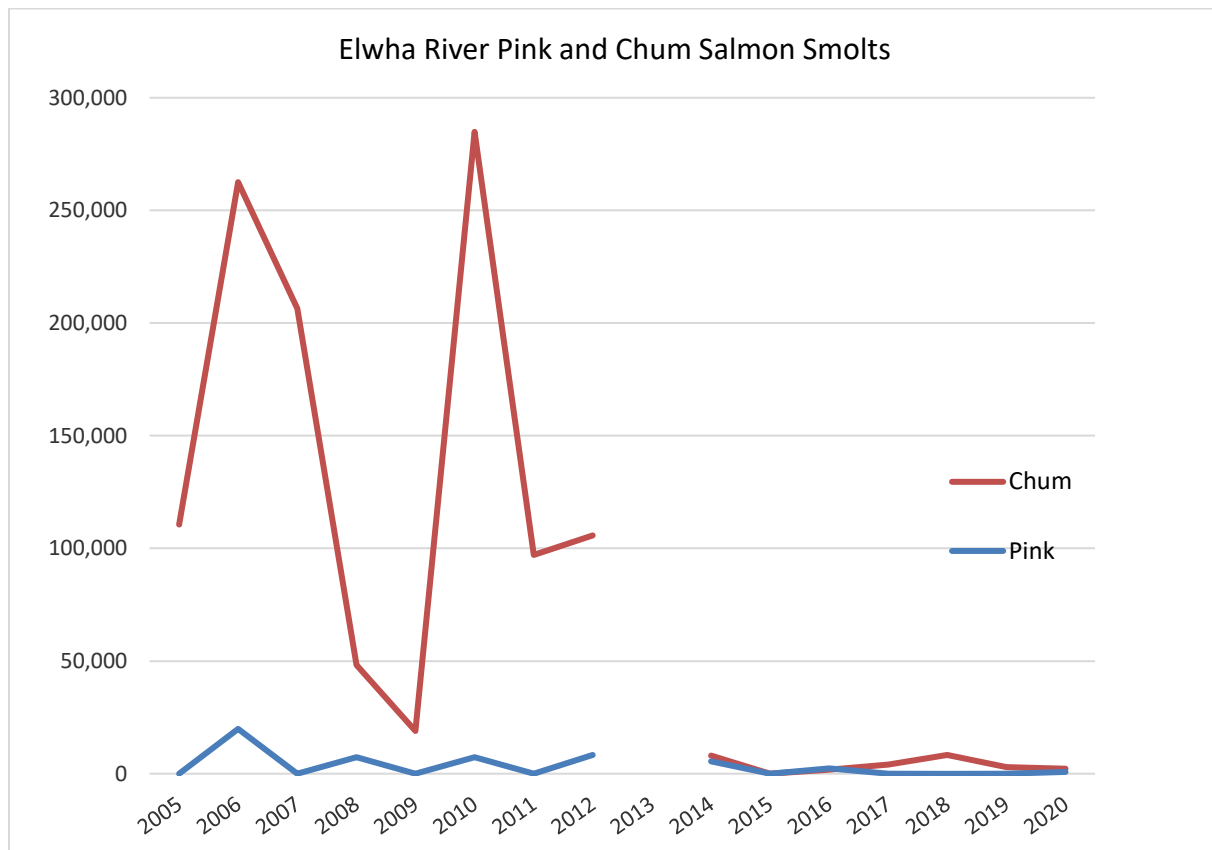


Figure 12. Pacific Lamprey captures at the Indian Creek Smolt trap (top) and sculpin (bottom) at the mainstem Elwha trap.

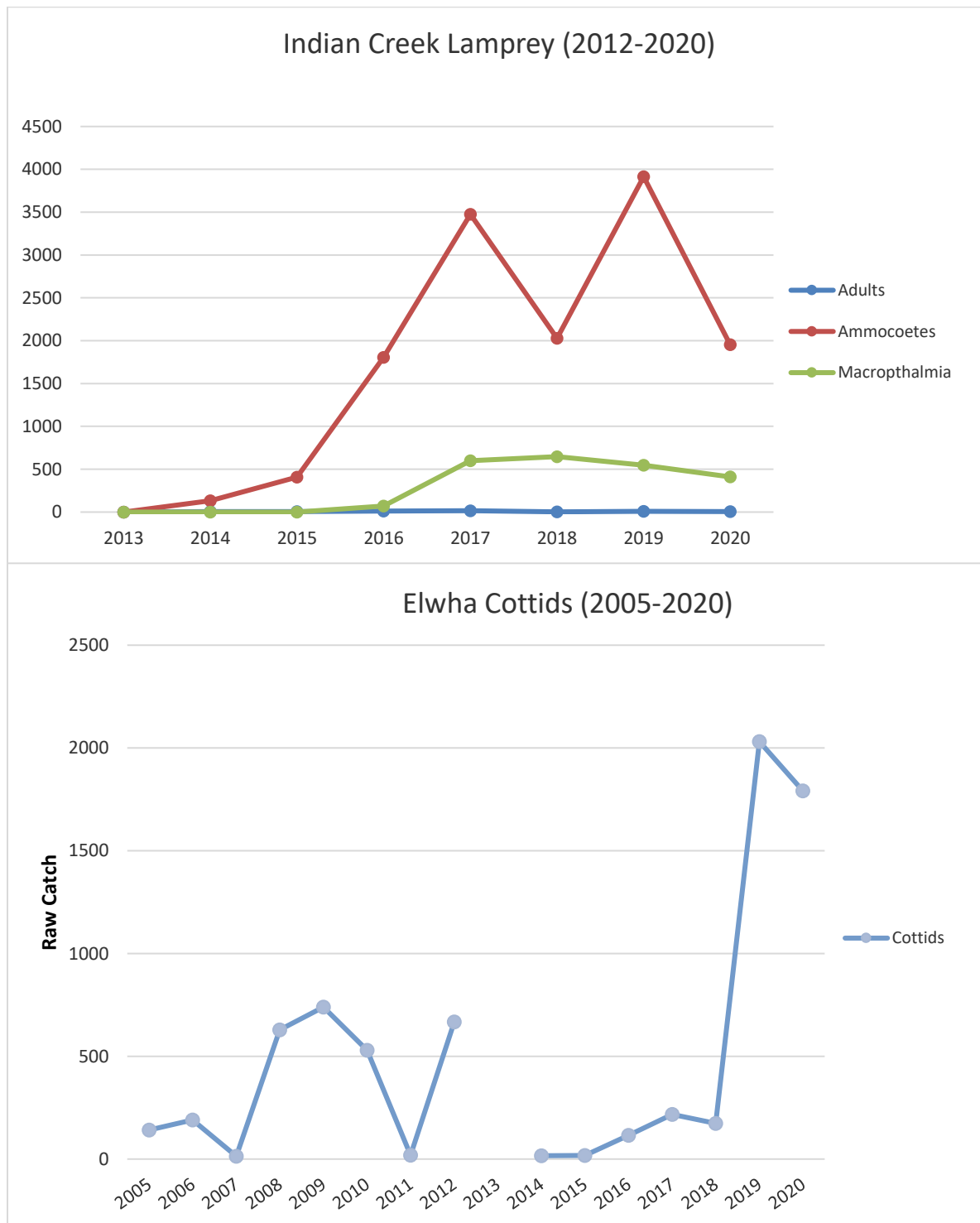
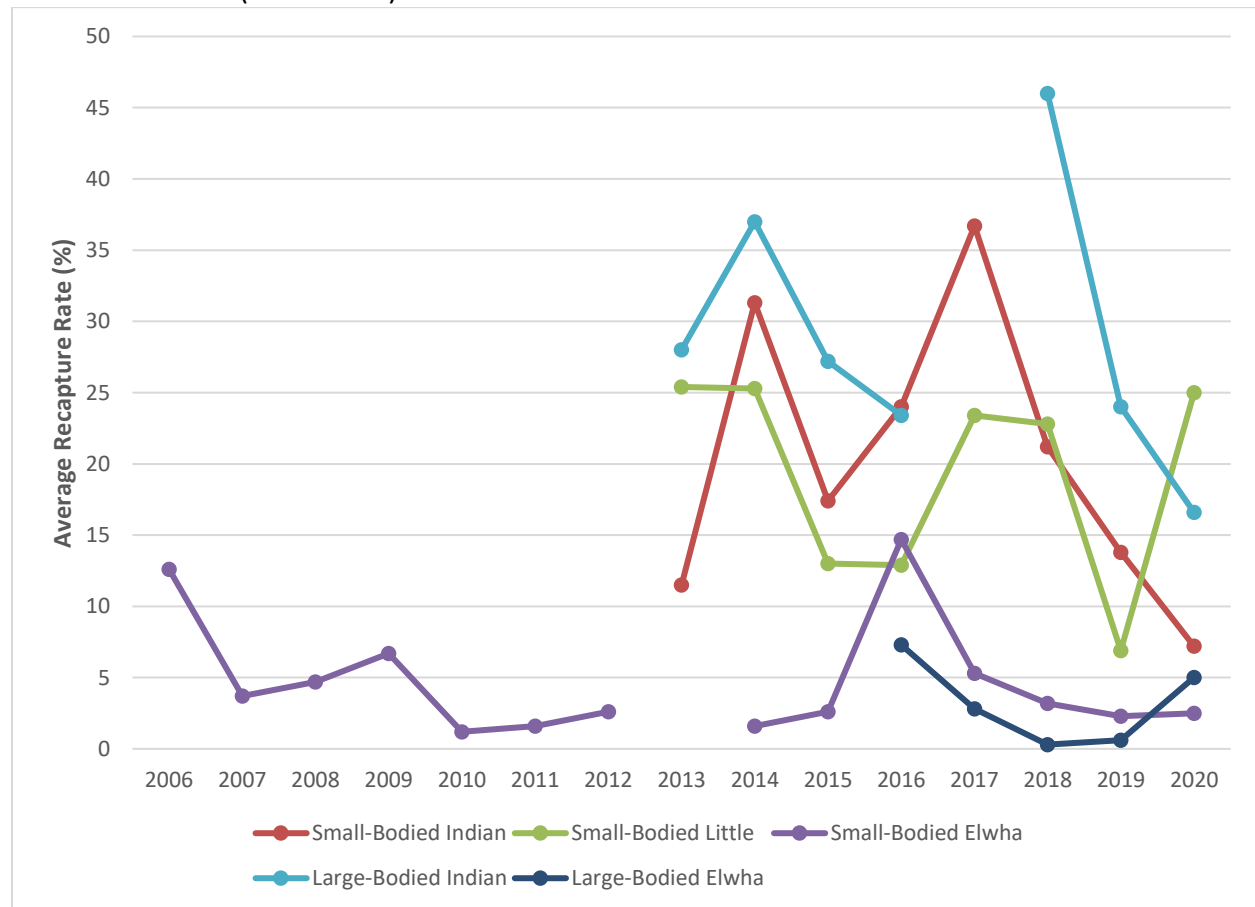


Figure 13. Trap Efficiency for small-bodied and large-bodied smolts for Elwha River, Little River and Indian Creek (2006-2020).



Appendix A.

Total passage past the trap (T_i) was assumed to follow a negative binomial distribution. This allows for over-dispersed counts (i.e. more variability than expected based on other distributions such as the poisson).

$$T_i \sim \text{negbinom}(\text{mean}_i \text{days}_i, \text{disp}_i)$$

$$\log(\text{disp}) \sim \text{normal}(0, 100)$$

Where the mean daily passage is a temporal random walk with the variance of the jump size proportional to the number of days the trap was fished before it was checked (days). This allows the mean to change from day to day but only incrementally.

$$\log(\text{mean}_i) \sim \text{normal}(\log(\text{mean}_{i-1}), \text{rwSD}_i \text{days}_i^{-1/2})$$

$$\text{rwSD}_i \sim \text{normal}(0, 100)$$

The observed catch (C_i) was modeled as a binomial distribution where a period specific proportion (p_i) of total passage past the reader (T_i) was captured.

$$C_i \sim \text{binomial}(p_i, T_i)$$

The proportion captured by the trap (i.e. the efficiency, p_i), was estimated from efficiency trials where a large groups of marked fish (M_j) were released above the trap and the number of marked fish recaptured at the trap (R_j) was recorded.

$$R_j \sim \text{binomial}(p_j, M_j)$$

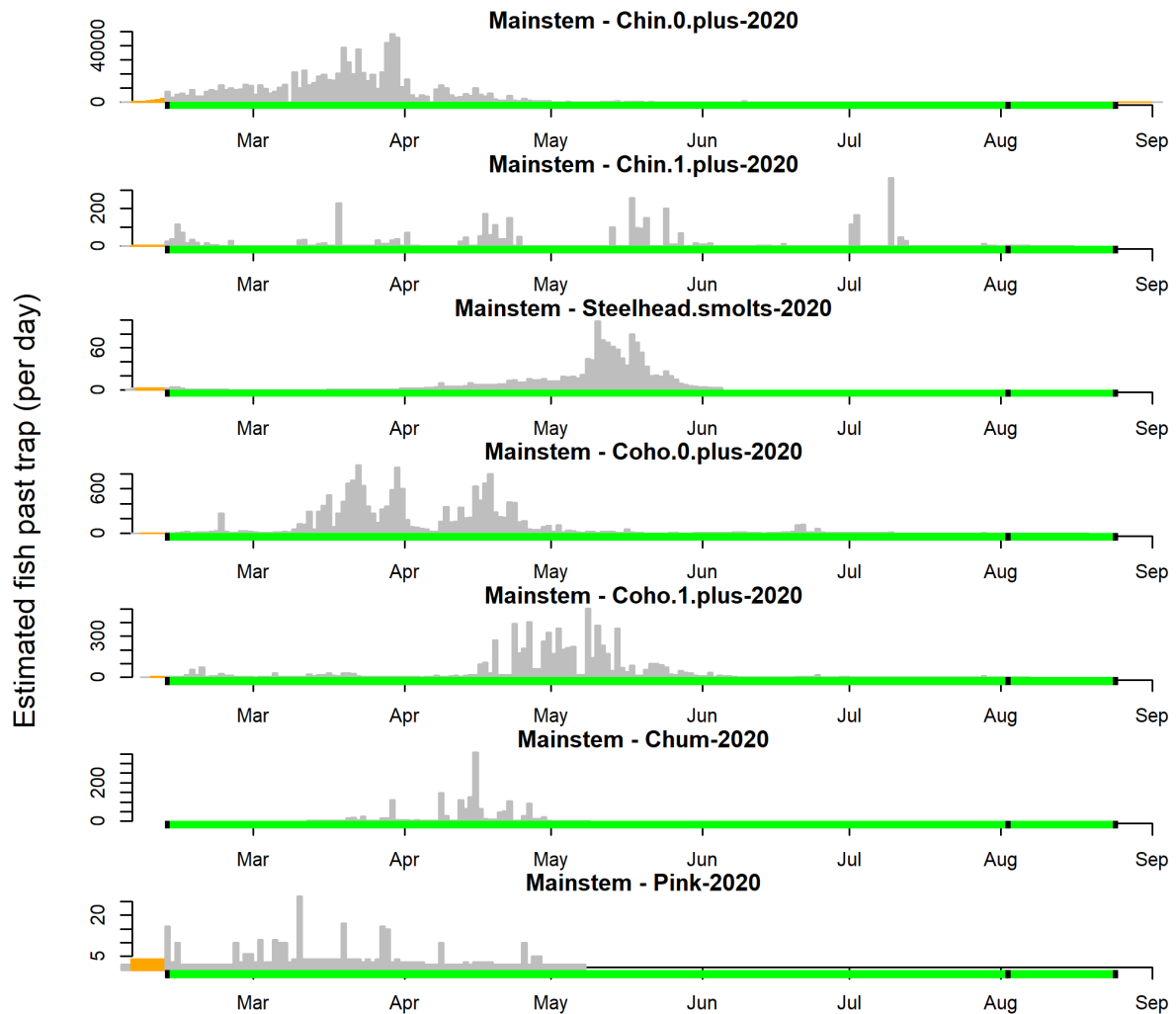
$$p_j \sim \text{beta}(1, 1)$$

The models were implemented in the JAGS software (Plummer 2003) and the R language (R Core Team 2015) was used for all synthesis. Chains were run until the model appeared to converge. Visual inspection of the trace plots and the Rhat statistic were used to assess convergence and determine the appropriate number of simulations. Model fit was also examined using plots of the data with estimated quantities overlaid.

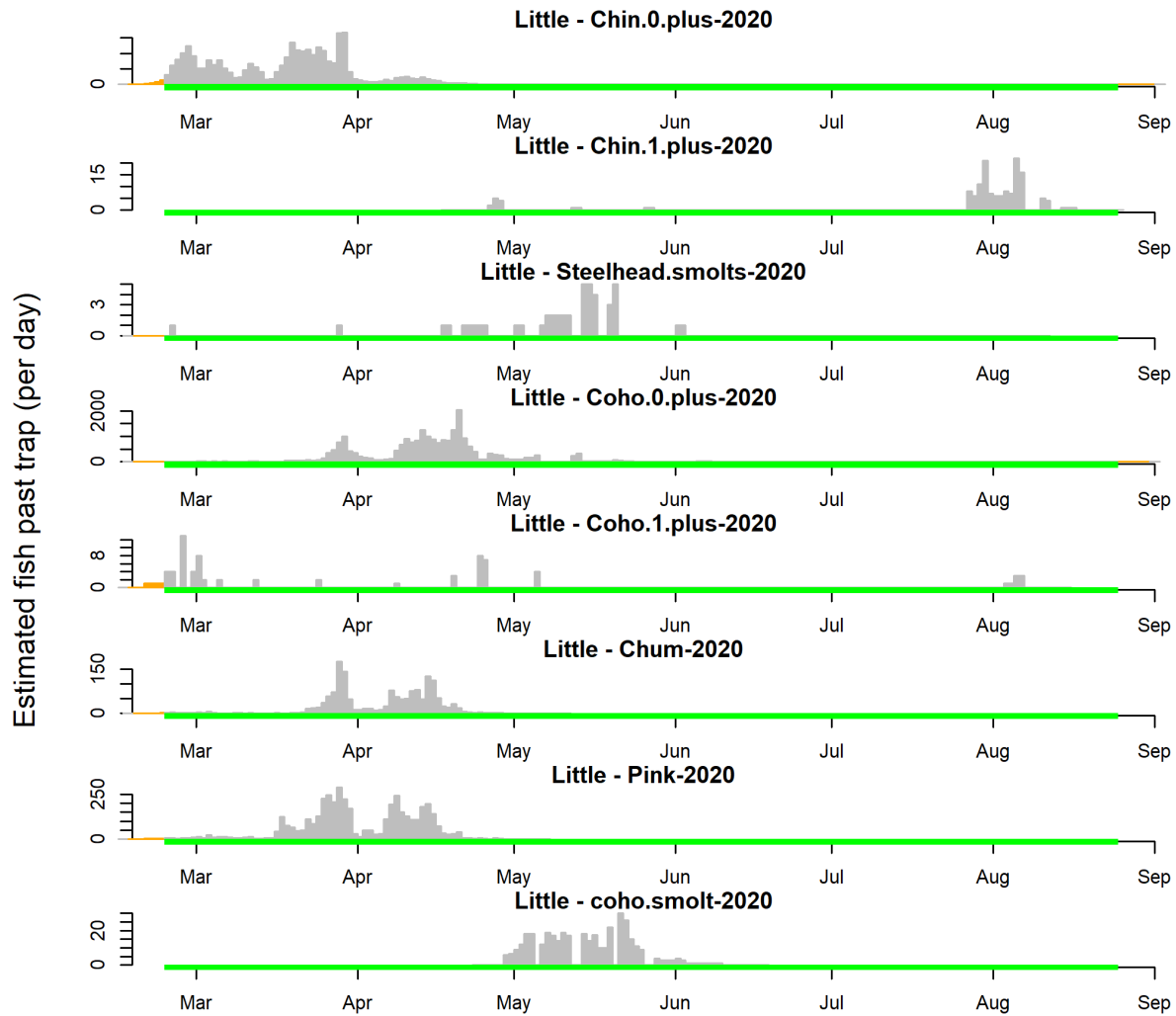
The estimates only incorporate passage during the trap operation. Therefore, if the trap was not in place during fish passage, these fish were not included in the estimate.

Appendix B.

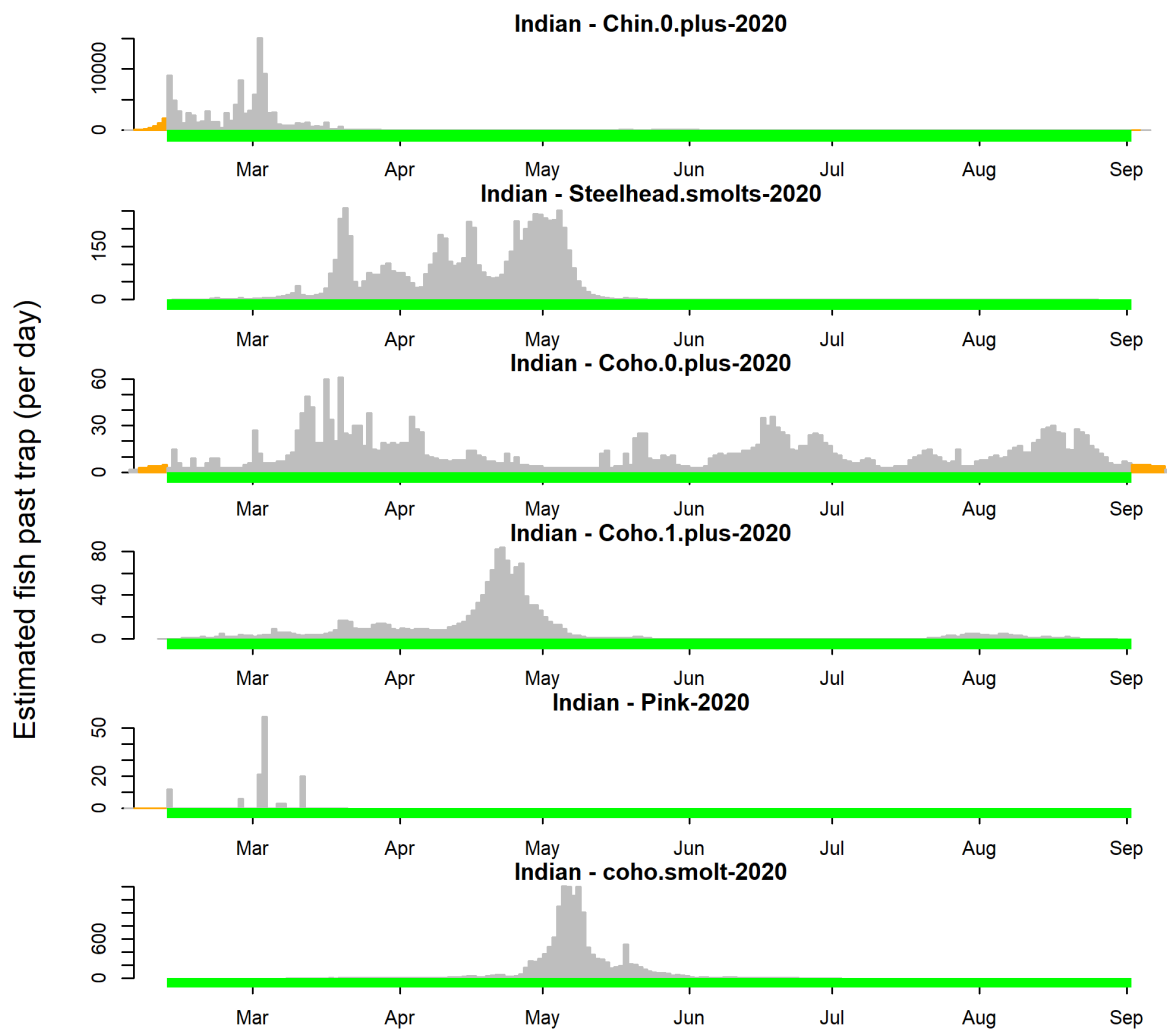
Estimated number of 0+ Coho, Coho smolts, 0+ Chinook, Steelhead and Chum outmigrants at the mainstem Elwha trap site by day during 2020.



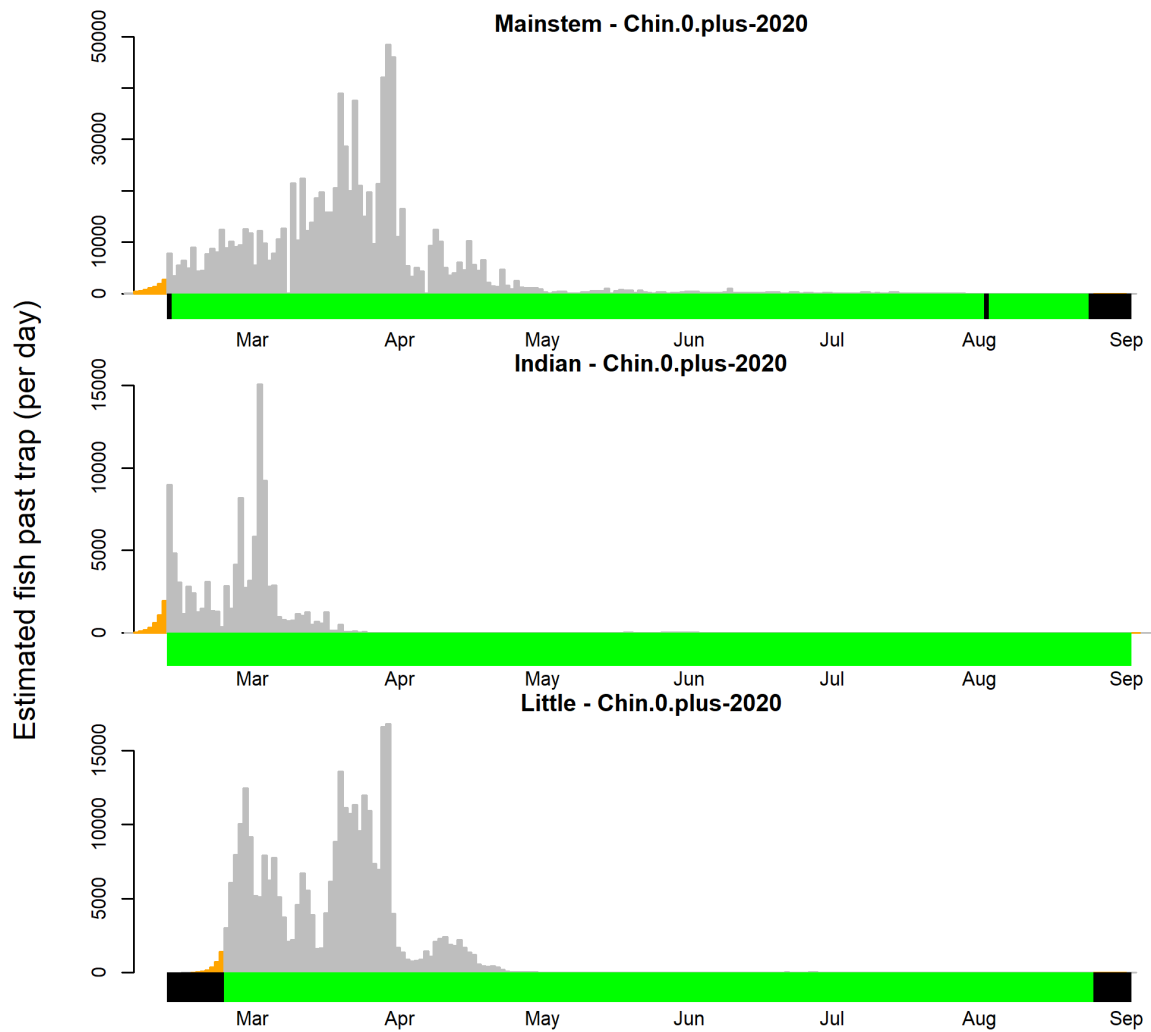
Estimated number of 0+ Coho, Coho smolts, 0+ Chinook, and Steelhead outmigrants at the Little River trap site by day during 2020.



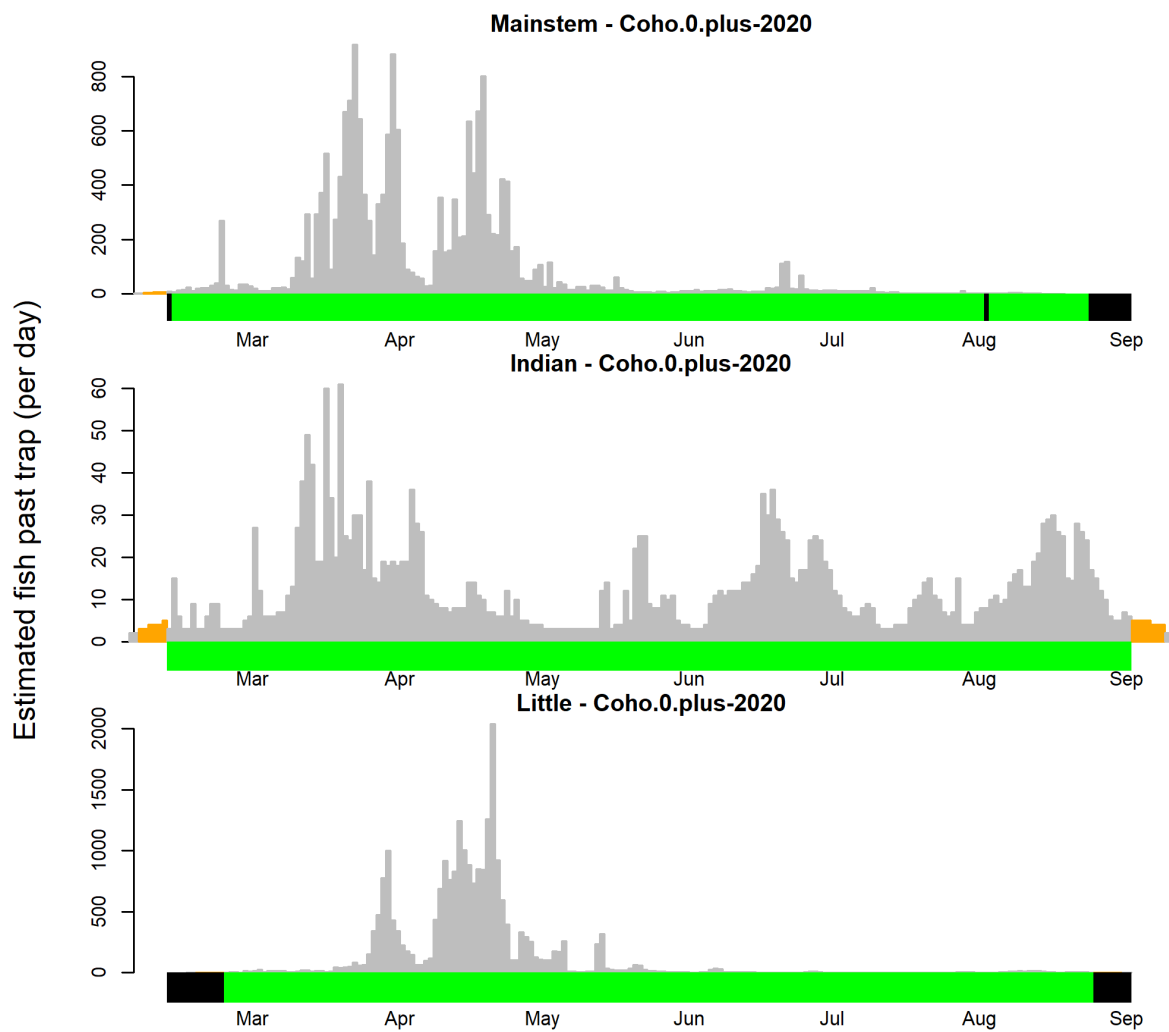
Estimated number of 0+ Coho, 1+ Coho, 0+ Chinook 1+ Chinook, and Steelhead outmigrants at the Indian Creek trap site by day during 2020.



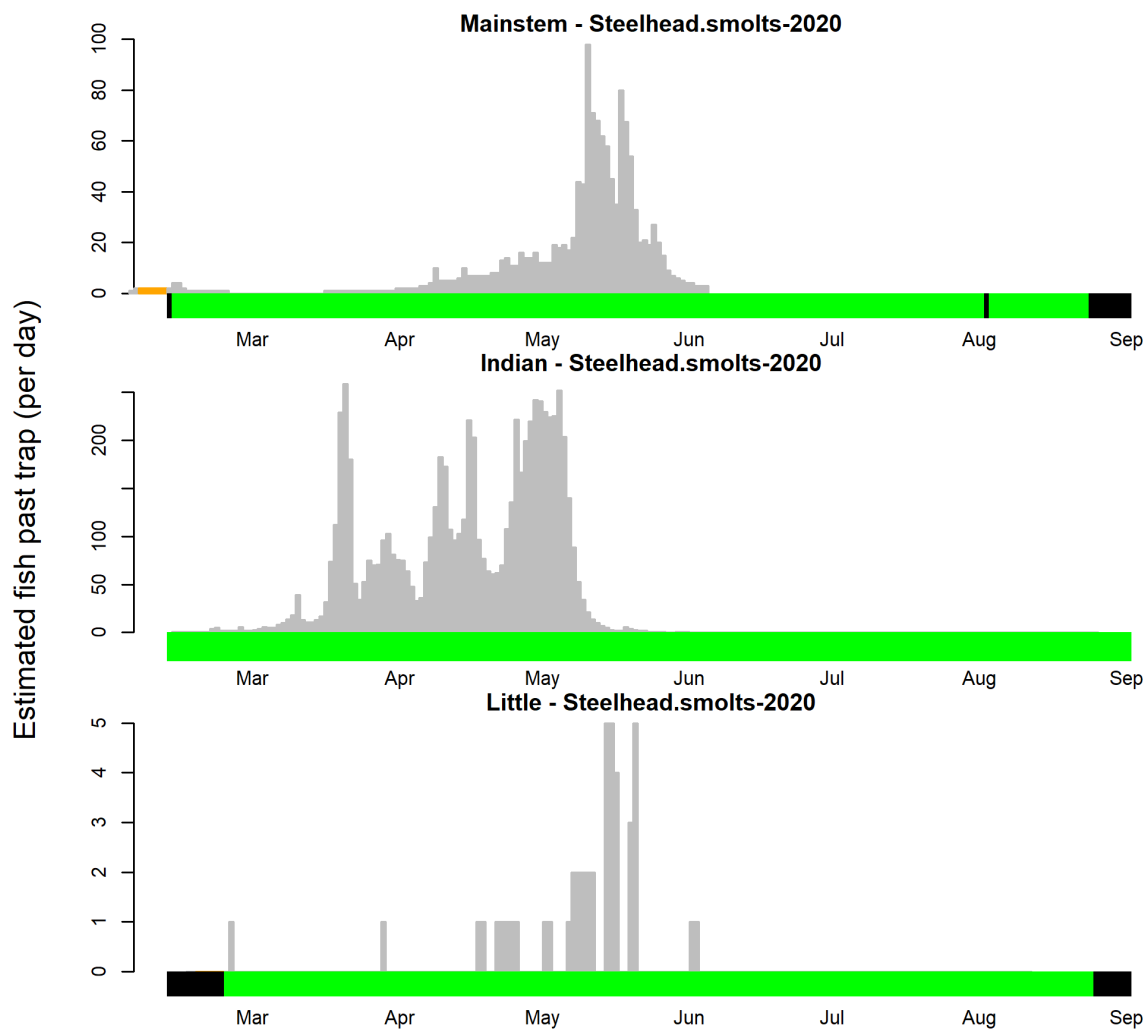
Estimated number of 0+ Chinook outmigrants at Indian, Little and mainstem Elwha trap sites by day during 2020.



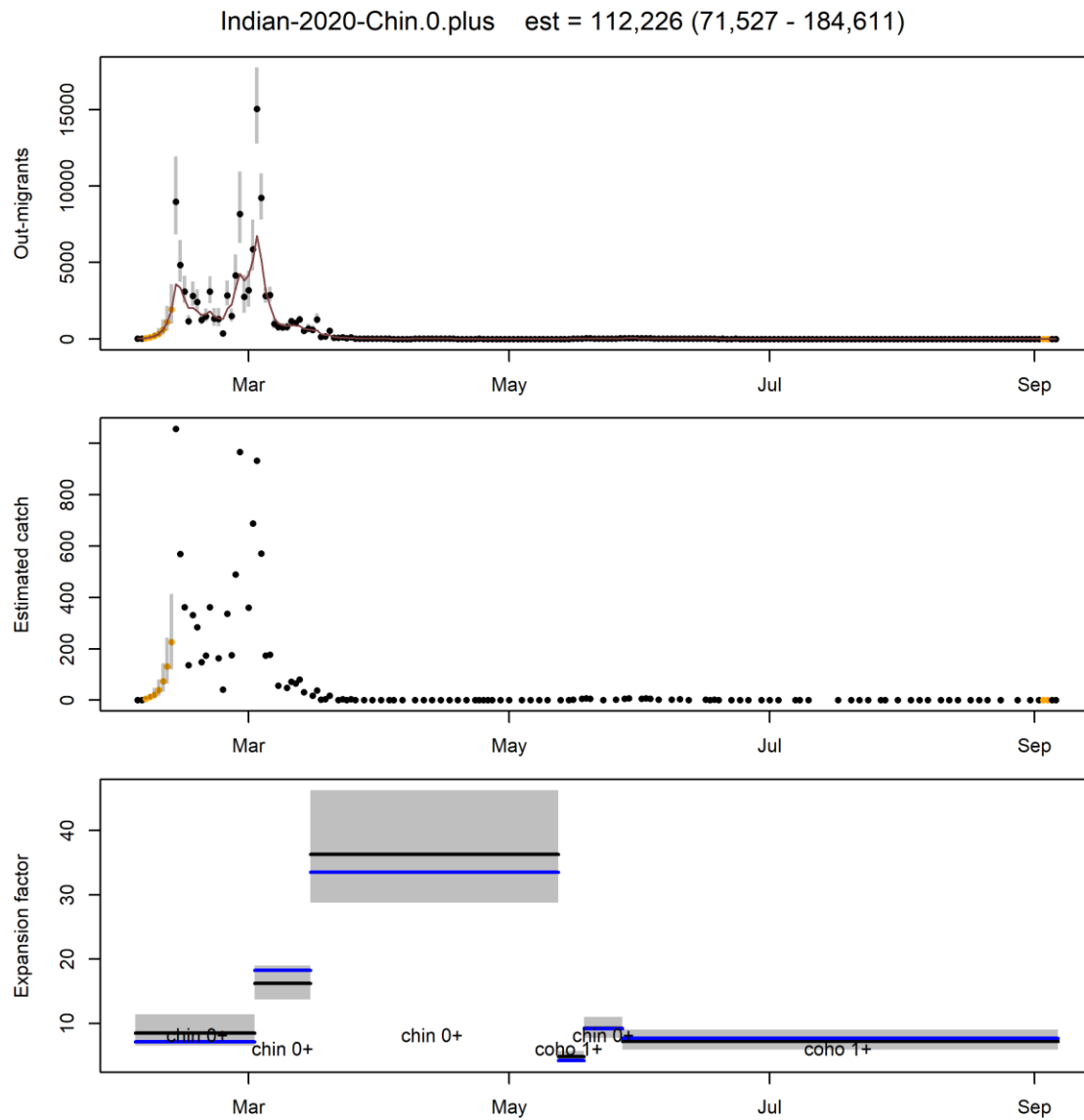
Estimated number Coho 0+ outmigrants at the Indian Creek, Little River and Elwha mainstem trap sites by day during 2020.

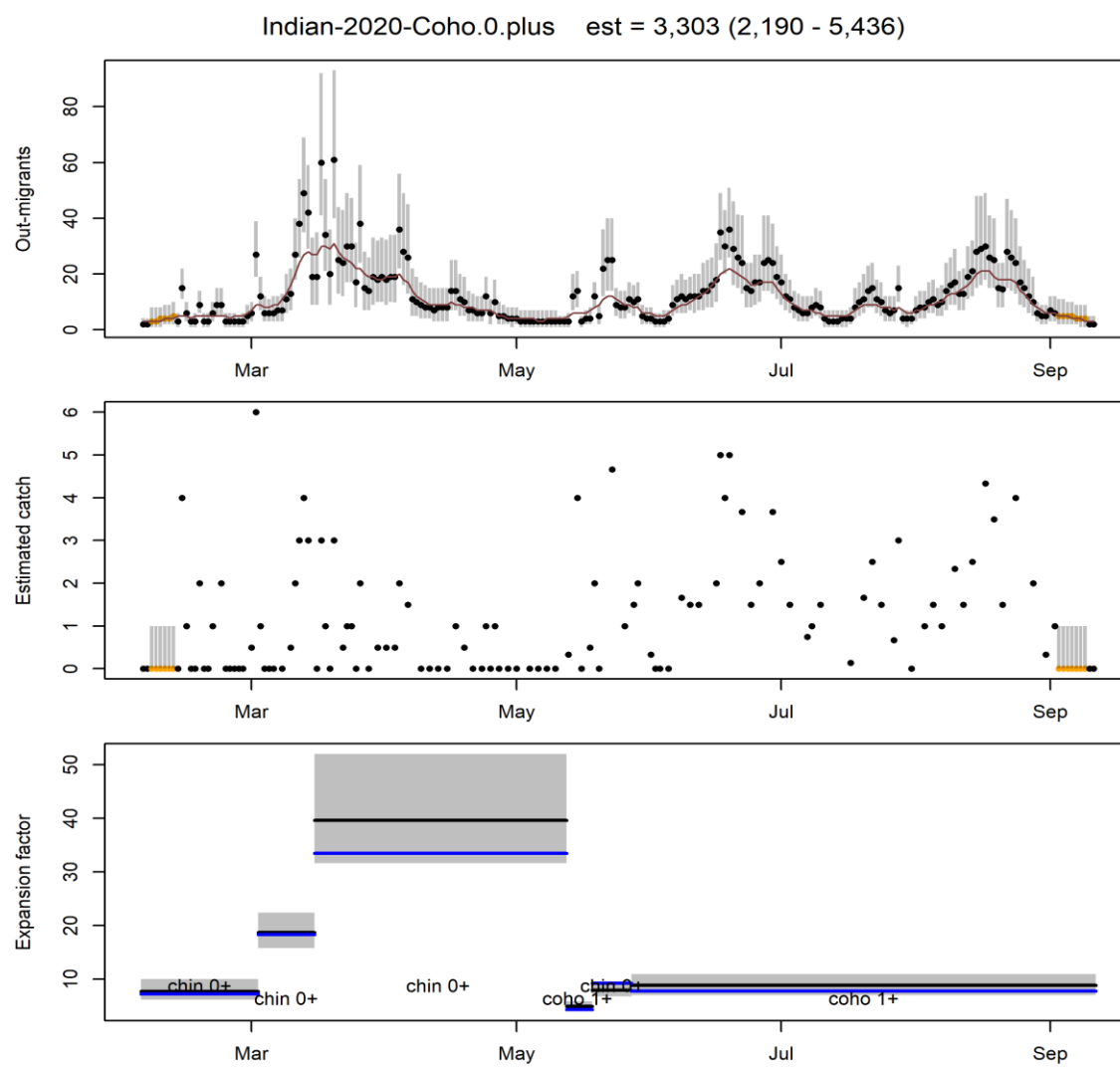


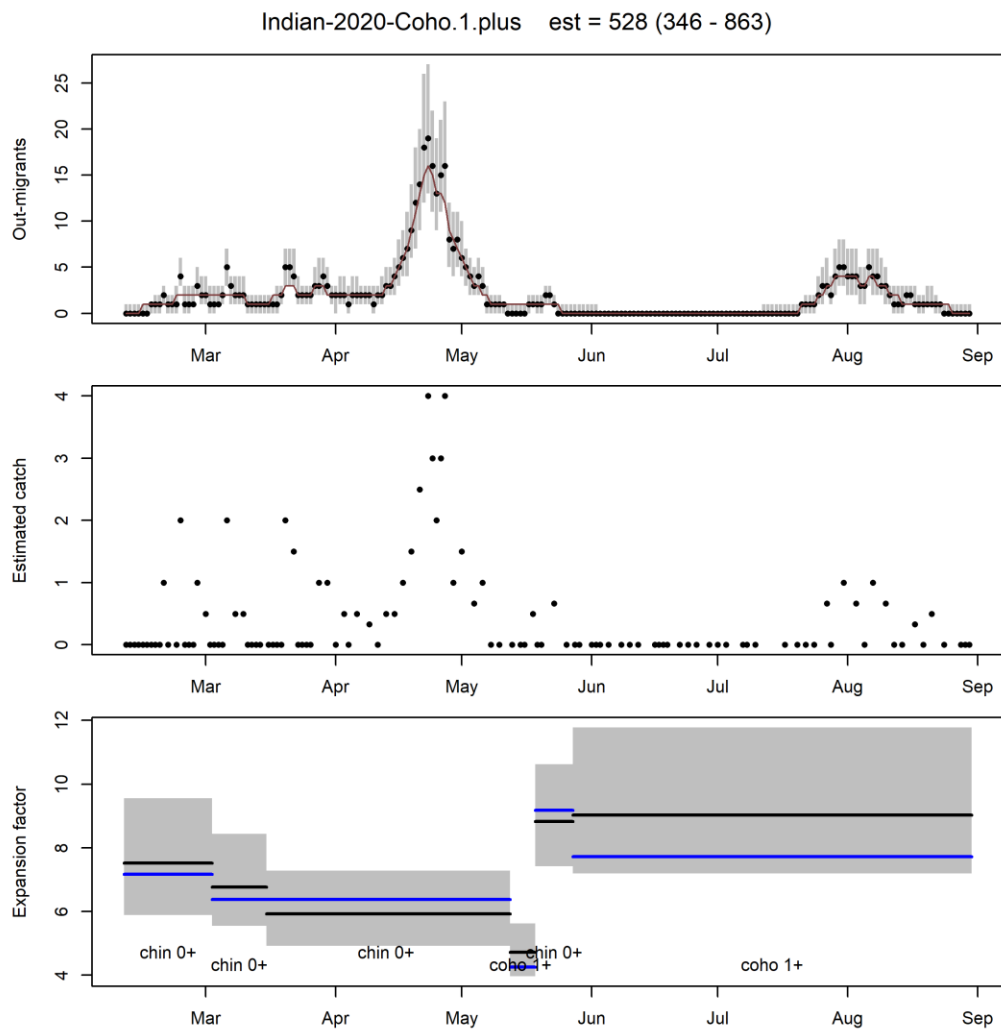
Estimated number and timing of Steelhead smolts at the Indian Creek, Little River and Elwha mainstem trap sites by day during 2020.

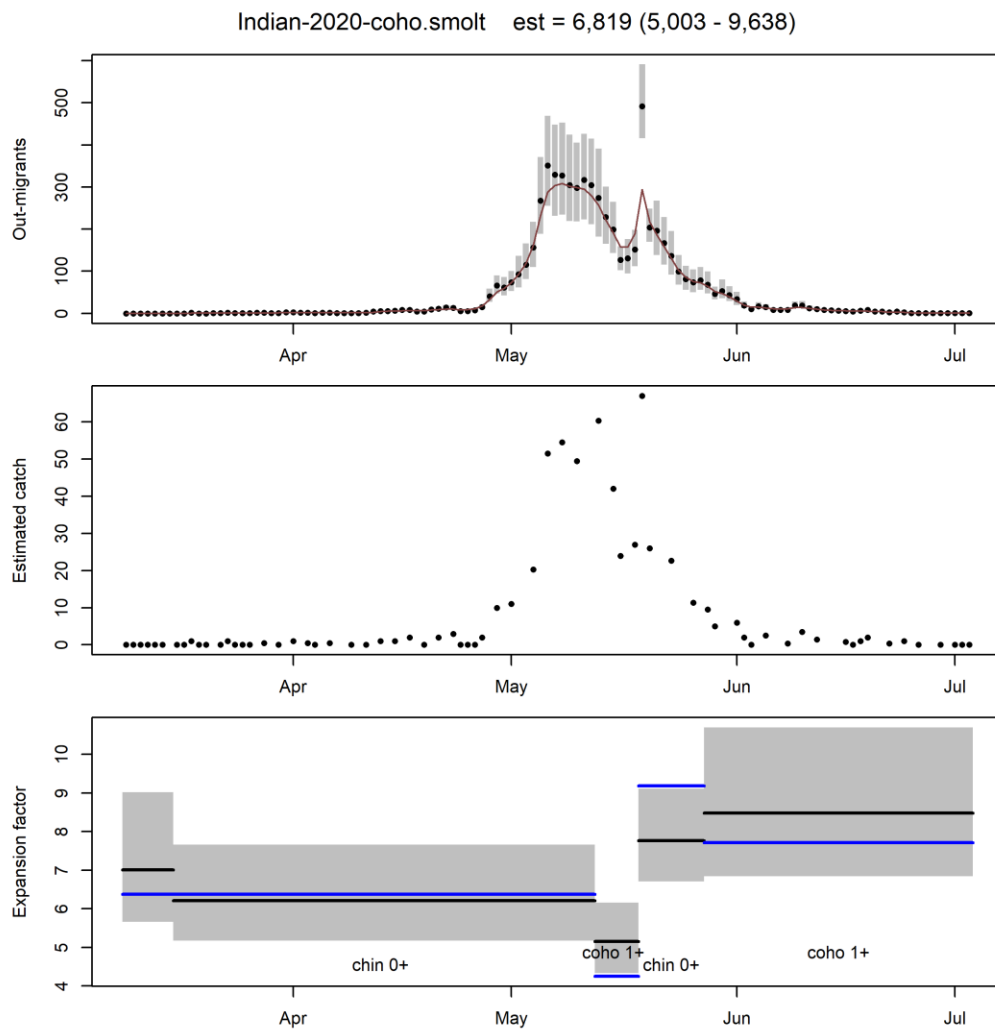


Appendix C. Plots of outmigrants, estimated catch and expansion factor by species and trap site for the 2020 smolt trapping season.

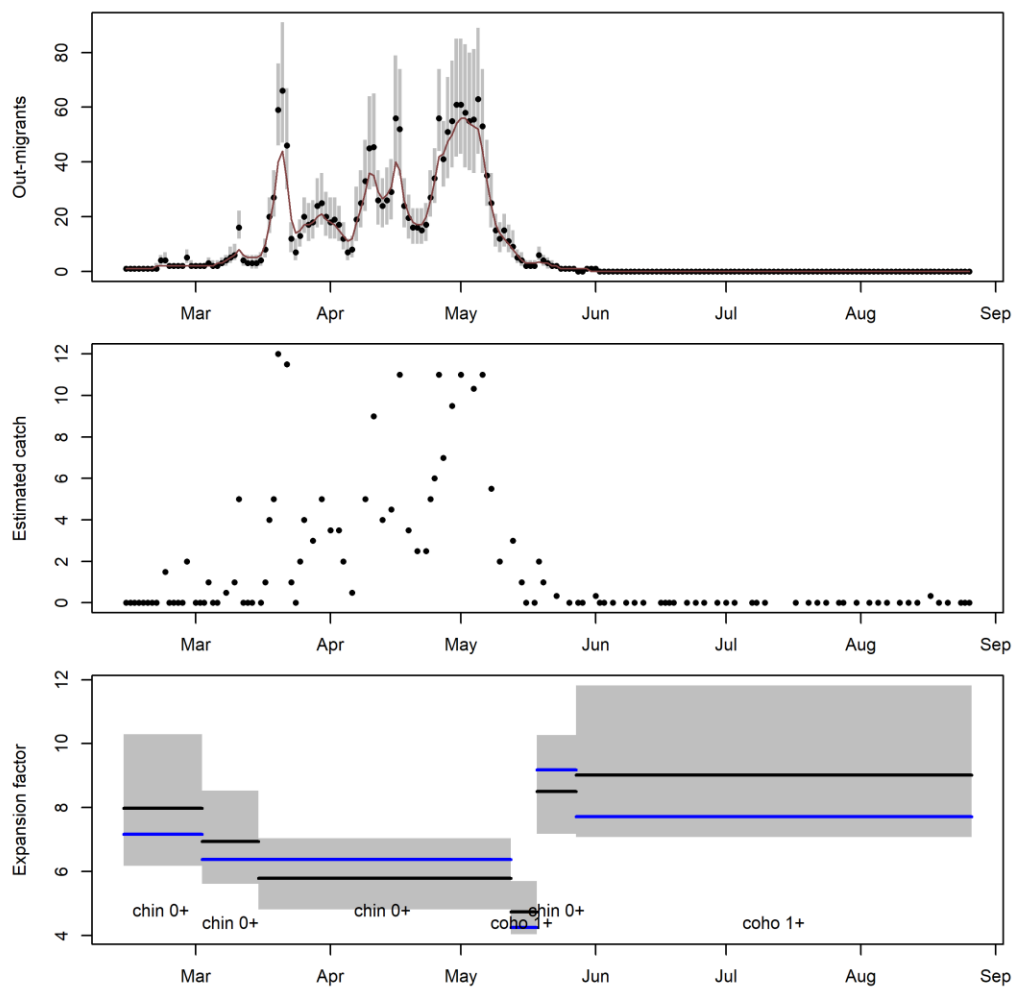








Indian-2020-Steelhead.smolts est = 2,008 (1,286 - 3,687)



Indian-2020-Pink est = 219 (107 - 619)

