

2018 Elwha River Smolt Enumeration Project Report

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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 2018 outmigration season. This represents the third year of monitoring during the post dam removal period, and the 13th consecutive year of smolt monitoring on the Elwha River. In 2018, we generated watershed production estimates, 95% confidence intervals (CI), and coefficient of variation (CV) estimates for smaller bodied (Age 0+) Chinook, Coho, and chum salmon. Additionally, estimates were generated for larger bodied (Age 1+) Coho salmon and steelhead smolts for the third consecutive year. We estimated a total outmigration of 21,490 (range 16,507-31,112) and 8,374 (5,696-13,595) for Chinook 0+ salmon and chum 0+ salmon smolts from the Elwha River in 2018. The Chinook 0+ salmon outmigration estimates for the Elwha River in 2018 was less than half of what was estimated in 2017, and was still within the range measured in the pre-dam removal period (2006-2011). For Coho salmon smolts we estimated a total outmigration of 24,022 (range 15,553-44,227), which is a substantial increase over previous years. The steelhead estimate of 11,412 (range 7,566-20,712) was nearly identical to 2017. Production of chum 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 itself.

At the tributary sites, smolt trapping was nearly continuous and we successfully operated over 90% of potential fishing days. For Indian Creek we estimated Coho salmon (ages 0+ and 1+), Chinook salmon (ages 0+ and 1+) and steelhead. For Little River we were only able to produce estimates for 0+ and 0+ Coho salmon and 0+ Chinook, as catch rates were extremely low for larger bodied species. Indian Creek had consistently higher numbers of outmigrants than Little River for all species and may be producing a significant proportion of the total Elwha smolt production for some species. Indian Creek produced an estimated 10,417 (8,929-12,876) Coho salmon (1+) smolts. This represents nearly half of the entire Coho salmon smolt production of the Elwha River in 2018. Steelhead and lamprey populations also continue to expand in Indian Creek. In 2018 we estimated a total steelhead outmigration of 1,898 (1,568-2,382), which represents 17% of the total Elwha steelhead production. Pacific lamprey populations also continue to expand as significant numbers of juveniles (ammocoetes) and outmigrating (macrothemia) were captured in 2018.

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 process the Elwha Monitoring and Adaptive Management (EMAM) plan was developed for federally listed populations of Chinook salmon (*Onchynchus tshawytscha*) and steelhead (*O. mykiss*) (Peters et al. 2014). The EMAM provides quantitative performance targets that can affect management actions through the 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 are thus intrinsically connected to the recovery of depleted and federally listed Elwha salmon populations. Additionally, 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 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 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 trap also can be used to support tagging studies or collect other life history information. 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 species including 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.

The 2018 trapping season represents the third year of main stem Elwha monitoring following dam removal. 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: 1) to 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 greater than 15%.

Methods

History of Operations

During the pre-project and dam-removal periods, 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 up to 3.5 million of 0+ Chinook salmon smolts from the WDFW hatchery in the later season. 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. 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 later June likely because the total natural production of salmon in the Elwha was so low. In other Puget Sound drainages, Chinook 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 pre-dam removal period, the mainstem 8' screw trap was fished continuously (24 hours/day) except when flows exceeded ~2000 cfs (~56 cubic meter/second). 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. 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 has been able to reoccupy the lower river site using the larger 8'screw.

This site was temporarily abandoned during the 2013-2014 seasons because of sediment aggradation associated with dam removal and operations were moved upstream to the Spruce Hole site at Rkm 4.43 (Figure 1). 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 (Figure 2). 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. This forced a reduction in the size of trap to a 5' screw trap (Figure 2) that LEKT could physically operate as the river was not deep enough to support the larger trap. Since the 2016 season enough sediment had evacuated the lower river fishing site to support the operation of the larger 8' screw trap.

LEKT established tributary smolt monitoring sites on Little River in 2012 and Indian Creek in 2013. Because of the difficulty accessing the lowermost portions of those drainages, we chose county road bridge crossings in each tributary for trap deployment. The bridges make for convenient launch sites (Figure 3) and we contracted a local crane operator for trap deployment and retrievals. The traps are lifted from transport truck to the river by the crane and deployment is complete in less than 15 minutes. 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 on pontoons that floats 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 narrower and shallower and to fish this site effectively LEKT used a 4' screw on a narrower pontoon since the inception of

fishing. Both traps have fished with excellent results to date and it is not anticipated that additional changes will be made at the tributary sites.

Daily Operations-2018

In 2018, LEKT commenced trapping operations in the mainstem on February 16 and ceased trapping efforts on August 15 when daily catches declined to very low levels. Over one month of fishing days were lost during the 4.7 months of potential fishing days were lost due to a combination of high flows (Figure 4), damage by debris and hatchery releases. In total, we were able to fish the mainstem trap for 140 of the 181 (77%) total fishing days in the 2018 fishing season. This was a slight improvement from 2015-2017, but was a significant improvement over 2014 when frequent spring freshets resulted in the loss of half the potential fishing days (McHenry et al. 2015). The majority of lost fishing days occurred from June 2-June 10 when the trap was closed during hatchery Chinook 0+ releases. Fishing was not impacted by fine sediment and woody debris as in the dam removal period.

For Indian Creek, trapping commenced on February 12 and ceased operations on November 2. At Little River trapping was also initiated on February 11 and was concluded on July 9 when flows became too low to turn the screw. For both tributary sites, the traps were fished almost continuously. Indian Creek fished for a total of 177 out of 181 (94%) potential fishing days. The Little River trap fished a total of 138 of 149 (91%) possible fishing days.

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 utilize plexi-glass 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. PIT tags are being used in the middle Elwha to assess the movements, growth and survival of salmon (Liermann et al. 2017). All fish that had PIT tags were also identified to species, measured, weighed and their unique tag number recorded. CWT's are inserted into the snouts of juvenile coho while steelhead produced at the Elwha Hatchery receive an adipose fin clip.

Determining the origin (hatchery vs natural) of most Elwha salmon species is facilitated by unique marks applied at the two hatcheries, although only a small percentage of the total

release of hatchery Chinook salmon are adipose clipped or marked with a detectable CWT¹. WDFW has two age classes of hatchery chinook releases on Elwha: one in early April of 1+ Chinook, and another in June of 0+ Chinook. We typically cease fishing for a period of several days immediately following any hatchery release. However, residual hatchery fish can remain in the system for several weeks and are inevitably captured in the trap. The hatchery 1+ Chinook salmon are generally larger than natural 1+ Chinook salmon and their origin is determined by size and timing. The smaller 0+ Chinook salmon are difficult to determine origin as they are of very similar size and appearance to naturally produced Chinook salmon. This has led to some uncertainty in determining the origin of Chinook salmon in past years. Elwha hatchery Chinook salmon are thermally marked in the hatchery and that results in a unique growth pattern which can be determined from an analysis of otoliths. In 2017 we collected 50 Chinook salmon over a several week period for otolith analysis following resumption of fishing two weeks after the release of hatchery 0+ Chinook salmon. Those fish were sent to the WDFW laboratory to determine origin. That proportion was applied to the total 0+ Chinook salmon catch during the period following 0+ Chinook salmon hatchery releases.

In order to evaluate catch efficiency (proportion of total outmigrants captured), we attempted to conduct multiple mark recapture tests at all three trap sites. On the tributaries, weekly samples of 50 to 100 fish, representative of the species migrating at any given time (i.e. Chinook salmon smolts, coho salmon parr, coho salmon smolts), were given a distinctive mark (Bismark Brown) and released upstream of the trap site. For the mainstem trap we used small bodied (0+) Chinook salmon or Chum salmon obtained from the LEKT and WDFW fish hatcheries for trap efficiency trials. For the small bodied fish we attempted five trials between late March and late May. One of the trials was invalidated because of high flows. The four successful trials resulting in similar recapture rates (2.8, 4.5, 4.2, 2.5%) for an average of 3.5%. We also attempted to use Coho salmon smolts captured, marked and released from the Indian Creek smolt trap to provide a separate trap efficiency test for larger bodied fish at the mainstem trap. Unfortunately, we were forced to abandon this test because of interruptions in fishing on the mainstem trap due to flows and hatchery releases. Because there were few efficiency trials, the trials were not evenly dispersed across the trapping period, and the fish used in the efficiency trial were not always representative. The credible intervals and CVs generated by the statistical model do not reflect the true uncertainty in these estimates.

We used Bismarck brown dye at each of the sites to give 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 (Figure 5). The subsample of

¹ Of the WDFW chinook 0+ releases 250,000 are adipose clipped and carry a detectable CWT. Additionally 200,000 1+ chinook receive CWT's only.

marked smolts were released approximately 100 m above each tributary trap site and approximately 1,000 m above the mainstem site. The percentage of smolts recaptured varied depending upon flow and site conditions. In general, the tributary sites had relatively high mean recapture rates (Indian Creek 34.7%/Little River 26.9%) in comparison to the mainstem site. Trap calibration tests for all sites are summarized in Table 1.

Data Analysis

The sum of daily catch data along with efficiency trials were used to estimate total production 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 although flows, damages and hatchery releases resulted in a significant number of lost days (28%) at the mainstem site, which likely affected the precision of our overall estimates. However, the 2018 trapping season was not significantly interrupted by sediment or small woody debris at the mainstem site and river conditions appear to have, in large part, stabilized following dam removal.

Catch rates for all species remained relatively low on the mainstem Elwha River in 2018. In 2018, we produced estimates for 0+ Chinook salmon, 0+ Coho salmon, 1+ Coho salmon, chum salmon and steelhead at the mainstem site (Table 2). We also generated estimates for larger bodied Coho salmon (1+) and steelhead because of improved capture rates. In 2018, 0+ coho and 0+ Chinook salmon were the most numerous species captured in the mainstem trap even though their relative numbers are low (361 and 579 total catch, respectively). We estimated a total outmigration of 21,490 0+ Chinook salmon, 13,276 0+ coho salmon, 24,022 1+ coho salmon, and 11,412 steelhead for the Elwha River in 2018. Low numbers of chum salmon

were also encountered, estimating a total outmigration of 8,374 smolts. Only five pink salmon were captured at the mainstem site in 2018 and we were unable to make an outmigration estimate for that species. Total catch, estimated catch and production estimates for the mainstem trap in 2018 are summarized in Table 2.

The 2018 tributary trapping season was again a tale of two sites. Both sites were fished nearly continuously with only limited breaks in fishing operations due to elevated streamflow in early spring. Production estimates for Indian Creek continue to be high for a number of species. We generated estimates for 0+ Chinook salmon (2,140), 0+ coho salmon (3,247), 1+ coho salmon (10,417), and steelhead (1,890) at Indian Creek (Table 3). Estimates for Little River, however, continue to be low because of low catches of larger bodied species. Species-specific estimates were generated for 0+ Chinook (4,048), 0+ coho salmon (15,151) and 1+ coho salmon (186) (Table 4). No Chum salmon or pink salmon were captured at either tributary in. Only one steelhead smolt was captured at Little River in 2018 and no production estimate was made for that species.

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 5). 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 and cutthroat 0+, 1+ and 2+ age classes that were captured at Indian Creek in 2018 (Table 5). Conversely, only small numbers of trout were encountered at Little River (Table 5). No bull trout were captured in Little River and 7 were encountered at Indian Creek. Additionally, we captured the greatest number of cutthroat smolts to date at Indian Creek (34). The only non-native fish encountered during trapping operations are brook trout, which are well established in Indian Creek. The 72 Brook trout captured at the trap were removed from the system. At the mainstem trap, we continue to encounter marine species that are of ecological significance. In 2018, we report the continued presence of eulachon (*Thaleichthys pacificus*) encounters in the trap with a total catch of 23. This population appears to vary greatly in abundance by year in the Elwha but is consistently observed. Eulachon and other marine species likely stray into the lower river on high tides and are subsequently captured in the trap.

Discussion

Contemporary History

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 particularly in 2012 and 2013. This coincided with water years 2013 and 2014 where total sediment transported during the incubation phase for Chinook salmon was 19.6 and 5.7 times higher than prior years. These conditions forced us to abandon trapping because of the amount of sediment and debris interfering with trap operations. Trap operation during 2014 was stopped because this coincided with the largest amount of sediment transport occurred, which was coupled with movement of large wood and continuous elevated spring runoff. Trapping conditions were much improved in 2015 because those outmigrants were subject to incubation conditions less severe than 2014, but still 10 times higher than prior to dam removal. It is important to note that sediment alone is not the only factor which influences potential smolt outmigration and flow can also have detrimental impacts to smolt productivity (see appendix a).

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. In 2015, 2016, 2017 and 2018 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%), and 140 of 181 days (77%), respectively. The 2016-2018 seasons represents the first years of post-dam removal data and provides a benchmark to assess the state of early recovery. We hypothesize that the worst of the sediment impacts from dam removal on smolt trapping operations have occurred because sediment loads are now at or below what was estimated prior to the initiation of dam removal.

Another confounding factor, irrespective of sediment issues, is the low capture rates of large bodied smolts such as coho salmon and steelhead. This has been problematic since smolt trapping was initiated on the Elwha in 2006. The return of the 8' screw trap to the mainstem site improved smolt estimation for both small and large bodied smolts since 2016. This result, now repeated in three consecutive years, represents a significant improvement in the overall smolt monitoring program. Since 2016 we are able to generate estimates for more species/life histories than in previous years.

Trends in Smolt Outmigration Over Time

The outmigration estimates for Elwha 0+ Chinook salmon smolts in 2018 was 21,490 (range 16,507-31,121), a reduction of 71% over the 2017 estimate. This is within the range of production measured from the Elwha River during the pre-project period, but on the low end of the range (Figure 7). In 2017, adult Chinook salmon escapement to the Elwha River was 3,083

salmon. This was slightly greater than 2016, however fewer redds were observed in 2017 (937 versus 767) (McHenry et al. 2016; 2017). 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 scour and unstable bed conditions. A negative correlation between peak flows and Chinook 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 Glines Canyon) during dam removal has also likely limited the survival of incubating embryos on the Elwha River to date. We 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 was negatively correlated with chinook survival for those years (Appendix B). Also of interest is what appears to be the reestablishment of a bimodal outmigration pattern for chinook 0+ smolts during the last two monitoring seasons (Appendix B). This pattern is consistent with other chinook populations in Puget Sound (Personal Communication, WDFW).

We compared the total outmigration estimates between tributaries and found some noticeable differences in abundance and timing (Appendix C). In past seasons for Coho salmon (0+), large numbers of fry outmigrants were moving downstream, presumably to rear in other habitats or immigrating to the Strait of Juan of de Fuca. This life history pattern has been documented in other nearby Strait of Juan de Fuca watersheds (Bennett et al. 2014). This pattern was not observed in 2016, likely as a result of the record low escapement of coho salmon in 2015. This pattern reappeared in 2017 and 2018 at all sites. For 1+ coho salmon smolts, Indian Creek produced an estimated 10,417 fish, a decrease of 40% from 2017. In contrast, we estimated a total production of 15,151 0+ coho salmon and 186 1+ coho salmon smolts in Little River in 2018.

The estimated number of 0+ Chinook salmon produced from Indian Creek (2,140) was similar to 2017, but much lower than observed in previous years. Little River also had low production of 0+ Chinook salmon in 2018 (4,048). In 2017, 35 and 9 Chinook salmon redds were observed in Indian Creek and Little River, respectively. The majority of redds in Indian Creek were observed below the trap site, while the seven of redds in Little River were located upstream of the trap site (McHenry et al. 2017). Since Elwha Dam was removed in 2014, Little River has had several years where few or no Chinook salmon having 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 in some years.

Steelhead smolt production in the Elwha River has steadily increased since 2014, going from no estimate to over 11,500 in 2017. In 2018 we estimated 11,412 (7,566 to 20,712) in the main stem Elwha River. Indian Creek has seen a similar trend going from approximately 500 to almost

2,000 in 2018. The increase in steelhead smolt numbers since 2014, in the mainstem Elwha and Indian Creek, suggests rebuilding is ongoing. Little River Steelhead smolt estimates have been considerably more variable and have not shown the same positive trend. In 2014 there were almost 500 estimated smolts, which was similar in 2015, and 2016, followed by a decline to 14 and no estimate in 2018. It is important to note that large numbers of juvenile steelhead outmigrate in the fall when the screw trap is not operating in Little River (Unpublished data, LEKT). We have documented this movement since 2012 with passive integrated transponder (PIT) antennas and PIT tagged juvenile *O. mykiss*. 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.

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). These 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.

Indian Creek has consistently produced larger numbers of coho salmon smolt (1+) outmigrants relative to Little River over the period of monitoring. Since 2012, surplus coho salmon adults from the LEKT hatchery have been relocated to the two middle Elwha tributaries (Table 7). All of these relocated fish have been visually tagged using colored spaghetti tags. Based upon observations on the spawning areas of the tributaries, the majority of the coho salmon spawners to date originated from these relocation efforts (Table 6) (McHenry et al. 2017). Both tributaries received similar numbers of relocated hatchery adult coho between 2011-2013. However no relocations have occurred in Little River since 2013. The larger numbers of Coho salmon 1+ outmigrants are likely due to the amount and quality of habitat within the sub-drainage. Indian Creek's headwaters include Lake Sutherland which moderates flow and temperature characteristics. Indian Creek also has significant groundwater influence as it flows downstream. A significant Beaver (*Castor canadensis*) population has also hydro-modified large areas downstream of Lake Sutherland and have created excellent rearing habitat for coho salmon rearing. Interestingly, our estimate of Indian Creek 1+ coho salmon outmigrants represents 91% of the total production from the Elwha watershed.

While the over trends for Chinook salmon smolt outmigrants are 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 (Figures 7 & 8). The 2017 Elwha chum estimate was 4,065 fish well below the

pre-dam removal average of 141,802 (2006-2012). The Elwha pink population is primarily an odd year timed run and as a result no smolts were captured in the 2017 outmigration year. For years in which we caught enough pink smolts to generate a production estimate those numbers show a steadily declining trend (Figure 8). Neither tributary to date has 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 to 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. There is concern that passage conditions at the former Elwha Dam site are problematic for some species and at some flows (ONP 2014, WDFW 2014). Comparison of historic photographs prior to dam construction with post dam removal conditions suggests that the site is currently significantly steeper (cascade versus pool). It is apparent that a significant amount of boulder debris was left in place in the channel creating numerous hydraulic jumps that have been difficult for some species of fish to ascend at least through the calendar year 2014. Passage conditions appeared to have improved during the winter of 2014-15, following floods that transported several large boulders downstream. However, during the summer of 2015, during very low flow conditions, the base of the former Elwha Dam was discovered. This indicates that the entire structure was not removed and needs to be closely monitored as conditions could change again. The lack of chum and pink salmon upstream of Elwha Dam through 2016 would seem to support those observations. Similarly, passage through Glines Canyon has only recently been improved, but it is unclear if chum and pink can pass this area. A large rock fall in the canyon entrance shortly following the removal of the structure has largely precluded upstream passage. This obstruction was systematically blasted in the fall of 2015 and continues to be monitored. Recovery of upriver populations and life histories is contingent upon successful fish passage at this site. If these trends continue, project managers should consider interventions that could amplify both populations.

Smolt trapping operations have documented several ecologically significant events that suggest the “reawakening” of anadromy or natural recolonization events. Those include the documentation of sockeye salmon smolts from Indian Creek/Lake Sutherland in previous years, the natural recolonization of Indian Creek by Pacific Lamprey, and the continued presence of eulachon in the lower river. 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. This may suggest that the Sutherland kokanee population is still producing sockeye smolts, albeit at a very low level. This mechanism has been previously documented in the Coquitlam and Allouette Rivers in British Columbia where sockeye 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. We intend to collect tissue samples from sockeye salmon in future years in order to elucidate the origin of this population.

Recolonization has successfully occurred for Pacific Lamprey (*Entosphenus tridentatus*) in Indian Creek, where adult captures were first documented in 2013 and subsequently again in later years at the smolt trap. These adults were 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 populations appear to be expanding rapidly in Indian Creek. 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. We expected that downstream migrating microthalamia 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 and Crossman 1973). However, in 2016 we encountered a total of 71 Pacific Lamprey macrothalamia (Figure 9) and in 2017 that number increased to 600. In 2018, the total number of macrothalamia was 649.

Sources of error

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, the realities of maintaining in-stream infrastructure in a large Olympic Peninsula river continuously for up to 7-8 months inevitably involves the possibility of unknown circumstances reducing the amount of data collected and thereby 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 the dam removal years, when large portions of the fishing season were lost, the biggest source of uncertainty confronting smolt trapping programs on the mainstem Elwha in 2018 was due to the combination of missed trap days and but the low numbers of some species of fish captured. The Coefficient of Variation (CV) for mainstem trapping

estimates ranged from 16% (0+ coho) to 27% (1+ coho salmon) and averaged 24% for all species.

In 2018 the CV was above the 15% threshold for all species 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. Due to missed fishing days immediately after trap efficiency tests, only three efficiency trials were used to expand all numbers for the mainstem. One of these was for coho 1+ and the other two for chinook 0+. We chose to use all three efficiency trials for the both large and small bodied species. This introduces a substantial amount of uncertainty to the mainstem estimates that is not accounted for in the confidence intervals and CVs.

In contrast, fishing on the tributaries was relatively trouble free and 93% of the potential fishing days were fished and continually per 24 hour day. The coefficient of variation at Little was close to the 15% target threshold. Little River estimated CV was 15% for 0+ Coho salmon and 14% for 1+ coho salmon (the only species estimated). For all species the CV for the Little River site was 14.6%. Indian Creek CV's were variable and ranged from 9% for 1+ Coho smolts to 32% for 0+ Chinook salmon. For all species the CV for the Indian Creek site was 17%. This is a significant improvement over 2017 when the CV averaged 28%.

For all trap sites we plotted estimated catch and expansion factors for all species (Appendix D).

Recommendations

Based on our experiences conducting smolt trapping on the Elwha River during the dam removal period we will implement the following changes for 2019 operations. For the mainstem Elwha River trapping effort we will discontinue the trapping operations at the downstream site at Rkm 0.3. The long term future of the 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. As a result, we propose to move the trap upstream to a site just downstream of Elwha River Road bridge. This is the only reliable road access point in the lower. It places the trap further upstream than desired (Rkm 4.0), 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 will result in fewer lost days from hatchery releases. It will also increase the precision of fish identification, particularly for 0+ chinook. 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 relied on small bodied hatchery produced smolts including Chinook salmon (0+), chum salmon (0+) and Coho salmon (0+). These sized fish are generally available and were convenient to use for trap efficiency tests. In 2017 we added trap tests using larger sized hatchery and natural origin smolts including Coho salmon 1+, steelhead, and Chinook salmon 1+. 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. 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).

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. This action has been indefinitely delayed however, because the 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 trap launching and daily maintenance thus LEKT will postpone this action until road access is reestablished.

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operations in 2018. Washington Department of Fish and Wildlife provided the majority of 0+ chinook and the Lower Elwha Klallam Hatchery provided 0+ chum salmon for trap testing.

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Tables

Table 1. Results of mark-recapture tests for Elwha River, Indian Creek and Little River for the 2018 smolt outmigration season.

Site	Date	Species	Number	Recaptures	Percentage (%)
Elwha	3/20/18	Chinook 0+	1,000	28	2.8
Elwha	3/29/18	Chinook 0+	1,000	20	2.0
Elwha	4/27/18	Chum 0+	1,000	42	4.5
Elwha	5/1/18	Chinook 0+	1,000	25	2.5
Elwha	5/22/18	Chinook 0+	1,000	45	4.5
<i>Elwha Average</i>			<i>5,000</i>	<i>160</i>	<i>3.2</i>
Little	3/20/18	Chinook 0+	100	2	2.0
Little	3/28/18	Chinook 0+	100	11	11.0
Little	4/4/18	Chum 0+	200	33	16.5
Little	5/1/18	Chinook 0+	100	23	23.0
Little	5/10/18	Chinook 0+	50	26	52.0
Little	5/22/18	Chinook 0+	100	32	32.0
<i>Little Average</i>			<i>650</i>	<i>147</i>	<i>22.6</i>
Indian	3/30/18	Chinook 0+	100	15	15.0
Indian	3/28/18	Chinook 0+	100	28	28.0
Indian	5/1/18	Chinook 0+	100	27	27.0
Indian	5/10/18	Coho 1+	50	21	42.0
Indian	5/22/18	Coho 1+	50	27	54.0
Indian	6/4/18	Coho 1+	50	21	42.0
<i>Indian Average</i>			<i>450</i>	<i>139</i>	<i>30.8</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, 2018 outmigration year. NE = no estimate.

Species	Catch	Estimated Total Catch	Estimated Outmigrants	95% C.I.	CV	gCV
Chinook Salmon(0+)	579	824	21,490	16,507- 31,121	0.17	0.16
Chinook Salmon(1+)	21	-	NE	NE	NE	NE
Coho Salmon(0+)	361	382	13,216	9,668- 18,811	0.18	0.17
Coho Salmon(1+)	350	775	24,022	15,533- 44,227	0.30	0.27
Chum Salmon	154	209	8,374	5,696- 13,595	0.24	0.23
Pink Salmon	5	NE	NE	NE	NE	NE
Steelhead	177	363	11,412	7,566- 20,712	0.29	0.26

Table 3. Total catch, estimated outmigrants, 95% C.I., CV and geometric CV for smolt outmigration from Indian Creek, 2018 outmigration year.

Species	Total Catch	Estimated Total Catch	Estimated Outmigrants	95% C.I.	CV	gCV
Chinook Salmon(0+)	347	405	2,140	1,407-4,904	0.44	0.32
Chinook Salmon(1+)	20	-	NE	NE	NE	NE
Coho Salmon(0+)	676	713	3,247	2,468-4,633	0.16	0.16
Coho Salmon(1+)	4,190	4,199	10,417	8,929-12,876	0.09	0.09
Pink Salmon(0+)	3	-	NE	NE	NE	NE
Chum Salmon(0+)	1	-	NE	NE	NE	NE
Steelhead	560	578	1,898	1,568-2,382	0.11	0.11

Table 4. Total catch, estimated outmigrants, 95% C.I., CV and geometric CV for smolt outmigration from Little River, 2018 outmigration year.

Species	Total Catch	Estimated Total Catch	Estimated Outmigrants	95% C.I.	CV	gCV
Chinook Salmon(0+)	694	721	4,048	3,185-5,645	0.17	0.15
Chinook Salmon(1+)	31	-	NE	NE	NE	NE
Coho Salmon(0+)	2,264	2,662	15,151	11,771-21,525	0.16	0.15
Coho Salmon(1+)	63	63	186	143-243	0.14	0.14
Pink Salmon(0+)	0	NE	NE	NE	NE	NE
Chum Salmon(0+)	0	NE	NE	NE	NE	NE
Steelhead	1	-	NE	NE	NE	NE

Table 5. Total catch of miscellaneous fish encountered at Elwha River, Little River and Indian Creek smolt traps, 2018.

Site	0+ Trout	1+ Trout	2+ Trout	Bull Trout	Brook Trout	Cutthroat Trout (Smolts)	Cottids	Redside Shiner	Ammocoete	Macrothallimia	Adult Pacific Lamprey
Elwha	148	48	7	5	0	0	74	14	75	26	2
Little	173	78	2	0	0	0	2	0	0	0	0
Indian	199	1,619	314	7	72	34	244	675	2,029	647	3

Table 6. Smolt production from the Nisqually River (2009-2015), (Kungle et al. 2017).

Species	Average	Range
Steelhead	60,667	47,061 - 74,273
1+ Chinook	4,618	2,382 - 7,697
0+ Chinook	165,218	145,264 - 186,187
1+ Coho	161,289	137,007 - 185,573
Chum	258,086	173,892 - 342,280
Pink	17,943,433	14,276,040 - 21,610,829

Table 7. Adult coho relocations and redd counts to Little River and Indian Creek 2011-2017.
NS=Not Surveyed. LS=Limited Surveys.

	Indian Creek		Little River		Mainstem	
Brood Year	Transfer	Redds	Transfer	Redds	Transfer	Redds
2011	134	95	137	-	326	Not Surveyed
2012	162	38	60	8	0	Not Surveyed
2013	596	126	442	160	0	Not Surveyed
2014	124	30	0	5	0	Not Surveyed
2015	0	1	0	NS*	0	Not Surveyed
2016	327	82	0	21	216	Not Surveyed
2017	146	LS	0	LS	218	Not Surveyed
2018	0	LS	0	LS	0	Not Surveyed

Figures

Figure 1. Elwha River smolt trap locations.

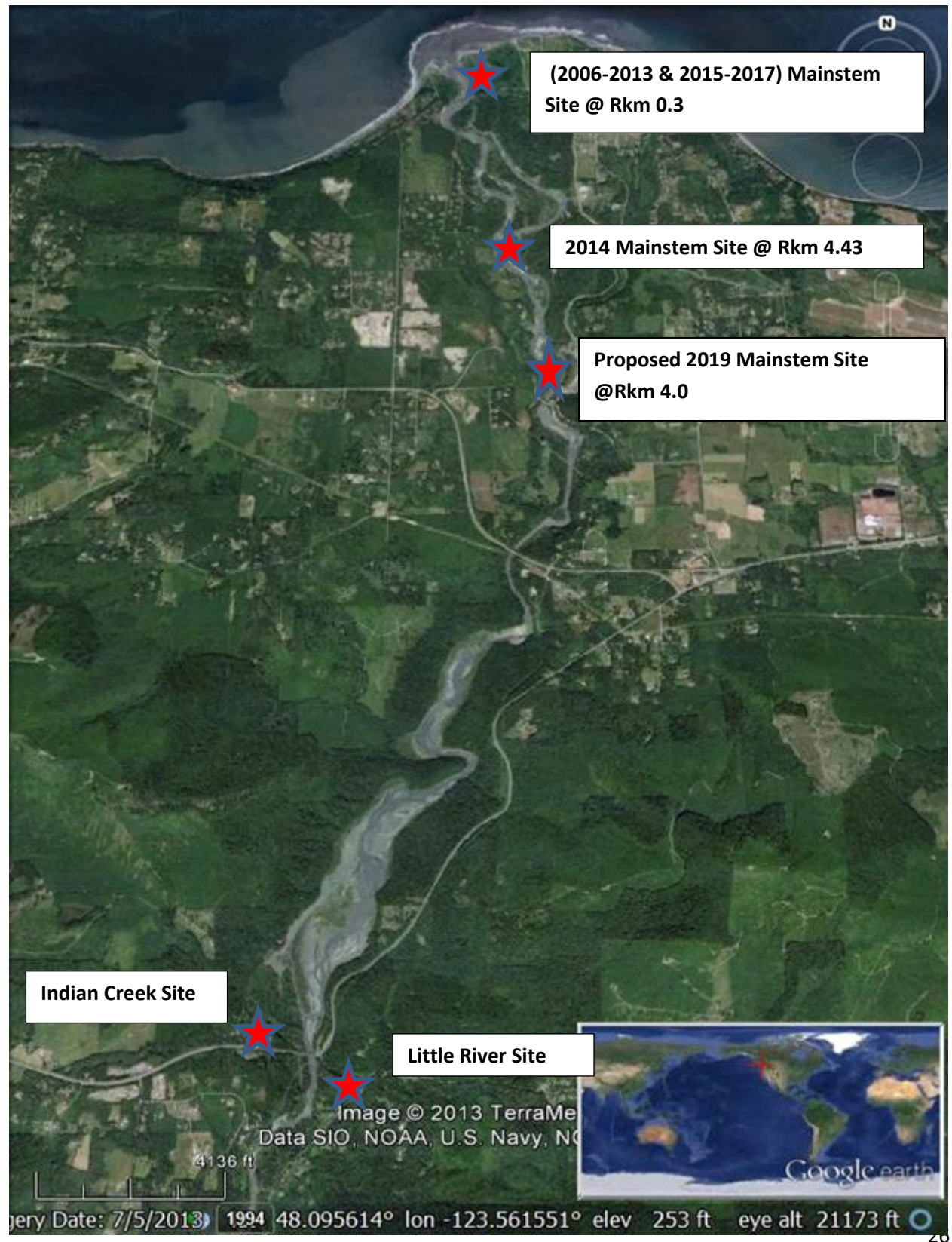


Figure 2. Top Elwha River 8' rotary screw trap fishing at Rkm 0.3 during the pre-dam and post-dam removal periods and bottom 5' rotary screw trap used during the dam removal period.



Figure 3. Little River (top) and Indian Creek smolt traps.



Figure 4. Elwha River flows (cfs) measured at the McDonald Gage Site, September 15, 2017 to April 15, 2018 (top-salmon incubation period) and January 15, 2018 to April 15, 2018 (bottom-smolt outmigration period).

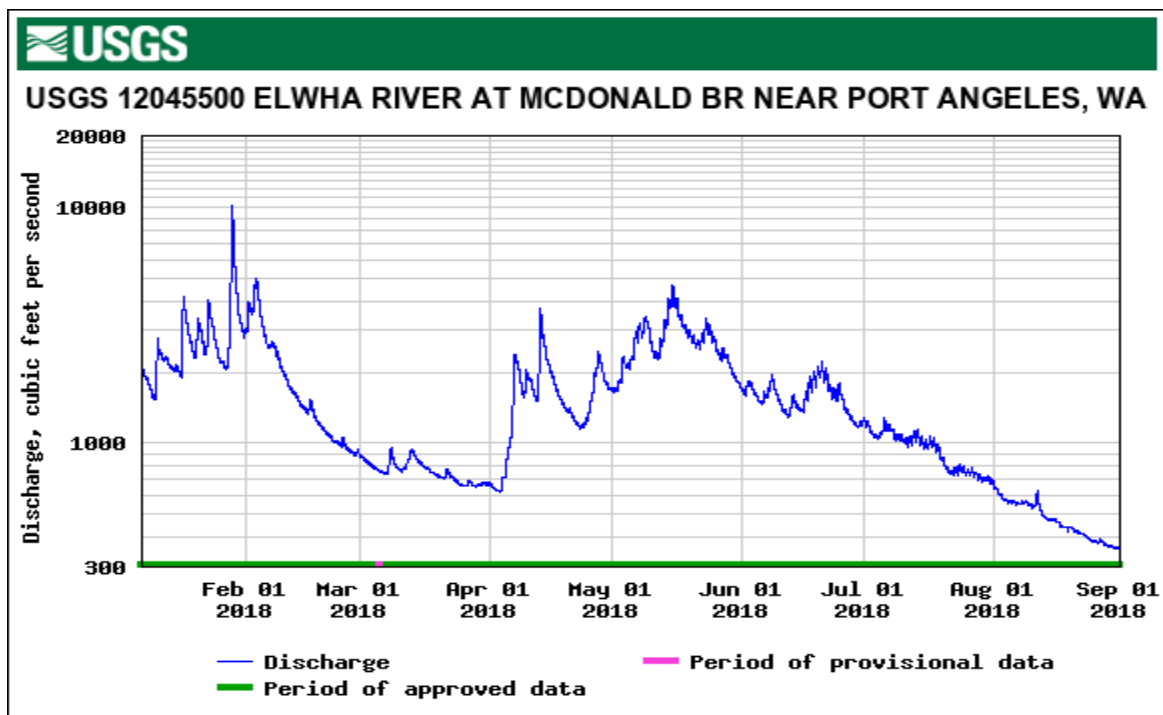
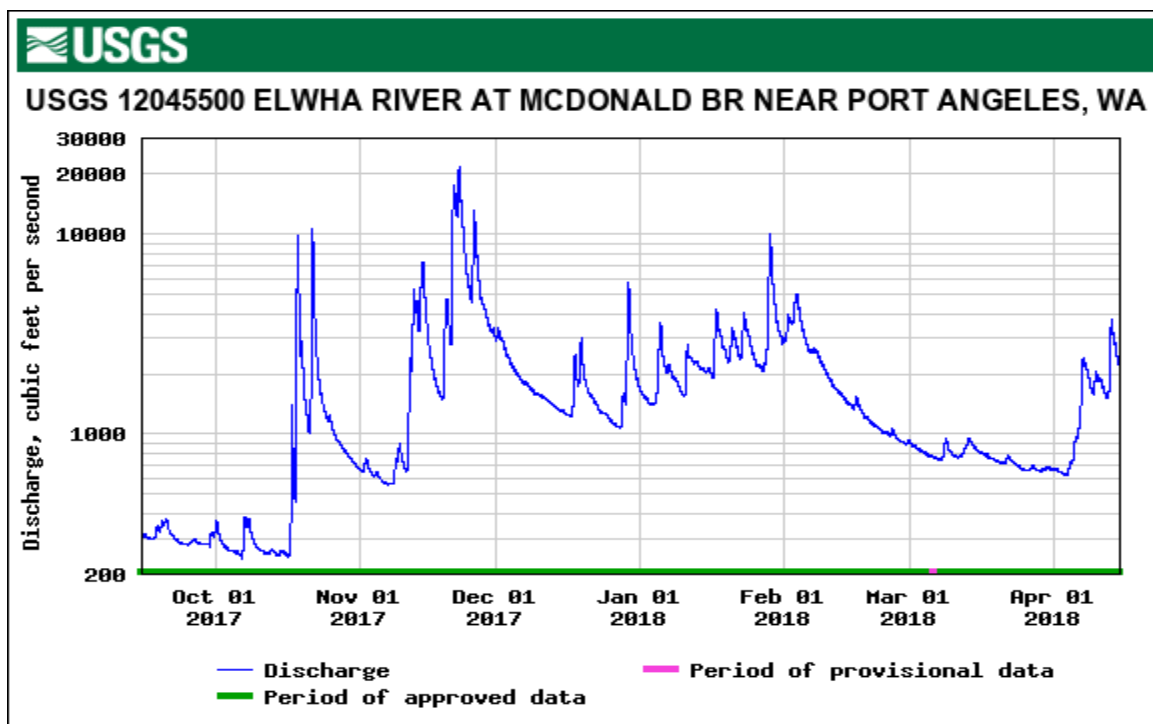


Figure 5. Bismark brown marked 1+ coho salmon for mark-recapture trap calibrations.



Figure 6. Pacific Lamprey ammocotes (top) and macrothalmia (bottom) captured at Indian Creek trap.



Figure 7. Estimated Elwha River Chinook, Chum and coho salmon smolt production (2006-2018).

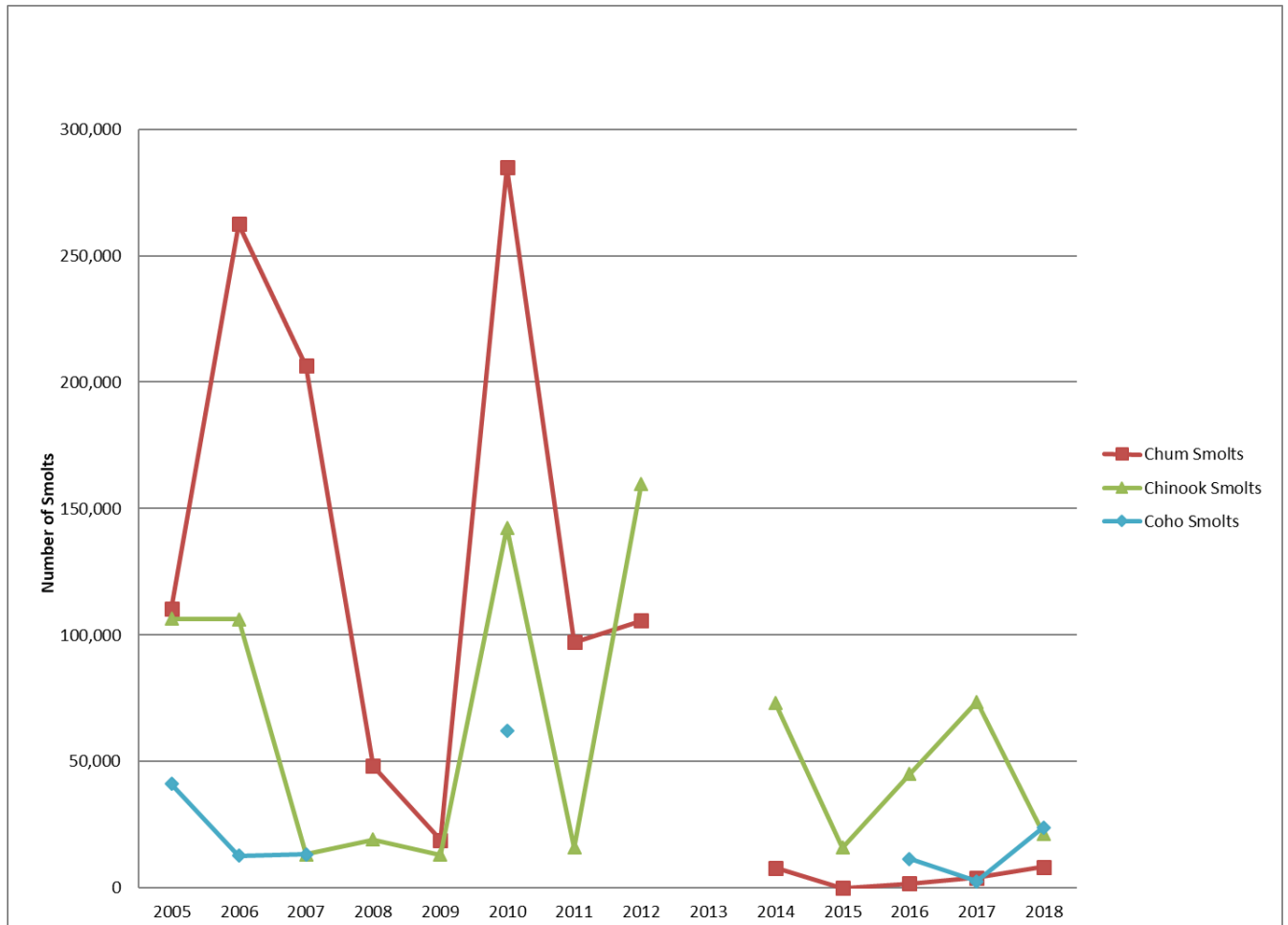


Figure 8. Estimated Elwha River pink salmon (odd year) smolt production (2006-2018). No estimate was made for 2018 as only 5 pink smolts were captured.

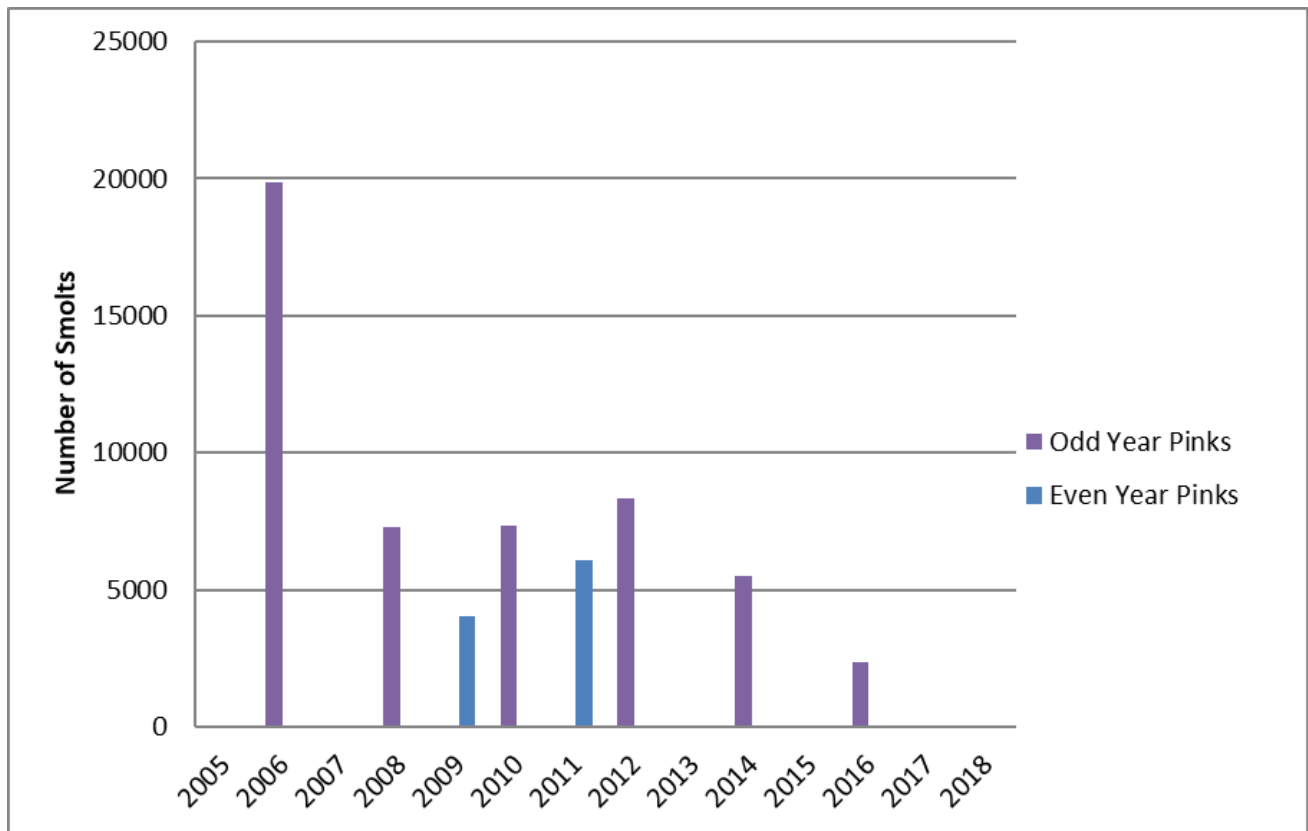
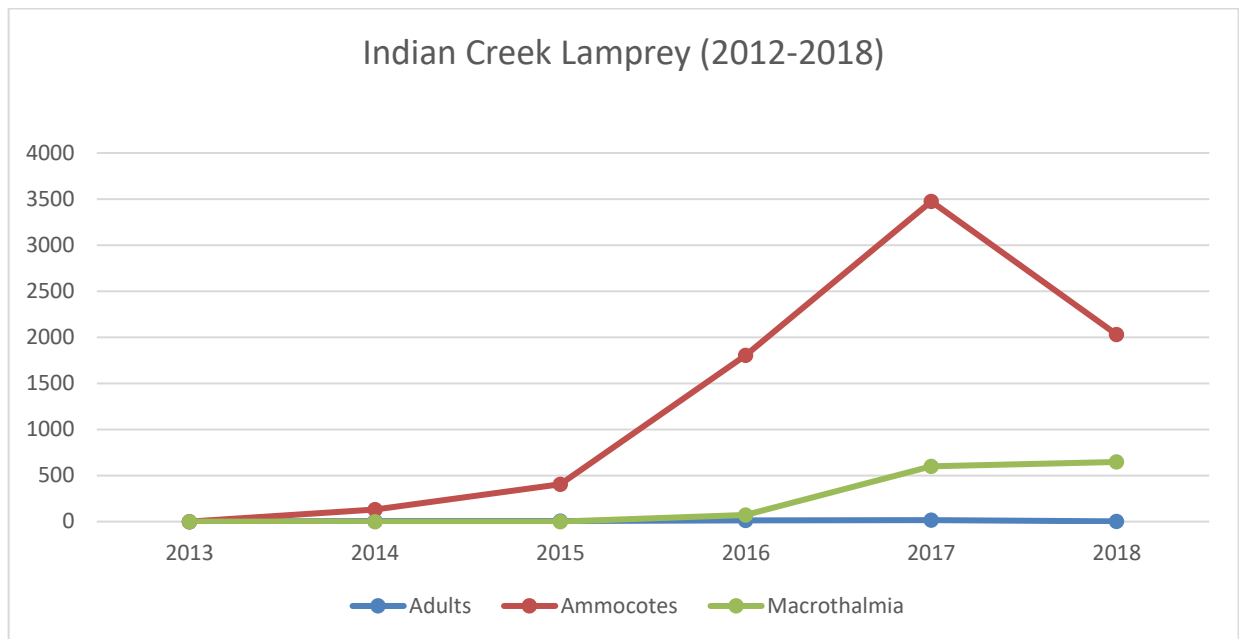


Figure 9. Pacific Lamprey captures at the Indian Creek Smolt trap.



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. Relating large flow events and sediment discharge to fry to spawner survival for Chinook salmon the Elwha River.

We examined the relationship between bankfull flow events (~2,000 CFS or greater), sediment discharge, and estimated fry to spawner estimates in the Elwha River from 2011 to 2017 in order to see if there is a strong correlation.

Methods

We used the following data:

Flow – USGS daily discharge data from 2011 to 2017

Sediment – USGS estimated sediment discharge (tonnes) per day utilizing the analysis that was recently completed for the Ritchie et al. 2018 paper.

Fish – Estimates for returning natural spawners (total escapement estimate – minus what was taken to the hatchery) and the estimated number of Chinook 0+ from the smolt reports (2014 to 2018), as well as previous estimates prior to 2014.

The equations developed and associated assumptions made are the following:

Flow index:

The development of a flow index that includes the number of days above 2,000 CFS (assumption that is bankfull flow) between October 1 and December 31st (assume that is the period of primary incubation).

We also then quantified the amount of flow greater than 2,000 CFS per day during that same time period, assuming that is a surrogate for stream power.

The number of days above 2,000 CFS was then multiplied by the average flow greater than 2,000 CFS to give an indication of the overall magnitude of potential events that could have an impact on egg to fry survival for the period of incubation.

Eq.1. Number of days > 2,000CFS * Average amount of flow > 2,000CFS

The major assumption with this equation is that the number of days and the amount of flow over the course of the entire incubation period would have the largest impact to egg to fry survival. I did not take into account when the flows occurred during that time period (i.e. early in incubation v. when the eggs may have hardened or when the fry would emerge from the gravels). This could also explain some of the variation between flow and fry to spawner productivity.

Sediment:

We summed the average total amount of sediment discharge (tonnes) for the period between October 1 and December 31st. The total amount of sediment discharge came from Ritchie et al. (2018). There was no data post 9/30/2016 data so I was able to pull together a rough estimate for October 1, 2016 to December 31st, 2016 utilizing the bedload data available from the BOR plates located near the water treatment facility. Based on previous years work the bedload sensor's quantify approximately 44% of the total bedload estimate. In addition the bedload is roughly 25% of the total sediment load mobilizing in any given day. Thus I was able to come up with an overall total sediment discharge estimate with the following equation:

$$\text{Eq.2. (Measured bedload (tonnes/day))/0.44)/0.25}$$

Note: We will be able to check this against the actual estimated sediment discharge in the next few weeks when Chris Curran and others provide the suspended sediment data as well as the daily ungauged bedload estimates.

Chinook salmon adult returns:

We used the existing escapement estimates from the Denton et al. SONAR reports from 2011 to 2018. I confirmed the number of reported Adult Chinook salmon taken to the hatchery with Joe Anderson (WDFW) to make sure I used an estimate of the number of naturally spawning Chinook salmon.

Chinook salmon fry estimates:

We used the Chinook salmon 0+ estimates from our smolt reports (2014 to 2017). For 2013 and 2012 we used the estimates made by Mike McHenry from the original spreadsheet with a modification to 2012. In that year there were no efficiency estimates made for Chinook salmon but rather just for Pink and Chum salmon. I went back to the efficiency estimates for Chinook salmon from 2010 to 2015 and examined the variation we identified in our efficiency estimates. The average efficiency estimates for Chinook salmon fry was 1.51% (+/-0.84%) for the years 2010, 2011, 2013, 2014, and 2015. Instead of using the pink and chum estimated I utilized the average for those years to change the estimate from 159,842 to 70,092 with a range of 43,300 to 183,540.

Flow and sediment combined:

We combined flow and sediment because of the change in sediment supply the river has experienced since dam removal. The flow/discharge rating curves for the incubation period vary each year due to the river either being sediment supply limited or sediment transport limited. This means that in certain years, the amount of sediment mobilized, and conversely the amount of scour, fill, and channel migration will vary according to the amount of sediment that is available. In sediment supply-limited years, there will be less sediment mobilized for a given flow event than in a sediment transport-limited year. For example, there were similar flow maximum flow events in water years (WY) 2015 and 2016 (12,300 and 12,100 CFs respectively), however the amount of sediment mobilized in WY 2015 was

approximately 2.91 times more (271,400 tonnes v. 93,140 tonnes) than in WY 2016. This would make for a much large amount of potential bed disturbance in WY 2015 v. WY 2016. The variation between years is large and needs to be taken into account when correlating flow and sediment to potential fry/spawner estimates (Figure 1).

We attempted to take the variation in sediment into account by defining the potential impact by multiplying the flow index with the total sediment discharge for the entire period of incubation (October through December)

Eq.3. (Number of days > 2,000CFS * Average amount of flow > 2,000CFS)*Total sediment discharge (tonnes)

Figure 1- Maximum discharge (CFS) v. Total sediment discharge (tonnes) from 2011 to 2017 in the Elwha River



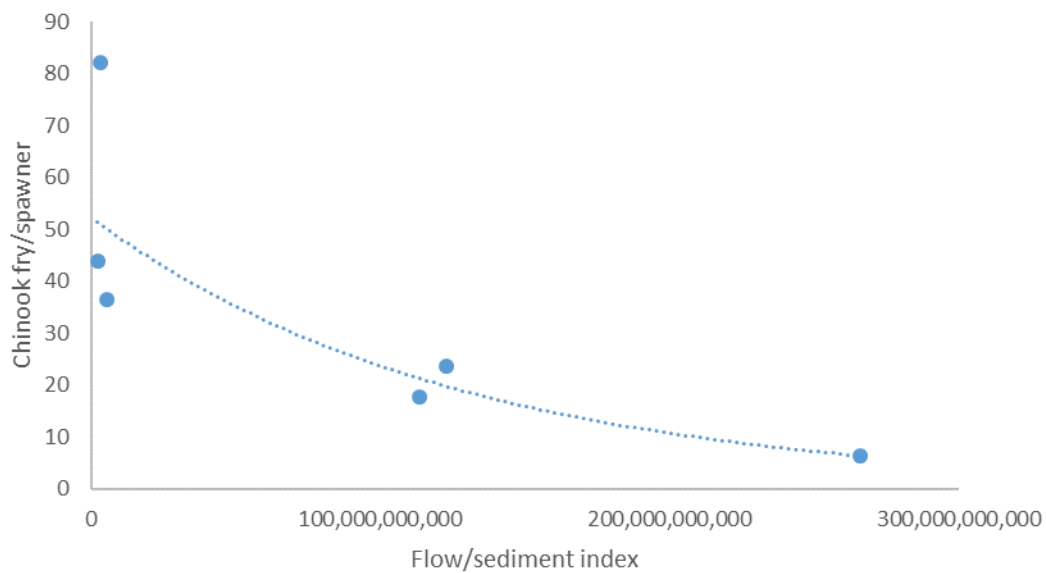
Results

Examination of the discharge, sediment, and fry per spawner data from 2011 to 2017 reveals a correlation between the flow/sediment index and fry per spawner (Figure 2). The number of fry per spawner decreases with an increase in the flow/sediment index in the form of a power function (Fry/spawner = $52.247e^{-8E-12(\text{Flow/sediment index})}$, $R^2=0.89$).

Discussion

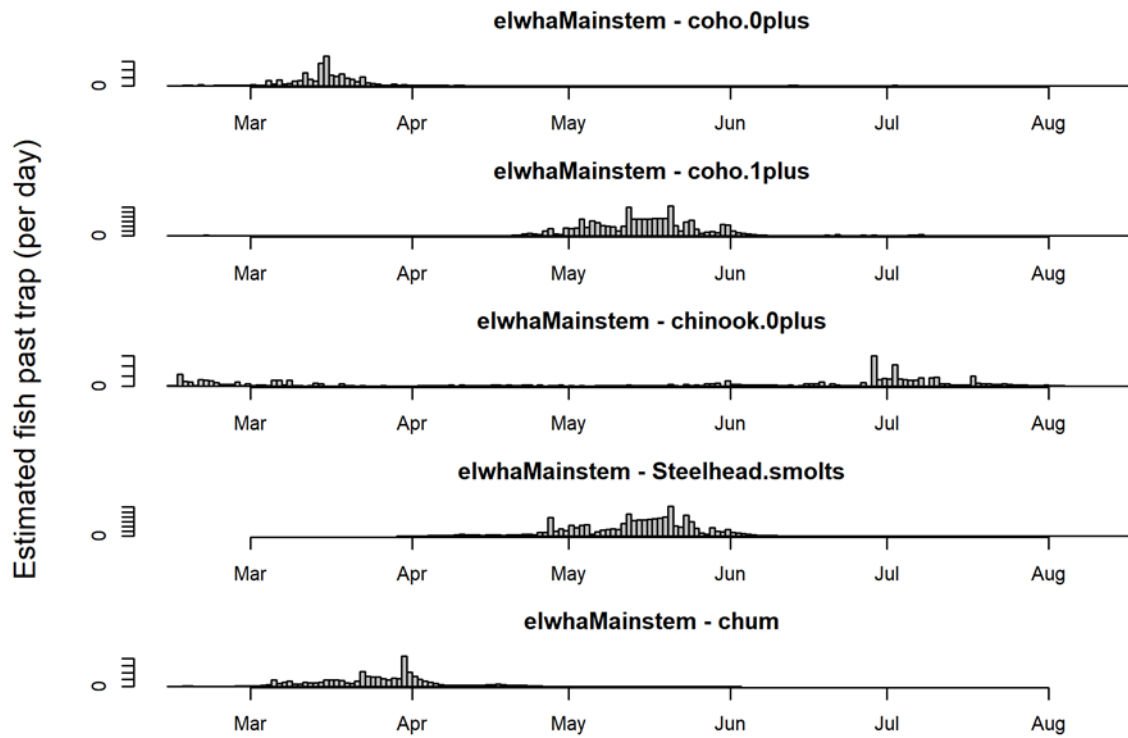
The basic relationship between flow and correlated fry survivorship as well as sediment and fry survivorship is relatively well known, however combining the two increases the explanatory power of these relationships a significant amount. This is due to the inter-annual variability, which is captured by combining the two correlative metrics to predict the potential disturbance to the streambed and subsequently to the fry survivorship.

Figure 2. Flow/sediment index v. Chinook salmon fry/spawner in the Elwha River from 2011 to 2017.

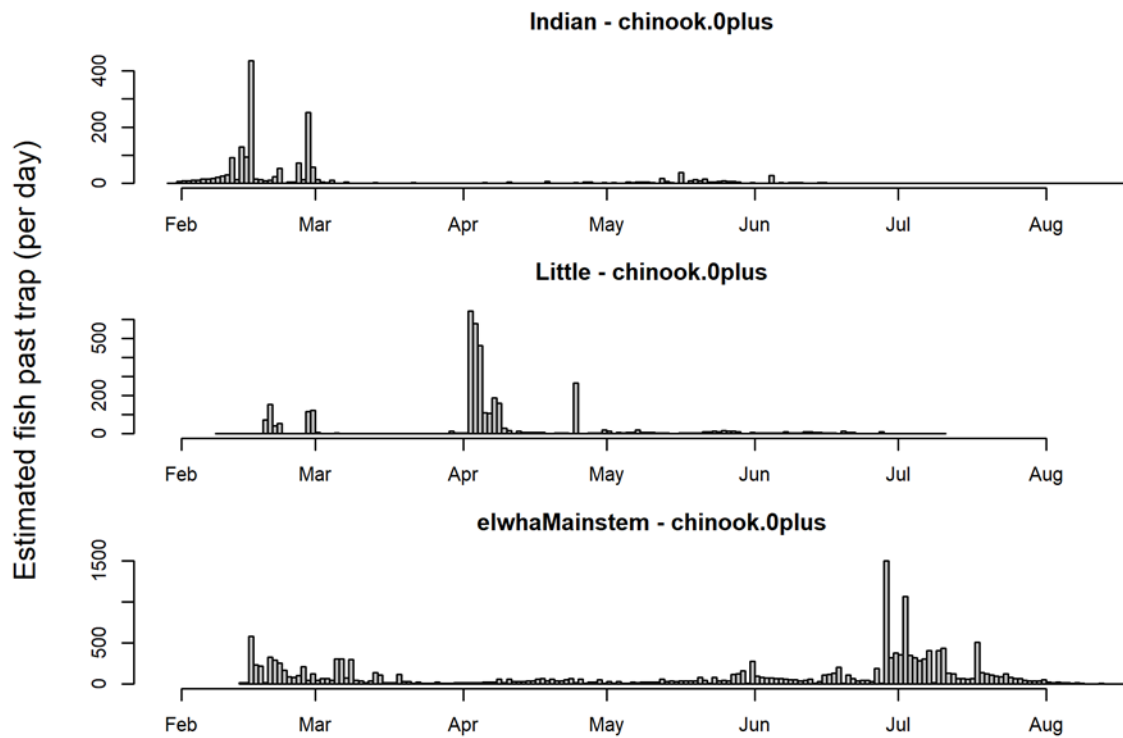


Appendix C.

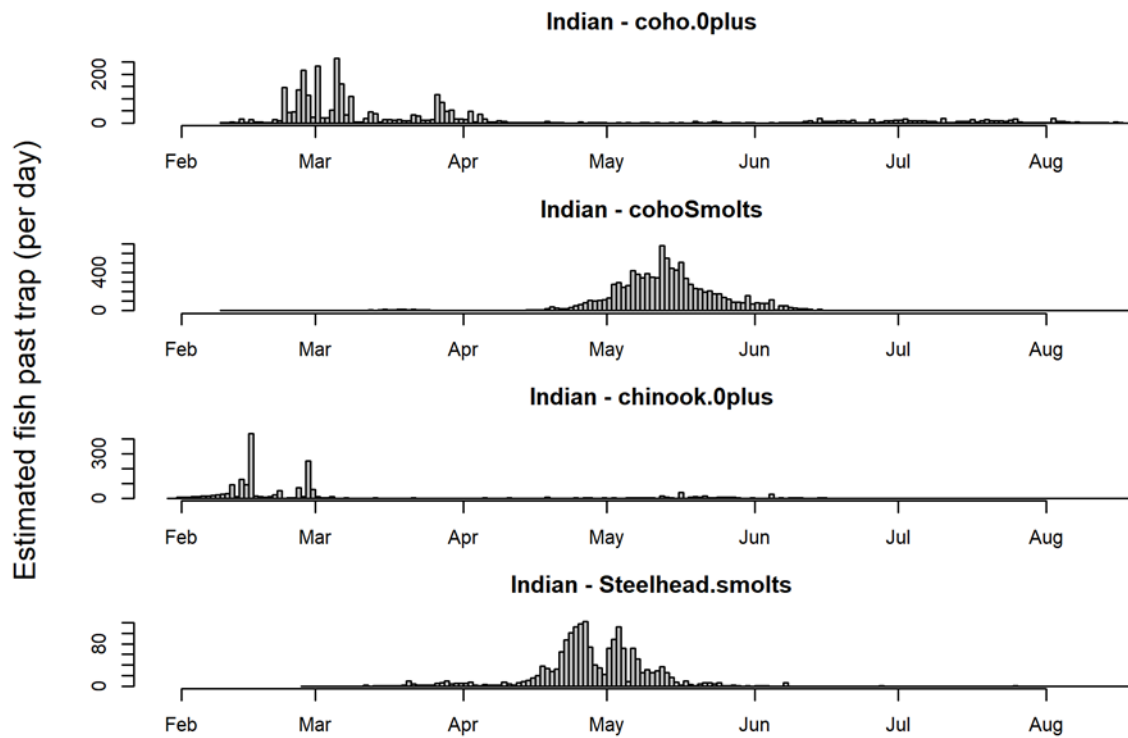
Estimated number of 0+ coho, coho smolts, 0+ Chinook, steelhead and chum outmigrants at the mainstem Elwha trap site by day during 2018.



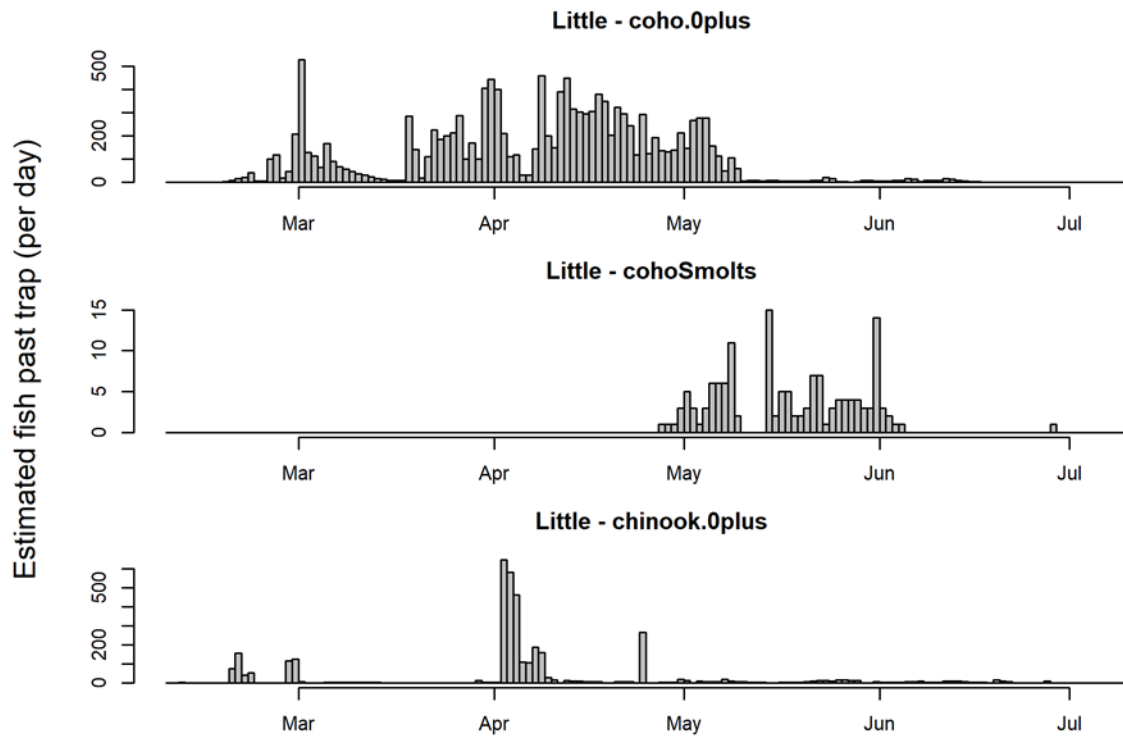
Estimated number of 0+ chinook outmigrants at Indian, Little and mainstem Elwha trap sites by day during 2018.



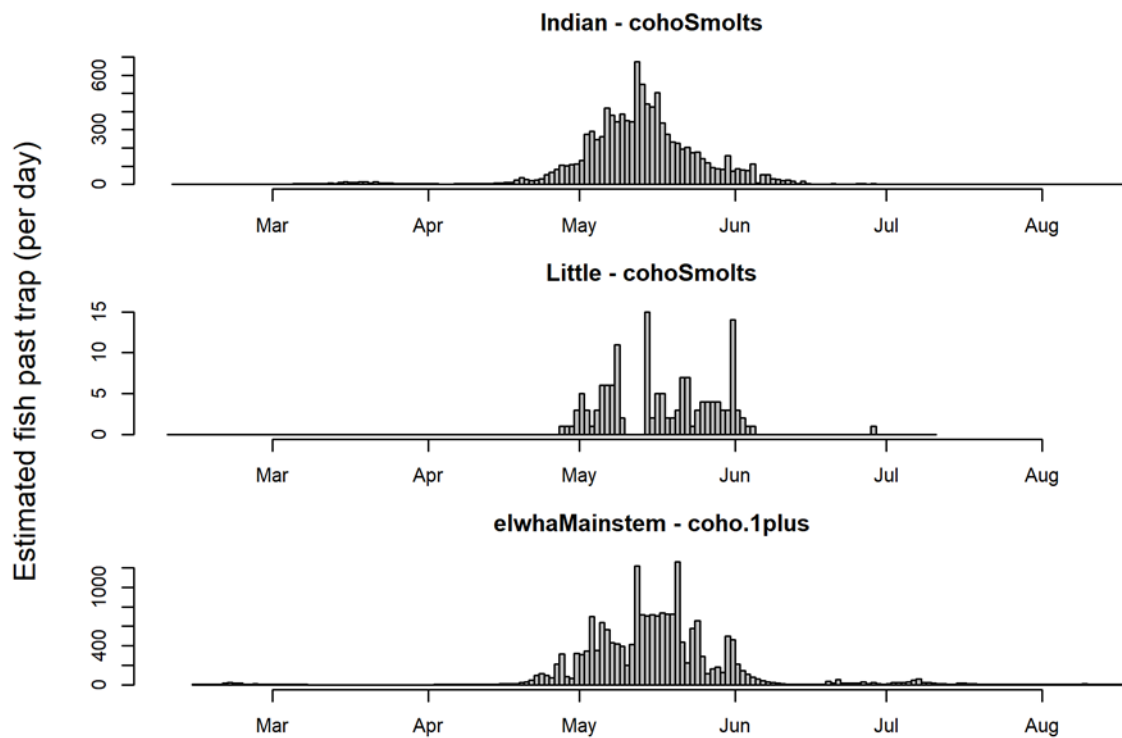
Estimated number of 0+ coho, coho smolts, 0+ chinook and steelhead outmigrants at the Indian Creek trap site by day during 2018.



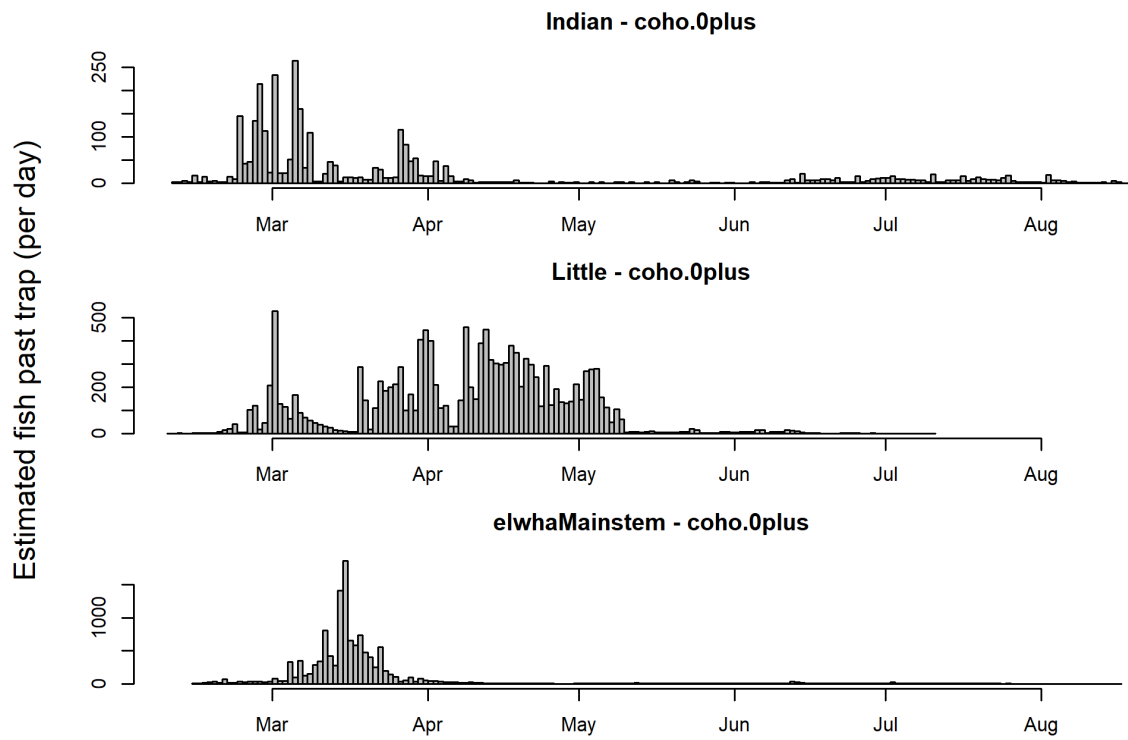
Estimated number and timing of 0+ coho, coho smolts and 0+ chinook outmigrants at the Little River trap site by day during 2018.



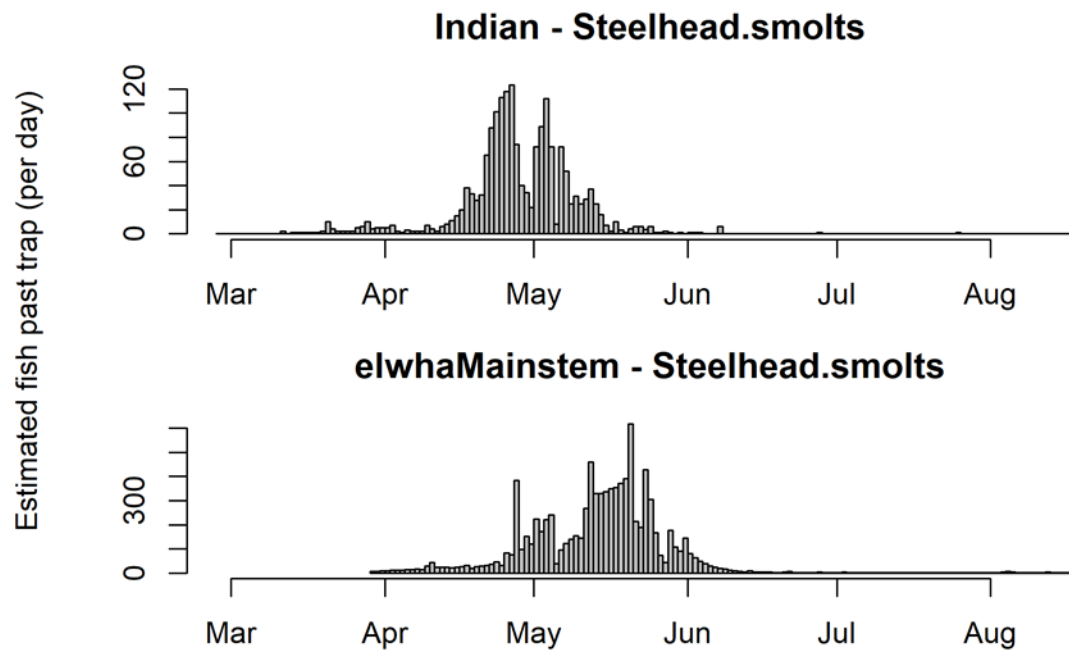
Estimated number coho smolt outmigrants at the Indian Creek, Little River and Elwha mainstem trap sites by day during 2018.



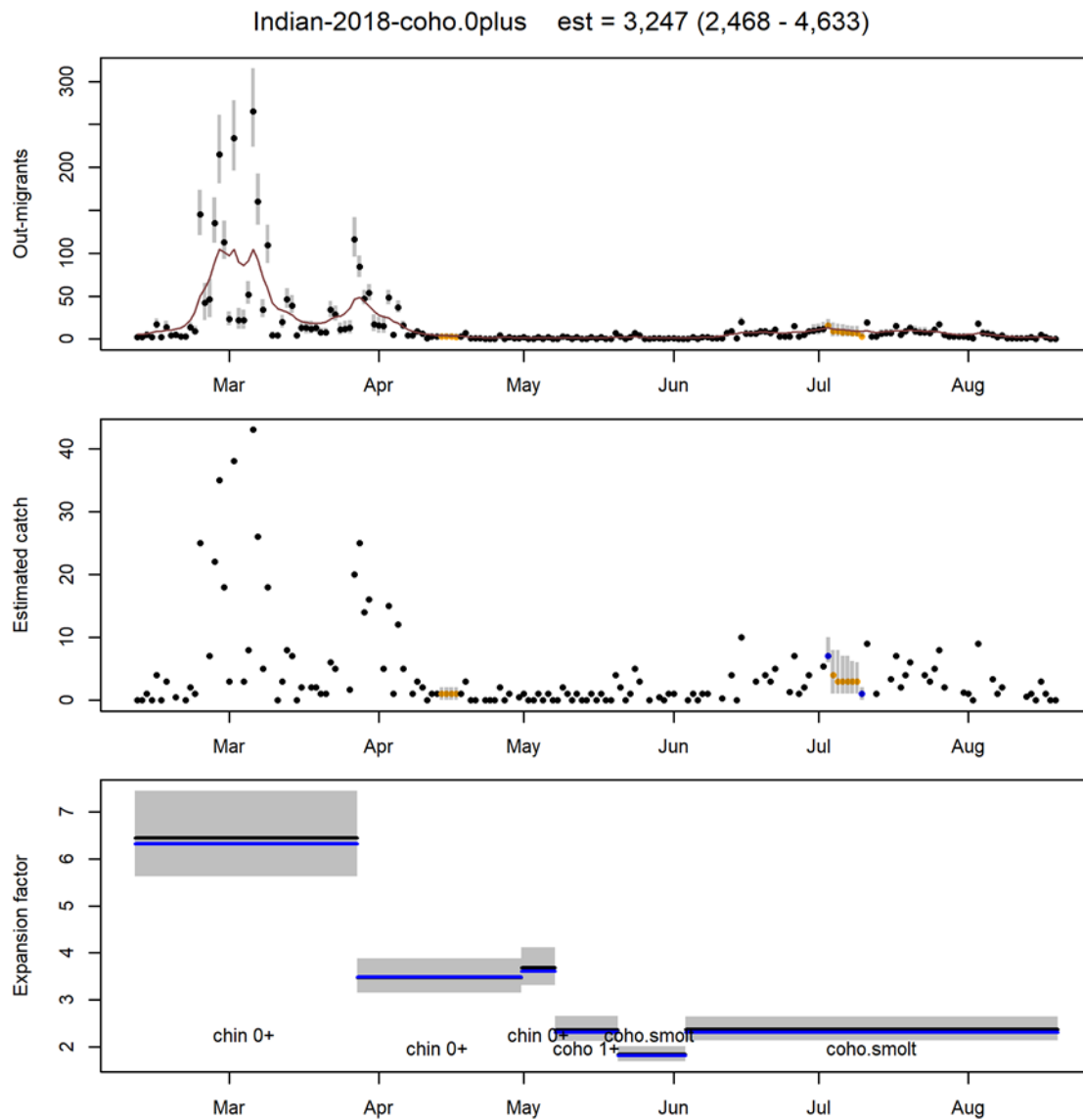
Estimated number and timing of coho smolts at the Indian Creek, Little River and Elwha mainstem trap sites by day during 2018.

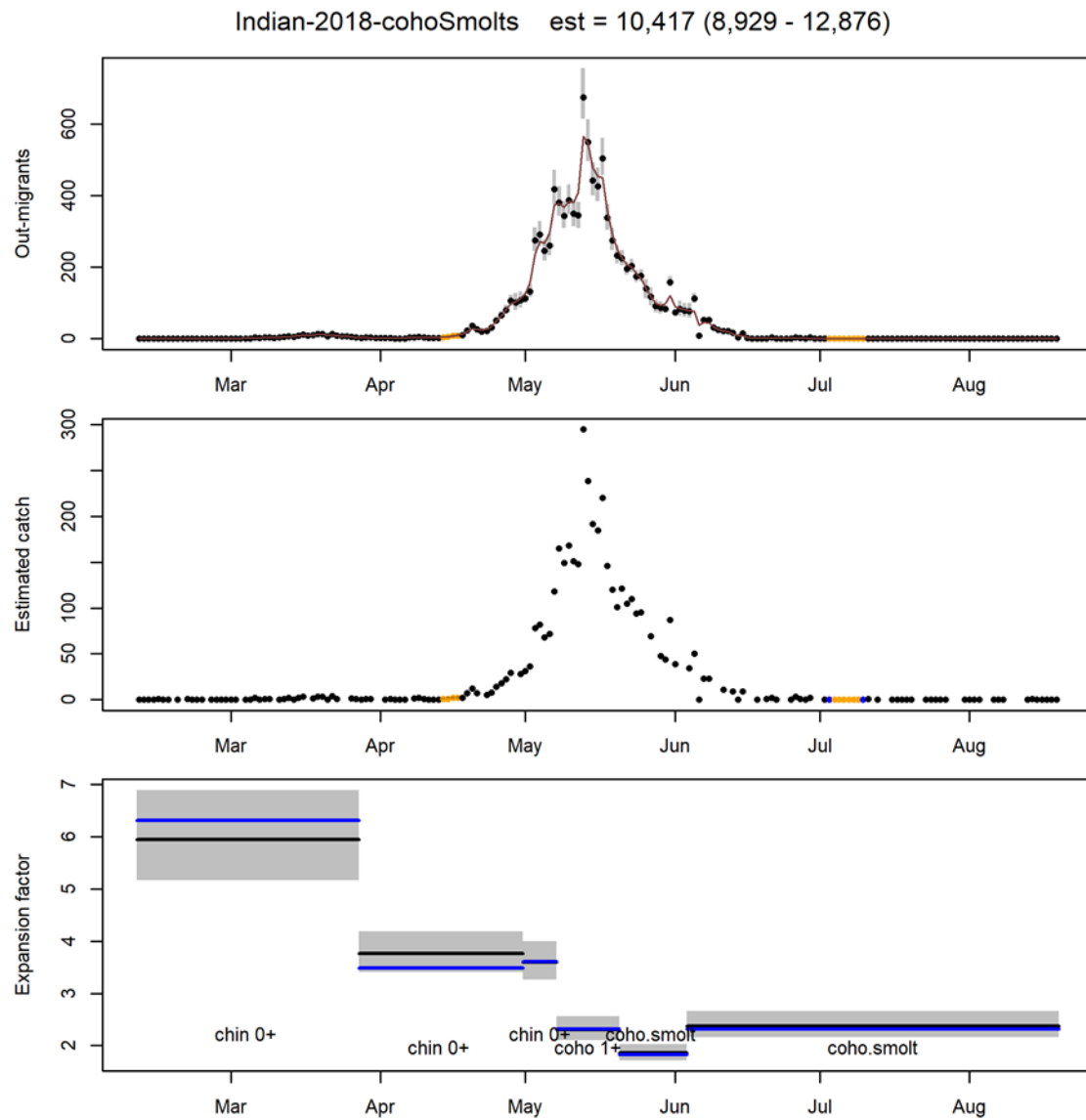


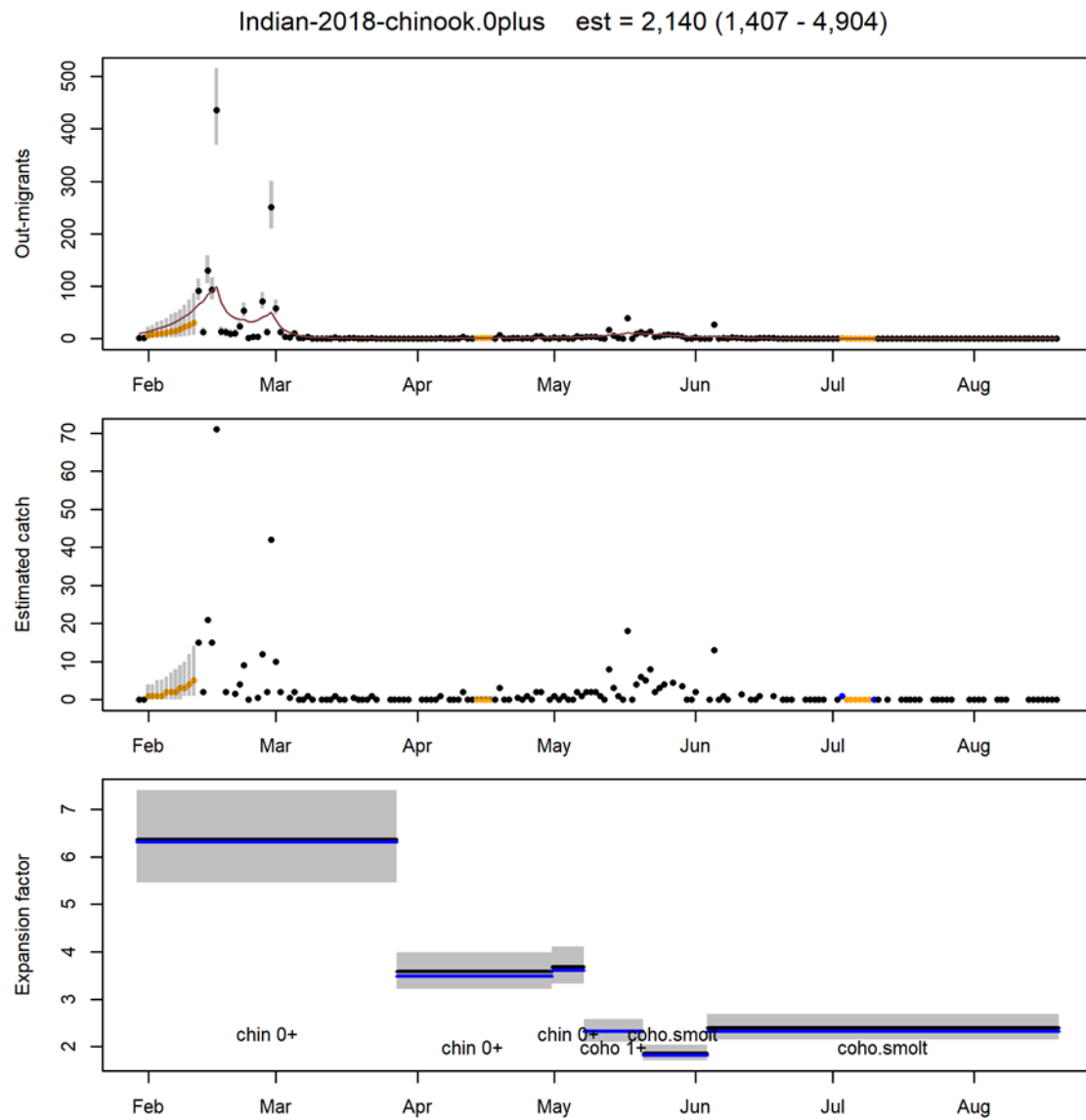
Estimated number and timing of steelhead smolts at the Indian Creek and Elwha mainstem trap sites by day during 2018.



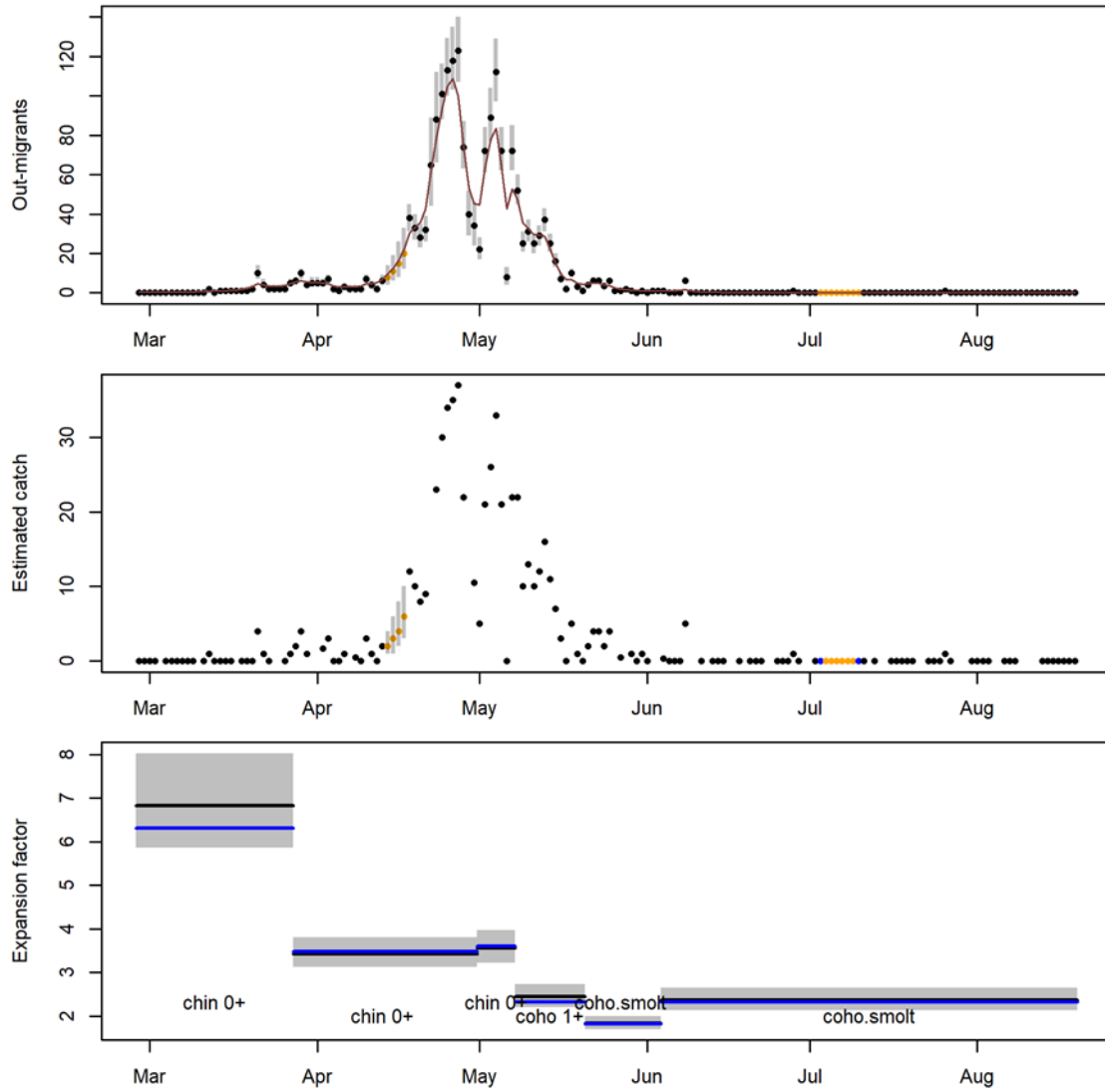
Appendix D. Plots of outmigrants, estimated catch and expansion factor by species and trap site for the 2018 smolt trapping season.

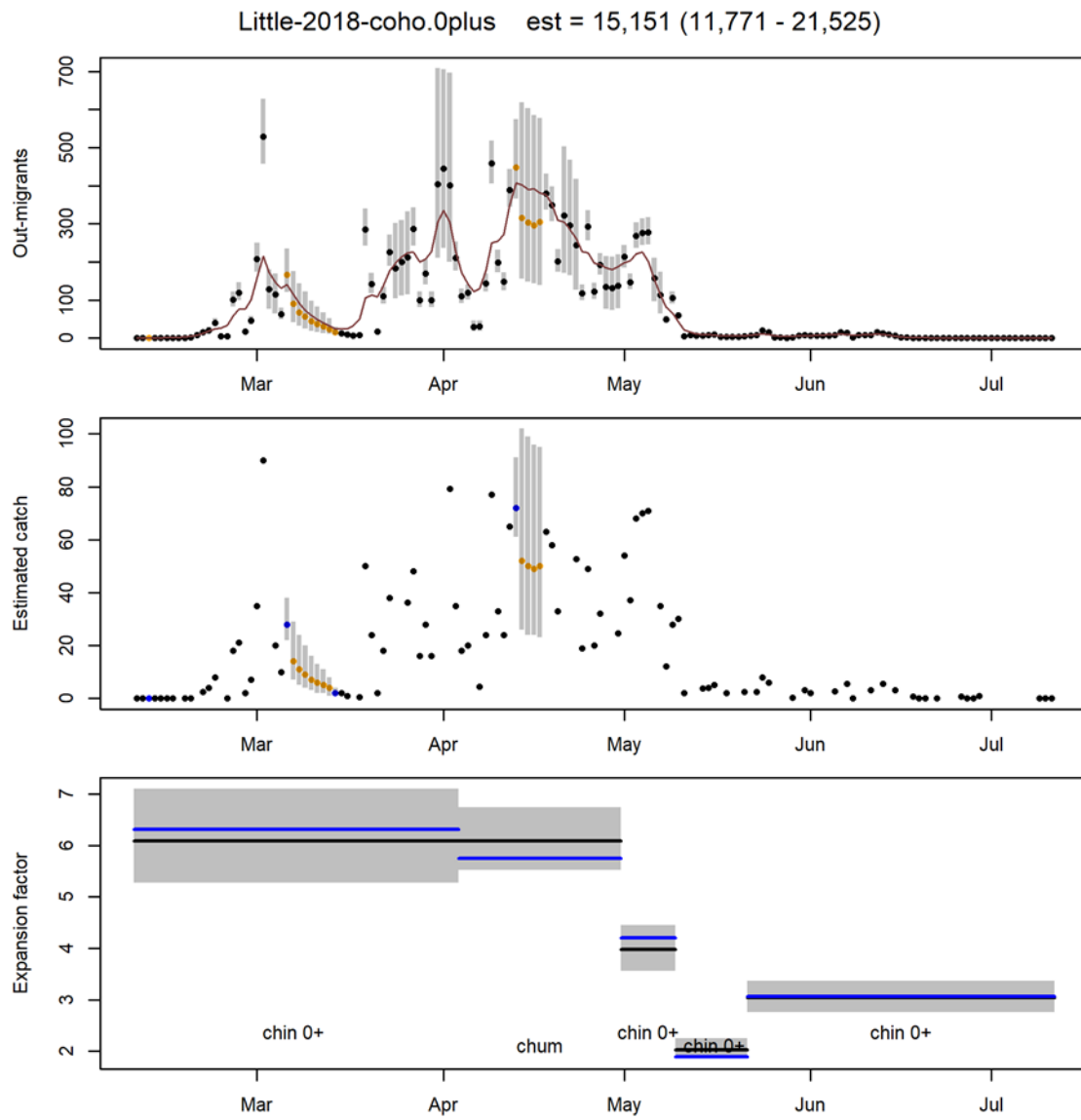




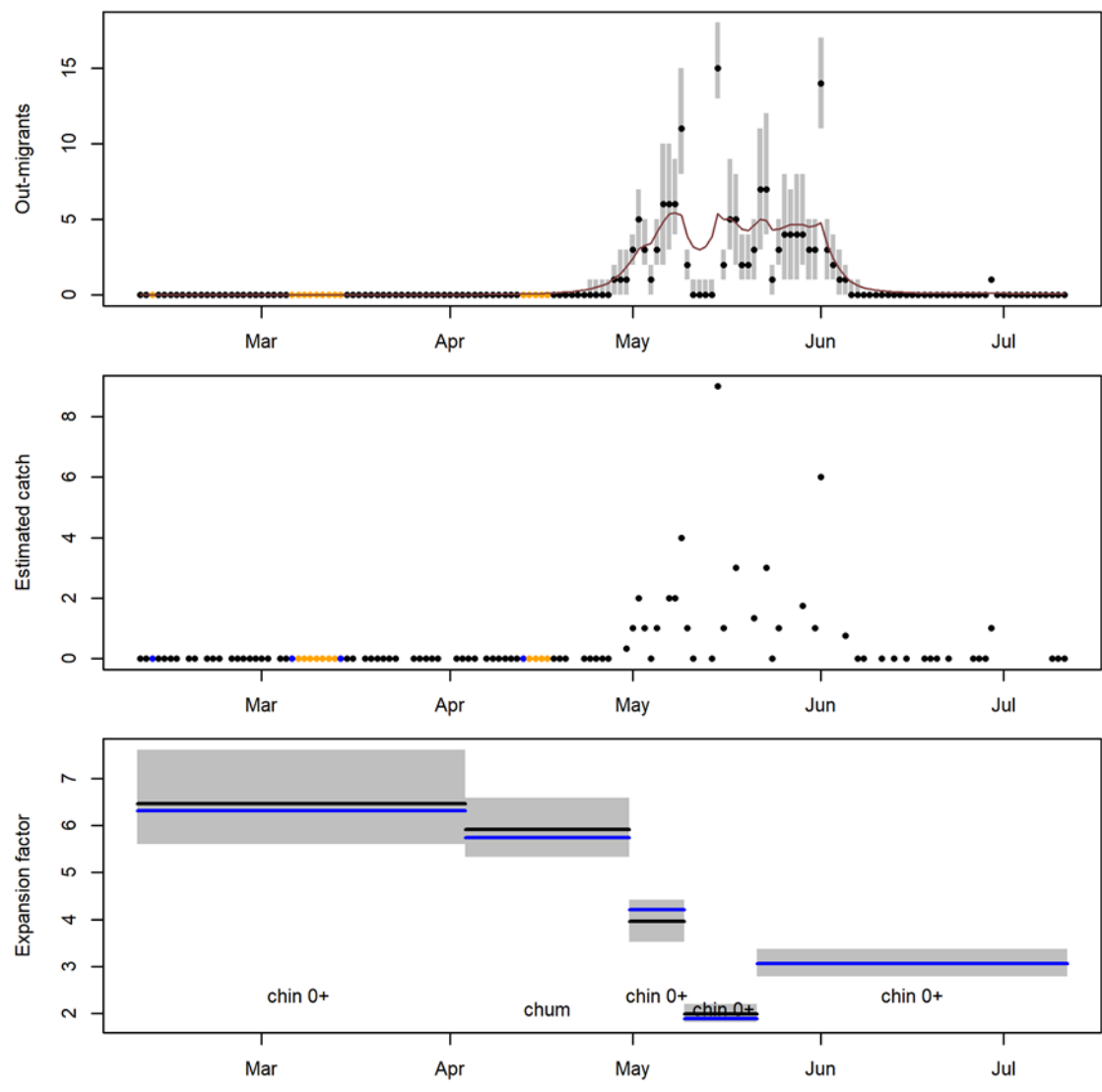


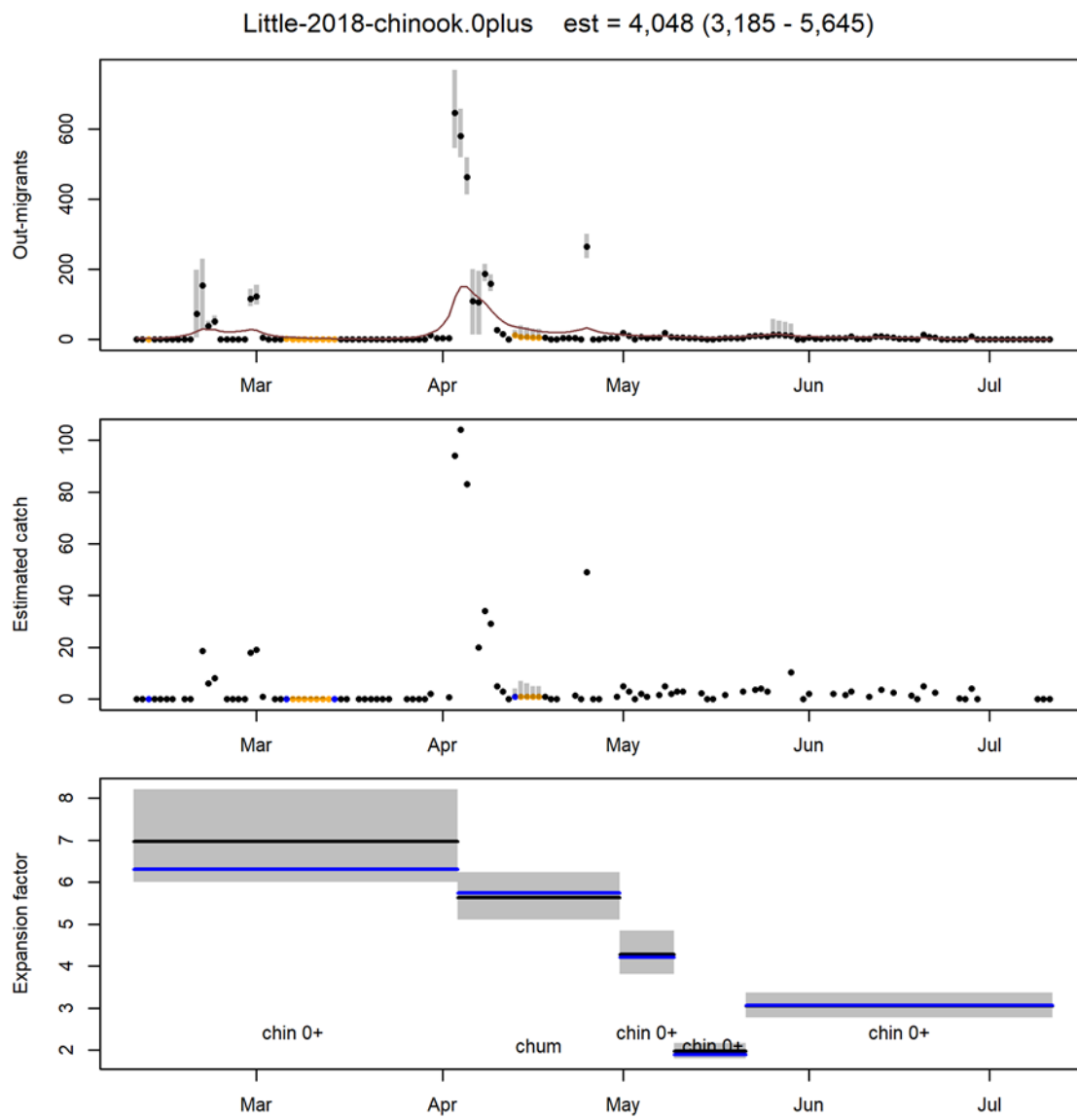
Indian-2018-Steelhead.smolts est = 1,898 (1,568 - 2,382)



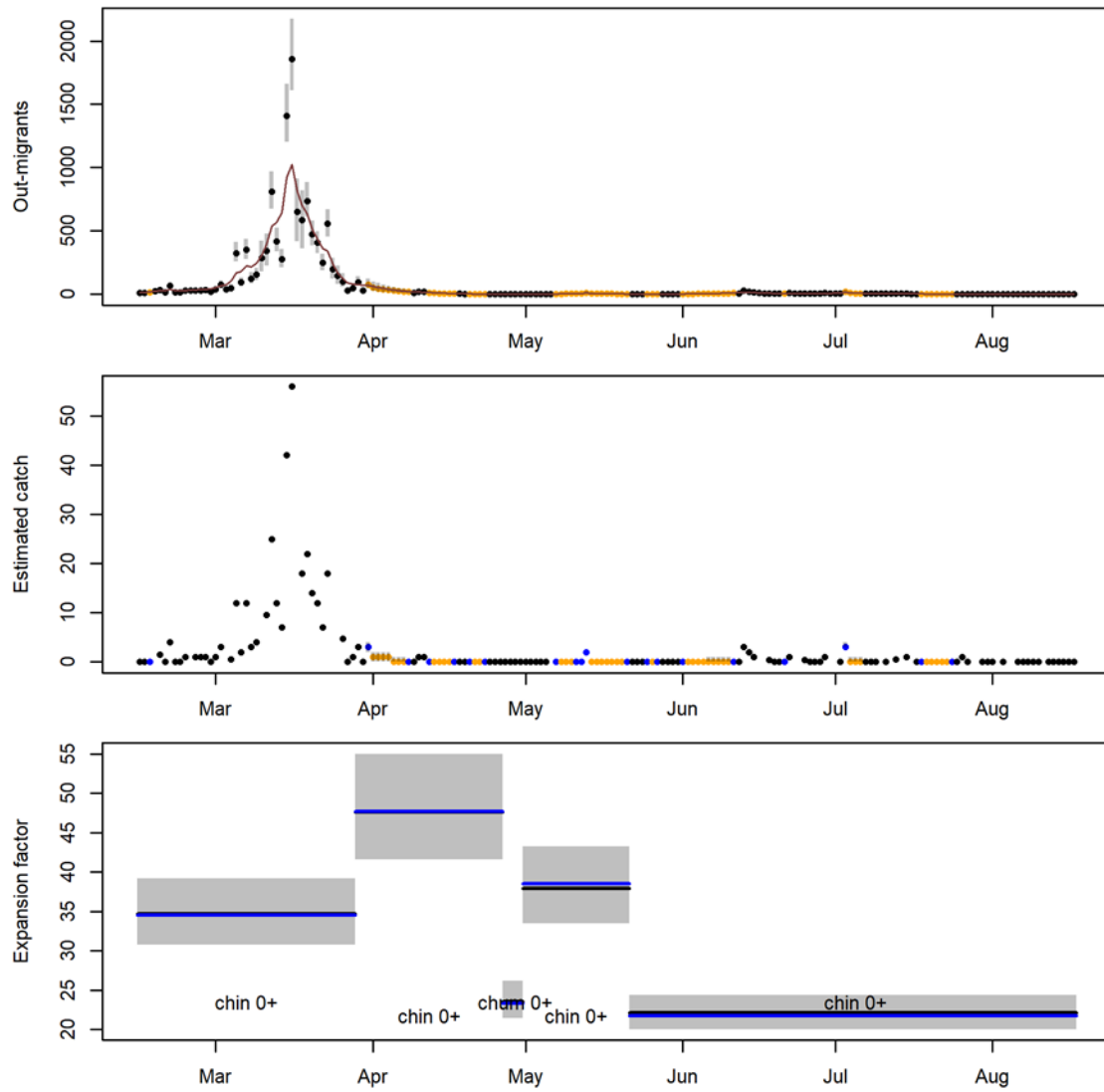


Little-2018-cohoSmolts est = 186 (143 - 243)

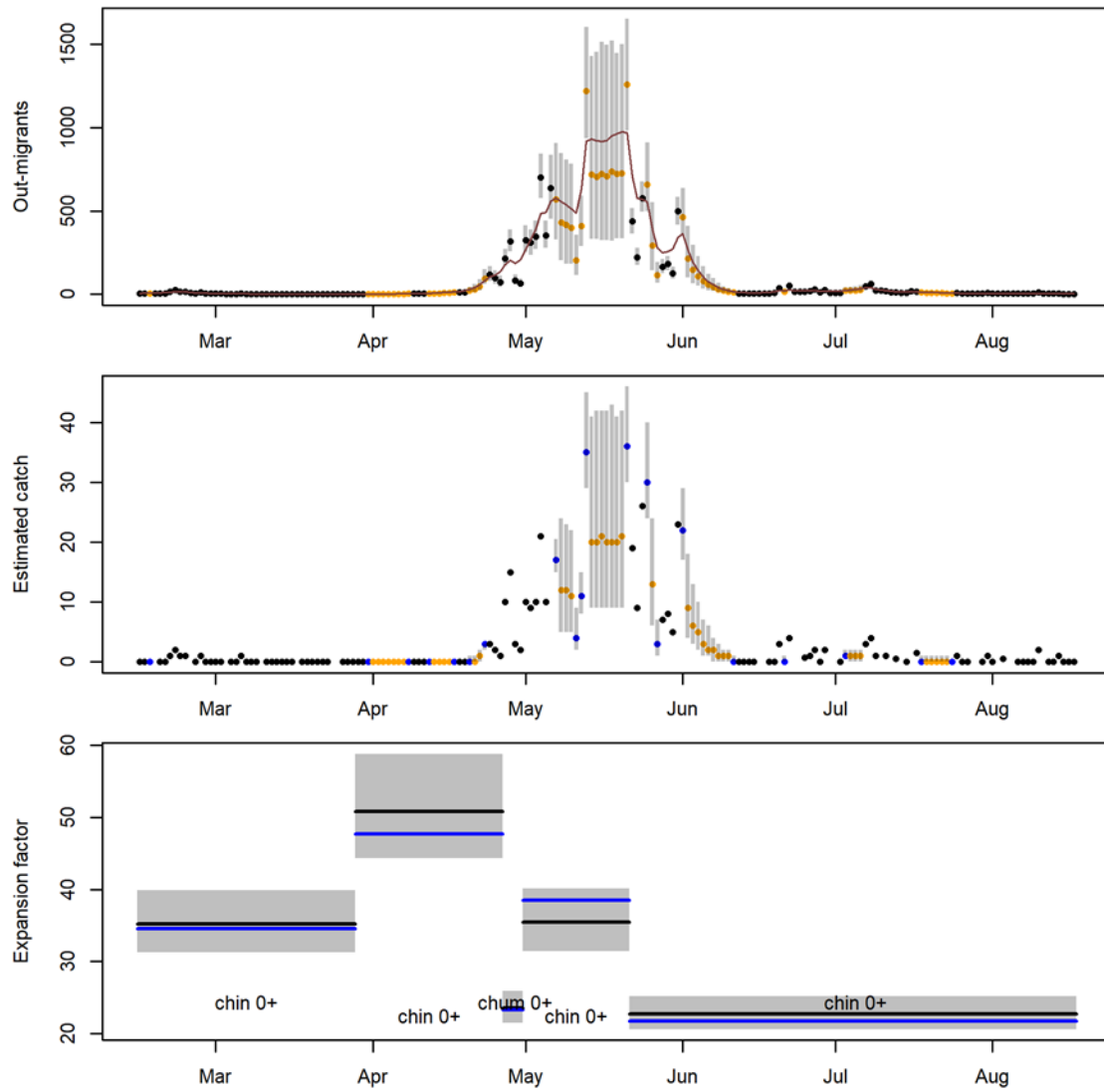




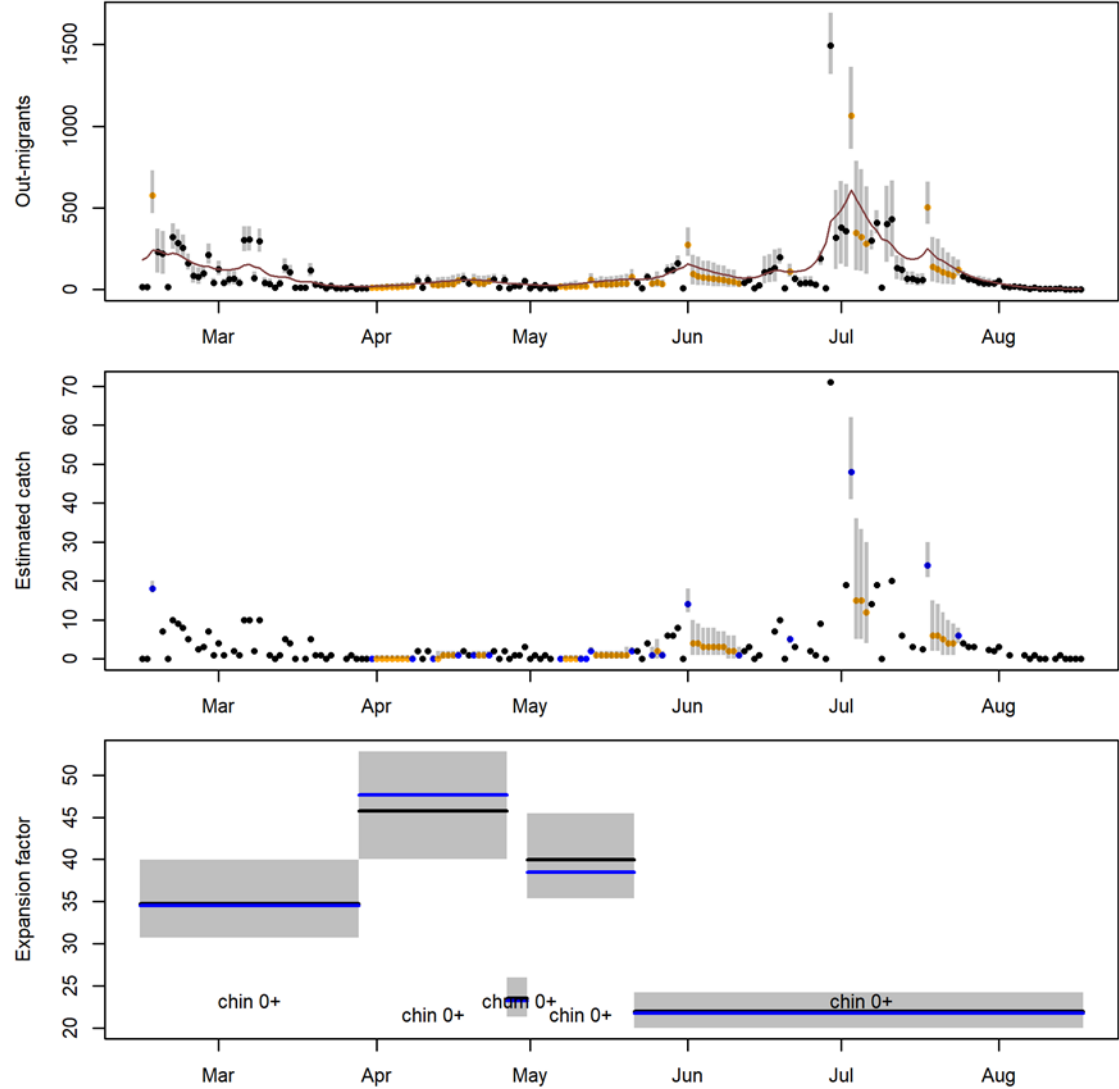
elwhaMainstem-2018-coho.0plus est = 13,216 (9,668 - 18,811)



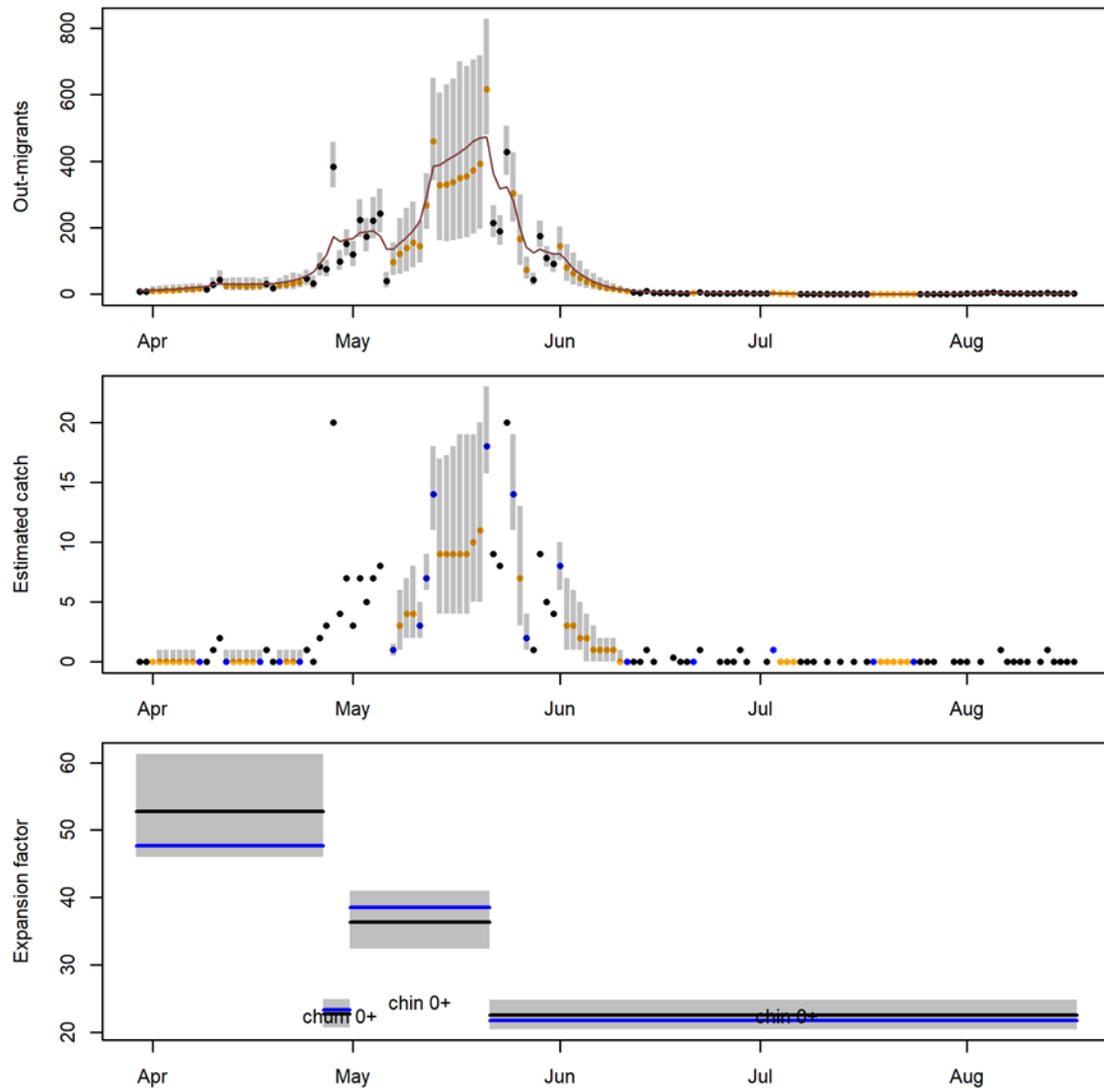
elwhaMainstem-2018-coho.1plus est = 24,022 (15,533 - 44,227)



elwhaMainstem-2018-chinook.0plus est = 21,490 (16,507 - 31,121)



elwhaMainstem-2018-Steelhead.smolts est = 11,412 (7,566 - 20,712)



elwhaMainstem-2018-chum est = 8,374 (5,696 - 13,595)

