

# 2015 Elwha River Smolt Enumeration Project Report

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Mike McHenry<sup>1</sup>, Mel Elofson<sup>1</sup>, Martin Liermann<sup>2</sup>, and George Pess<sup>2</sup>

1. Lower Elwha Klallam Tribe, 51 Hatchery Road, Port Angeles, WA

2. NOAA-NWFSC, 2725 Montlake Blvd East, Seattle, WA 98112

## Executive Summary

Smolt enumeration monitoring was conducted on the mainstem Elwha River and in two tributaries, Little River and Indian Creek during the 2015 outmigration season. At the mainstem site, flow and river sediment conditions were generally favorable for trapping operation for the first time since dam removal began in 2011 and the trap was operated over 90% of the potential season. However, we incurred very low capture rates and were only able to generate production estimates, 95% confidence intervals, and coefficient of variation (CV) estimates for Chinook salmon (age 0+), and Coho salmon (age 0+). Low catch rates precluded estimation for larger bodied smolts (age 1+) at the mainstem trapping site. We estimated a total outmigration of 15,860 (range 10,416-27,845) and 1,271 (range 1,271-4,251) Chinook 0+ and coho 0+ smolts, respectively, from the Elwha River in 2015. For the first time since the project began, we did not capture any chum or pink salmon smolt outmigrants at the mainstem site during the monitoring period. The 0+ Chinook salmon outmigration estimates for the Elwha River in 2015 fell within the range measured in the pre-dam removal period (2006-2011), but on the low end. The mainstem results strongly suggest that the survival of naturally produced salmon in the river was poor, likely as a result of the unstable habitat conditions in the river following dam removal. For the Indian Creek site, smolt trapping was nearly continuous and we successfully operated in over 90% of potential fishing days. For Indian Creek we were able to generate estimates for Coho salmon (ages 0+ and 1+), Chinook salmon (ages 0+ and 1+) and steelhead. In Little River trapping was negatively affected by extremely low streamflows associated with a record low snow pack. Flows dropped rapidly in the spring and trapping was discontinued in mid-May, seven weeks earlier than in 2014. Estimates were only made for early outmigrating species (Coho 0+ and Chinook 0+). Indian Creek had consistently higher numbers of outmigrants than Little River for all species. Indian Creek produced nearly 3 times more 0+ Chinook outmigrants than the mainstem and this result shows the importance of the middle river tributaries during dam removal. Indian Creek also produced an estimated 6,045 coho salmon (1+) smolts, a reduction of over 80% from 2014. These fish are progeny of both naturally colonizing fish and adult relocations from the lower river hatcheries first initiated in 2011. We also report on the first catches of sockeye salmon smolts in Indian Creek during 2015. We discuss planned 2016 trapping season improvements which include modifications to the Little River trap, reintroduction of the 8' screw trap to the mainstem site and increased use of large sized smolts for trap efficiency tests.

## 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 and represents the largest dam removals attempted to date. Dam removal on the Elwha has generated national interest 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 is of particular interest, and for the Elwha Project, general monitoring goals have been developed that include: 1) Reestablishing self-sustaining anadromous salmon populations and habitats as quickly as possible, 2) the preservation of native anadromous salmon before, during and after dam removal, and 3) restoring the physical and biological processes of the ecosystem (Ward et al. 2008).

To guide this 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). This plan provides adaptive management targets that affect management actions for the recovery of the populations. 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 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 typed to recovery of depleted and listed Elwha salmon populations.

In addition, 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 steps the NPS intends to undertake to document dam removal impacts to listed salmon species and meet the requirements of the BiOp. Smolt outmigration monitoring is a required component of the Biological Opinion.

Fundamental questions regarding the health and trajectory Elwha River salmon populations can in part be addressed through smolt enumeration. These include not only abundance and productivity trends, but life history parameters. The Lower Elwha Klallam Tribe (LEKT) established a smolt enumeration program on the Elwha River beginning in 2006. Between 2006 and 2011 the tribe successfully estimated the number of outmigrating Chinook salmon, chum salmon (*O. keta*) and pink salmon (*O. gorbuscha*) smolts using an 8' rotary screw trap fished at

river kilometer (Rkm 0.3). Funding of trap operations during this period was provided by the Pacific Coast Salmon Recovery Fund (NOAA). 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 been more problematic because of their avoidance behavior relative to the traps. With the onset of dam removal in 2011, trapping conditions have deteriorated as the Elwha River has been transporting large volumes of sediment and wood debris (Warrick et al. 2015) that interfere with trapping operations. In 2012, we were able to generate Elwha mainstem outmigration estimates with some difficulty using a smaller 5' rotary screw trap. However, in 2013 we were forced to abandon mainstem trapping efforts as the trap was simply overwhelmed with sediment and debris associated with dam deconstruction efforts and no estimates of production were possible. In 2014, mainstem trapping efforts were reinitiated, however operations were impacted by river conditions and over half the potential fishing days were lost. During the dam removal period, LEKT has focused the majority of its efforts on estimating smolt production from Indian Creek and Little River, two large tributaries located above the former Elwha Dam site. These tributaries have been the site of both natural and human assisted (adult relocations) recolonization events. LEKT has been able to estimate production for the aforementioned species from the tributaries during the dam removal period. The 2015 trapping season represents the first year of main stem Elwha monitoring following dam removal. This 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 describe and to discuss the: 1) field protocols for smolt outmigration data acquisition in the mainstem and tributary sites in 2015; 2) procedure for deriving a smolt production estimates from raw catch counts in 2015; 3) sources of uncertainty in the 2015 estimates; and lastly to 4) document issues that resulted in a coefficient of variation that was greater than 15% for the 2015 smolt outmigration estimates.

## **Methods**

### **Mainstem Site/Trap Selection**

In 2015, we utilized similar site selection criteria previously established by LEKT for the tributary sites, with a major site modification based on physical changes in the mainstem following dam removal. For the mainstem site, we reoccupied the lower river fishing site at the end of Lower Elwha Road (Rkm 0.3). 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 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 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 3) that LEKT could physically operate during the 2012-14 seasons. During 2015 we again used the 5' screw trap. The smaller trap has a lower efficiency than the larger trap as it fishes a smaller cross-sectional area of the rivers flow. However, the larger screw has a much larger pontoon structure and requires a minimum of 1.5 m of depth to operate. In 2015 the river was not deep enough to fish the larger trap and we were forced to use the smaller trap. It is anticipated that within several years after dam removal is completed, the river will slowly begin to come into balance with its sediment supply and pools will again form. Once that occurs, LEKT will reinitiate mainstem trapping efforts using the 8' screw trap<sup>1</sup>.

### **Tributary Site/Trap Selection-2015**

LEKT established tributary smolt monitoring sites on Little River in 2012 and Indian Creek in 2013. Because of the difficulty accessing those drainages, we choose county road bridge crossings as low as possible in each tributary for trap deployment. The bridges make for convenient launch sites 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 0.5 (Figure 4). For Indian Creek, we used the bridge crossing on Aldwell Reservoir Road located at Rkm 0.6 (Figure 5). 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. The Indian Creek site is narrower and shallower and to fish this site effectively LEKT contracted the construction of a 4' screw on a narrower pontoon. Both traps have fished with excellent results to date and it is not anticipated that additional changes will be made at the tributary sites.

### **Season of Operation-2015**

During the pre-project period, 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 millions of Chinook salmon smolts from the WDFW hatchery in the later season. LEKT is aware that these dates are not ideal in terms of capturing the early portion of Chinook outmigration

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<sup>1</sup> During the 2016 trapping season LEKT was able to deploy the 8' screw trap.

(Weinheimer & Zimmerman 2012) and has committed to initiating mainstem trapping efforts in late January to early February 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 later June. 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 months (Kinsel et al. 2008; Kiyohara and Zimmerman 2012). As Chinook salmon colonize areas above the dam it is anticipated that a bimodal outmigration pattern will redevelop similar to other Puget Sound rivers. In 2015 LEKT commenced trapping operations in the mainstem on February 24<sup>th</sup> and ceased trapping efforts on July 9. The early deployment target was not met because of flow conditions including an approximately 15,000 cfs flood in early February (Figure 6). For Indian Creek, trapping commenced on January 20th and ceased operations on July 8th. At Little River trapping was initiated on January 23<sup>rd</sup> and was concluded on May 19, when the screw ceased turning due to low flows from the record low snowpack (<5% of normal) in the Olympic Mountains during the winter of 2014-15. It should be noted that flow conditions in Little River likely greatly affected trapping operations well prior to the cessation of operations. For several weeks prior to that date, flows were insufficient to consistently turn the screw. Field notes indicated that the screw began turning intermittently as early mid-April. During this period larger fish (coho 1+, steelhead, trout) were observed swimming in and out of the trap box. This greatly affected catch rates and ultimately our ability to generate accurate estimates of larger bodied smolts such as steelhead, 1+ coho and 1+ Chinook.

### **Daily Operations-2015**

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). Since dam removal was initiated in 2011, sediment and debris entrained in the river have greatly reduced the time that the trap has been able to fish. Trapping operations were, in fact, abandoned in 2013 because of these issues. Conditions have also influenced the size of trap and location fished. The smaller 5' allowed LEKT to fish during the 2014 and 2015, however it has lower efficiency, is susceptible to impact and cannot be fished safely above flows greater than ~1,500 cfs.

In 2014, LEKT made several modifications to the mainstem trapping operations including: 1) reducing the screw size from 8' to 5', 2) modifications to the trap box, 3) keeping a crew at the trap during daily operations for continuous cleaning and fish enumeration, and 4) sampling as much as possible during a given 24 hour period to accommodate the extra effort associated with maintaining personal on the trap during fishing, and safety concerns. We further modified

the trap box by cutting a large hole in the bottom and welding 3/16" mesh screen to the opening to allow fine sediment to flush during cleaning. In 2014, we also added a two person crew on the mainstem trap dedicated only to Elwha fishing operations. This allowed the trap to be continuously cleaned and catch enumerated while fishing. These modifications were maintained during the 2015 season and low flows allowed almost continuous fishing operations. The mainstem trap was launched on February 24 and retrieved on July 9, 2015. In total we were able to fish the mainstem trap for 155 of the 166 (94%) total fishing days in the 2015 fishing season. This was a significant improvement over 2014 when frequent spring freshets resulted in the loss of half the potential fishing days (McHenry et al. 2015). During 2015 fishing was not impacted as in past years, by fine sediment and fine woody debris (Figure 5) was much reduced over the 2014 season.

For the tributary sites, the traps were also nearly fished continuously except during brief flood events in February. Indian Creek was launched on January 20<sup>th</sup> and retrieved on July 8<sup>th</sup> and fished for a total of 157 out of 169 (93%) fishing days, slightly less than in 2014 (94%). Little River was launched on January 23<sup>rd</sup> and retrieved on May 17<sup>th</sup>. The Little River trap fished a total of 117 days (100%) possible fishing days, however trapping operations were impacted at Little River by a record low snowpack and the trapped ceased fishing in mid-May when the screw stopped turning.

## **Field Methods**

For all sites, the traps were inspected and cleaned 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 and identified to species, counted and immediately released downstream of the trap. A weekly subsample of all species caught was measured and weighed. Fish greater than 55 mm were also scanned for presence of PIT (Passive Integrated Transponder) tags. PIT tags are being used in the middle Elwha to assess growth and survival of salmon (Personal Communication, George Pess, NOAA Northwest Fishery Science Center).

In order to evaluate catch efficiency (proportion of total outmigrants captured), we attempted to conduct continuous mark recapture tests at all three sites. Several trap efficiency trials had to be cancelled as a result of interruptions in fishing because of floods and damage to traps. On the two 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. For the mainstem trap site, because of the relatively low numbers of total fish captured, we used releases of 1000-1500 0+ Chinook salmon obtained from the Washington Department of Fish and Wildlife (WDFW) hatchery for all trap calibration tests. We were unable to obtain larger sized smolts from the LEKT hatchery. At all sites we used Bismark

brown dye to give the fish a distinctive mark, 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 generally is visible for 7 to 10 days following marking (Figure 7). The subsample of marked smolts was released 100 m above each tributary trap site and approximately 1000 m above the mainstem site. The percentage of smolts recaptured was highly variable depending upon flow and site conditions. In general, the tributary sites had relatively high recapture rates (2.0-28.6%) while the mainstem site had relatively low recapture rates (0.7-2.9%). The mainstem recapture rates were almost identical to those measured in 2014. Trap calibration tests for 2015 are summarized in Table 1.

## **Data Analysis**

The sum of daily catch data along with efficiency trials was 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. See appendix A for more details. 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).

## **Results**

Smolt trapping on the Elwha River was successfully completed, albeit with a number of difficulties particularly at the Little River site, where fishing was abandoned on May 19<sup>th</sup> due to unprecedented low flows associated with the record low snow pack in the winter of 2014-15. For the first time since dam removal was initiated, the 2015 trapping season was mostly not interrupted by flows, sediment or debris at the mainstem site. Based upon our experience operating the 5' screw trap in the Elwha, operations became unsafe in flows exceeding ~1,500 cfs (~56 cms). Additionally, the river has been severely impacted by changes associated with the dam removal project, namely an increase in the transport of wood. The combination of high flows and increased wood supply led to an increase in the rate of collisions between the trap and large pieces of wood floating downriver. This led to prolonged periods of lost fishing time in past years. In 2015, we were able to fish the mainstem trap for a total of 155 of 166 days (93%).

Despite the best mainstem fishing conditions encountered since dam removal began, estimation was impacted by very low catch rates of all species. This did not appear to be due to trapping operations as catch efficiency tests were within the range measured over the past several years using the 5' screw trap. As a result we were only able to generate estimates of smolt outmigration for Chinook salmon (0+) and Coho salmon (0+) at the mainstem site (Table 2). Due to availability of chinook 0+ fish, the last efficiency trial at the mainstem site was April 16th, after which a significant proportion of the coho 0+ and chin 0+ out migration occurred. We applied that last efficiency trial results to this period which introduces unquantifiable error into the estimate. The estimates should therefore be interpreted with caution. For the first time since smolt monitoring began on the Elwha River no pink or chum salmon were encountered at the mainstem trap. We were also unable to generate estimates for Coho salmon (1+), Chinook salmon (1+) and steelhead due to the very low catches of those species and/or the lack of efficiency data for larger sized fish. Low capture rates of large bodied smolts such as coho (1+) and steelhead have been problematic since smolt trapping was initiated on the Elwha in 2006. Larger bodied smolts appear to be more able to avoid capture in the trap and this phenomenon has been observed at other trapping sites in western Washington (Personal Communication, Joe Anderson, WDFW). Chinook salmon (0+) and Coho salmon (0+) were the most common species captured in the mainstem trap, however their numbers were very low (281 and 38 total catch, respectively). Total outmigration estimates of 15,860 Chinook salmon (0+) and 2,144 Coho salmon (0+) salmon were generated for the Elwha River in 2015. It should be noted that these estimates are only for natural origin fish and as explained above should be reviewed cautiously. Catches of hatchery reared fish are noted in the field data sheets but are not included in these estimates. Elwha hatchery produced fish can generally be recognized by the presence of unique marks such as adipose clips or the presence of coded wire tags (Coho salmon), or by size, physical appearance and the timing of release (Chinook salmon (0+), steelhead).

The 2015, tributary trapping season was a tale of two sites. Indian Creek was generally seamless with only brief breaks in fishing operations due to periods of elevated streamflow. Indian Creek fished 93% of the total potential fishing days and fishing was nearly continuous. We generated estimates for 0+ Chinook salmon (42,180), 1+ chinook (165), 0+ coho salmon (3,697), 1+ coho salmon (6,045), and steelhead at Indian Creek (Table 3). In contrast, trapping at Little River was concluded prematurely due to extremely low flows that were insufficient to turn the screw. Trapping operations were ceased on May 19<sup>th</sup> approximately 7 weeks earlier than in previous years. As a result, we did not attempt to generate estimates for larger and later timed species including 1+ coho, 1+ Chinook salmon and steelhead. Species specific estimates were generated for 0+ Chinook salmon (121) and 0+ coho salmon (5,722) (Table 4). No Chum salmon or pink salmon were captured at either tributary in 2015 and therefore no

estimates were made for those species. Only eight Chinook salmon (1+) were captured at Little River in 2015 and therefore no estimates were generated for that species.

We compared total outmigration estimates between tributaries and found some striking differences in abundance and life histories (Figure 8). 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). For 1+ coho salmon smolts, Indian Creek produced an estimated 6,045 fish, a reduction of 81% from 2014. In contrast, we only captured 11 1+ coho in Little River in 2015. We attribute the low number to low flow conditions which allowed larger fish to avoid or swim out of the trap. Additionally the trap stopped fishing because of low stream discharge in mid-May during the peak outmigration period for 1+ coho smolts.

The numbers of outmigrating Chinook 0+ were greater from Indian Creek relative to Little River. These numbers likely reflect the numbers of adult Chinook salmon that spawned in each system in 2014 (58 redds in Indian Creek and 1 in Little River). The estimate of chinook out-migrants from Indian Creek is also conservative as a significant proportion of the redds observed in 2014 were located downstream of the trap site. The number of 0+ Chinook produced from Indian Creek was also approximately 3 X what was estimated at the mainstem site.

For steelhead, Indian Creek produced an estimated 153 (377-715) outmigrating smolts in 2015, numbers similar to what was observed in 2014. We were unable to estimate steelhead production in Little River in 2015 due to low catch rates (23 captures) and low flow problem previously discussed. Steelhead adults were first observed in both tributaries during the spring of 2012. 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 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 (Unpublished Data, Gary Winans, NOAA) from 2013-2015.

We assembled the miscellaneous species catch records for all three trap sites that included three year classes of trout (*O. mykiss*), sockeye salmon (*O. nerka*), bull trout, brook trout, cutthroat 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. In Indian Creek, we report the first capture of sockeye salmon smolts where a total of 7 were captured in 2015 (Figure 9). For rainbow trout it is interesting to note that higher numbers of

0+, 1+ and 2+ age classes were captured at Indian Creek than in Little River. This was opposite of what was reported in 2014 (McHenry et al. 2015). This pattern also reversed for bull trout where we caught 8 bull trout in Indian Creek and none in Little River. Additionally, we only encountered cutthroat smolts in Indian Creek. Anadromous forms of cutthroat trout were thought to be rare on the Elwha, at least prior to dam removal. Indian Creek/Lake Sutherland supports the largest and most diverse source of cutthroat trout in the Elwha watershed, including an adfluvial population that spawns in upper Indian Creek in the fall (MacMillan et al. 2015). The presence of cutthroat trout smolts may suggest a “reawakening” of this life history form in the Elwha over time. Such recolonization appears to be occurring for Pacific Lamprey (*Entosphenus tridentatus*) in Indian Creek, where adult captures were first documented in 2013 and again in 2014 at the smolt trap. Small numbers (7) Pacific Lamprey were captured in 2015. We believe that the observations of juvenile Brook lamprey (*Lampetra richardsoni*) previously reported (McHenry et al. 2015) at the Indian Creek Trap were incorrectly identified. We now believe these were actually Pacific lamprey ammocetes. Ammocetes were first encountered at Indian Creek in 2013, one year following the initial recolonization event by adults in 2012. In 2014 we captured 132 ammocetes and in 2015 the number increased to 407. We expect that downstream migrating microthemia from Pacific Lamprey will eventually be encountered at Indian Creek; however this is not anticipated for several more years because of their prolonged freshwater residency estimated at 5-6 years (Scott and Crossman 1973)<sup>2</sup>.

At the mainstem trap, catches of marine species are of ecological significance. In 2015, we report the continued presence of eulachon (*Thaleichthys pacificus*) encounters in the trap with a total catch of 24. A large number of eulachon were observed in the lower Elwha River during January and large numbers of bald eagles (>100) were observed fishing for them. In addition we captured 25 herring (*Clupea harengus*) and 16 American Shad (*Alosa sapidissima*). American shad are not native to the west coast of North America but are well established in the Columbia River. The captured shad were all sub-adults that are rearing in Puget Sound.

## Discussion

Removal of two mainstem hydroelectric dams on the Elwha River was completed between 2011-2014. This is the largest intentional dam removal attempted to date and is of great scientific interest in terms of the recovery of the Elwha ecosystem and its historically large salmon populations. Long term monitoring of the response of salmon to dam removal is ongoing on the Elwha and smolt enumeration programs are a critical component of that effort. Smolt trapping on the Elwha was initiated in 2006 and the period from 2006-2011 represents

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<sup>2</sup> Microthemia have been captured at the Indian Creek trap during the 2016 season.

pre-project conditions when anadromy was limited to 7.9 kilometers of degraded habitat and hatchery production dominated salmon returns. Smolt outmigration estimation from 2012-2014 represents the production of salmonids during dam removal period. This period is characterized by the highest rates of sediment transport as the river now can access and transport over a hundred years of accumulated sediment in the former reservoir bottoms. Mainstem smolt trapping efforts during the dam removal period have been challenging and in 2012 and 2013 we were forced to abandon trapping because of the very high level of sediment and debris interfering with trap operations. 2014 was also problematic but primarily due to elevated spring flows and large woody debris. The fact that we were able to generate any mainstem estimates at all is encouraging. We believe that the worst of the impacts from dam removal on smolt trapping operations have already occurred. The 2015 season represents the first year of post dam removal data and provides a benchmark to assess the state of recovery early in the recovery process.

Low catches impacted our ability to estimate mainstem smolt numbers for many species/life histories and were only made for 0+ Coho and 0+ Chinook salmon in 2015 on the Elwha River. Estimates for other species were not possible due to the combination of low catch rates and the lack of calibration data for larger sized smolts. The outmigration estimates for Elwha Chinook salmon smolts was 15,860 (range 10,416-27,845). 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. In 2014, adult Chinook salmon escapement to the Elwha River was the highest in over two decades and a total of 1310 individual redds were counted in the mainstem (McHenry et al. 2015). Because of the consistently elevated sediment supply from dam removal, it was hypothesized that egg to emergence survival of Chinook salmon that spawned in 2014 would be low. Our catch estimation data would seem to support that hypothesis. It should be noted that the winter of 2014-15 was characterized by several large discharge events including three flows with peak flows greater than 10,000 cfs. Such flows may have produced scour events that exceeded the depth of incubation for Chinook salmon eggs and resulted in high mortality. Such negative correlation between peak flows and Chinook survival has been reported in Skagit River (Greene et al. 2005). It should be noted that adult Chinook salmon did not access areas above Glines Canyon dam during 2014, as the dam was not removed until after spawning had peaked. As a result the distribution of spawners was mostly confined to the mainstem where incubation conditions were hypothesized to be unstable.

The estimate of Chinook 0+ outmigrants *from Indian Creek* was almost three times that of the estimated total for the Elwha River mainstem trap. There are a number of possible explanations. First, the bulk of the Indian River Chinook 0+ had passed the Indian Creek trap before the Elwha mainstem trap was installed on February 24<sup>th</sup>. If these fish migrated directly to the ocean they would have therefore been missed. Second, there is 8 miles of mainstem habitat

between the Indian River trap and the mainstem trap. Given that these are 0+ fish substantial mortality could have occurred between the two traps (especially if they didn't migrate out immediately). Finally, the mainstem trap efficiency was very low and based on fish from the hatchery. The efficiency estimates may be over-optimistic resulting in an underestimate of total Chinook 0+ production.

In 2014, a significant number of adult Chinook ascended Indian Creek, and 58 redds were counted during fall surveys (McHenry et al. 2015). We conservatively estimated 44,368 0+ chinook outmigrants in 2015 from this event. This is approximately 3 times what was estimated for the mainstem and clearly demonstrates the importance of the middle River tributaries as refuge habitat during the dam removal period. While Little River did not produce any significant numbers of 0+ Chinook in 2015, it has in other years (2013 and 2014). The position of the Elwha River in 2014 was on the west side of the river valley and Little River flowed over a broad, shallow gravel bar. As a result very few chinook entered the Little River in 2014.

We compared the outmigration timing of Chinook and Coho salmon outmigrants from both tributary sites (Figure 8). In general and consistent with 2014, outmigration timing was earlier for Chinook salmon 0+ and both age classes of Coho salmon from Indian Creek as compared to Little River. For Chinook salmon 0+ the bulk of outmigration was completed by second week of March, while in Little River it was completed by the first week of April. For Coho salmon yearlings outmigration timing was about a month earlier between systems. These differences appear to be temperature driven. Little River has a northern aspect and drains off Hurricane Ridge and has much greater elevation landforms than Indian Creek. Little River has a snowmelt hydrology while Indian Creek is primarily rainfall driven and moderated by a large lake in its headwaters. As a result, Little River is significantly cooler than Indian Creek. Maximum temperatures in Little River are on the order of 7-10° C, while in Indian Creek maximum temperatures average 10-15° C. Little River also is severely degraded in terms of in stream habitat features. A recent assessment of the watershed shows that the system has lost most of its in-channel large wood and has incised by 0.5-3.5 meters (NSD 2016). As a result, pool habitat and quality are limited. Without adequate pool structure, juvenile coho salmon have fewer areas to rear and may be seeking other habitats downstream.

Indian Creek has consistently produced larger numbers of coho salmon outmigrants relative to Little River over the period of monitoring. Since 2012, surplus coho adults from the LEKT hatchery have been relocated to the two middle Elwha tributaries. 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 spawners to date originated from these relocation efforts. While the number of adults relocated into the two tributaries is similar (Table 6), the differences in production are not. 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 rearing.

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, 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 are thought to have extirpated by dam construction, the plan states that the primary mechanism for recovery of sockeye 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 Indian Creek since Elwha Dam was removed, the numbers have been very low and spawning has not been documented. This would 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 Coquiltam 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 also likely have an anadromous origin. We intend to collect tissue samples from sockeye in future years in order to elucidate the origin of this population.

Neither tributary has been colonized by significant numbers of returning adult chum or pink salmon. The lack of chum and pink salmon to both tributaries 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 the 2014 would seem to support those observations<sup>3</sup>. Similarly, passage through Glines Canyon has not yet been assured. 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 will need to be closely monitored. Recovery of upriver populations and life histories is contingent upon successful fish passage at this site.

### **Sources of Error**

While we have strived to keep the aforementioned sources of uncertainty low in order to stay within a coefficient of variation of 15% or less, 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 has been 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, the biggest source of uncertainty confronting smolt trapping programs on the mainstem Elwha in 2015 was not physical conditions but the low numbers of total fish captured in combination with the lack of trap efficiency testing using larger bodied smolts. The CV for mainstem trapping estimates ranged from 23% (0+ coho) to 26% (0+ Chinook) in 2015. 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. These differences are largely due to the larger 8' trap used during pre-dam removal and the low number fish encountered in 2015.

In contrast, fishing on the tributaries was relatively trouble free and over 90% of the potential fishing days were fished and continually per 24 hour day. However, flow conditions on Little River resulted in such low catch rates of larger and later timed outmigrants that no estimates were made. The tributary sites had lower coefficients of variation than in 2014. Little River's only estimated CV was 25% for Coho salmon (0+). Indian Creek CV's ranged from 23% for steelhead to 47% for Chinook salmon (0+). The two tributary sites also had higher CVs than the desired 15% threshold.

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<sup>3</sup> Pink and Chum salmon were observed in moderate numbers above Elwha Dam for the first time in 2015 indicating that passage conditions were adequate during that year. Fish passage conditions through the former Elwha Dam site are dynamic and may change between years and flow conditions.

## Recommendations

Based on our experiences conducting smolt trapping on the Elwha River during the dam removal period we will implement the following changes for 2016 operations. For the mainstem Elwha River trapping effort we will continue the trapping operation at the downstream site at Rkm 0.3. A 1.5-2.0 m deep pool has reformed there and we intend to fish the 8' screw trap at the downstream site in 2016. This will increase our overall catch and trap efficiency relative to the 5' trap. We are also modifying the 5' Little River screw trap for the 2016 season by changing to a 4' screw similar to what we are using at Indian Creek. We believe this smaller screw will be able to operate at lower velocities.

The problem of low catch rates for larger sized smolts at the mainstem trap will be partially addressed by increasing fishing time as outlined above. In theory more fishing time should result in higher catches of large smolts such as steelhead and Coho salmon 1+. However, the other problem for these species is the expansion of raw catch estimates to generate production estimates. To date all mainstem trap efficiency tests on the Elwha River have relied on small sized 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 2016 we propose to add trap tests using larger sized hatchery origin smolts including Coho salmon 1+, steelhead, and Chinook salmon 1+. Alternatively we may consider marking larger sized smolts 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. No modifications are proposed for the tributary sites.

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 (e.g. 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).

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## Tables

Table 1. Results of mark-recapture tests for Elwha River, Indian Creek and Little River for the 2015 smolt outmigration season.

| Site                  | Date    | Species     | Number       | Recaptures | Percentage (%) |
|-----------------------|---------|-------------|--------------|------------|----------------|
| Elwha                 | 3/4/15  | Chinook 0+  | 897          | 26         | 2.9            |
| Elwha                 | 3/11/15 | Chinook 0+  | 900          | 6          | 0.7            |
| Elwha                 | 4/8/15  | Chinook 0+  | 1,000        | 24         | 2.4            |
| Elwha                 | 4/16/15 | Chinook 0+  | 1,000        | 18         | 1.8            |
| <i>Elwha Average</i>  |         |             | <i>2,900</i> | <i>74</i>  | <i>2.5</i>     |
| Little                | 3/5/15  | Chinook 0+  | 50           | 8          | 16.0           |
| Little                | 3/11/15 | Chinook 0+  | 50           | 1          | 2.0            |
| Little                | 3/19/15 | Chinook 0+  | 100          | 11         | 11.0           |
| Little                | 3/26/15 | Chinook 0+  | 100          | 12         | 12.0           |
| Little                | 4/2/15  | Chinook 0+  | 100          | 12         | 12.0           |
| Little                | 4/9/15  | Chinook 0+  | 100          | 13         | 13.0           |
| Little                | 4/16/15 | Chinook 0+  | 100          | 9          | 9.0            |
| <i>Little Average</i> |         |             | <i>600</i>   | <i>56</i>  | <i>9.3</i>     |
| Indian                | 1/27/5  | Chinook 0+  | 100          | 21         | 21.0           |
| Indian                | 2/4/15  | Chinook 0+  | 100          | 16         | 16.0           |
| Indian                | 2/17/19 | Chinook 0+  | 100          | 23         | 23             |
| Indian                | 2/26/15 | Chinook 0+  | 42           | 6          | 14.3           |
| Indian                | 3/4/5   | Chinook 0+  | 50           | 11         | 22.0           |
| Indian                | 3/11/15 | Chinook 0+  | 50           | 5          | 10.0           |
| Indian                | 3/18/15 | Chinook 0+  | 100          | 19         | 19.0           |
| Indian                | 4/1/15  | Chinook 1+  | 100          | 32         | 32.0           |
| Indian                | 5/14/15 | Coho 1+     | 99           | 21         | 21.2           |
| Indian                | 5/26/15 | Trout 0+/1+ | 7            | 1          | 28.6           |
| <i>Indian Average</i> |         |             | <i>748</i>   | <i>155</i> | <i>20.7</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, 2015 outmigration year. NE = no estimate.

| Species               | Catch | Estimated<br>Total<br>Catch | Average<br>efficiency<br>(weighted) | Estimated<br>Outmigrants | 95% C.I.          | CV   | gCV  |
|-----------------------|-------|-----------------------------|-------------------------------------|--------------------------|-------------------|------|------|
| Chinook<br>Salmon(0+) | 281   | 282                         | 0.0133                              | 15,860                   | 10,416-<br>27,845 | 0.34 | 0.26 |
| Chinook<br>Salmon(1+) | 25    | NE                          | NE                                  | NE                       | NE                | NE   | NE   |
| Coho<br>Salmon(0+)    | 38    | 38                          | 0.0148                              | 2,144                    | 1,271-<br>4,251   | 0.48 | 0.32 |
| Coho<br>Salmon(1+)    | 18    | NE                          | NE                                  | NE                       | NE                | NE   | NE   |
| Chum<br>Salmon(0+)    | 0     | NE                          | NE                                  | NE                       | NE                | NE   | NE   |
| Pink<br>Salmon        | 0     | NE                          | NE                                  | NE                       | NE                | NE   | NE   |
|                       |       |                             |                                     |                          |                   |      |      |
| Steelhead             | 23    | NE                          | NE                                  | NE                       | NE                | NE   | NE   |

Table 3. Total catch, estimated outmigrants, 95% C.I., CV and geometric CV for smolt outmigration from Indian Creek, 2015 outmigration year.

| Species            | Total Catch | Estimated Outmigrants | 95% C.I.       | CV   | gCV  |
|--------------------|-------------|-----------------------|----------------|------|------|
| Chinook Salmon(0+) | 5,374       | 44,368                | 27,820-117,022 | 0.47 | 0.31 |
| Chinook Salmon(1+) | 39          | 147                   | 102-236        | .24  | NE   |
| Coho Salmon(0+)    | 703         | 3,773                 | 2,814-5,591    | 0.18 | 0.25 |
| Pink Salmon(0+)    | 0           | NE                    | NE             | NE   | NE   |
| Chum Salmon(0+)    | 0           | NE                    | NE             | NE   | NE   |
| Steelhead          | 153         | 153                   | 377-715        | .17  | 0.23 |

Table 4. Total catch, estimated outmigrants, 95% C.I., CV and geometric CV for smolt outmigration from Little River, 2015 outmigration year.

| Species            | Total Catch | Estimated Outmigrants | 95% C.I.      | CV   | gCV  |
|--------------------|-------------|-----------------------|---------------|------|------|
| Chinook Salmon(0+) | 8           | NE                    | NE            | NE   | NE   |
| Chinook Salmon(1+) | 8           | NE                    | NE            | NE   | NE   |
| Coho Salmon(0+)    | 692         | 5,550                 | (3,885-9,148) | 0.25 | 0.23 |
| Coho Salmon(1+)    | 11          | NE                    | NE            | NE   | NE   |
| Pink Salmon(0+)    | 0           | NE                    | NE            | NE   | NE   |
| Chum Salmon(0+)    | 0           | NE                    | NE            | NE   | NE   |
| Steelhead          | 23          | NE                    | NE            | NE   | NE   |

Table 5. Total catch of miscellaneous species of fish encountered at Elwha River, Little River and Indian Creek smolt trap sites, 2015.

| Site   | 0+<br>Trout | 1+<br>Trout | 2+<br>Trout | Bull<br>Trout | Brook<br>Trout | Cutthroat<br>Trout | Cottids | Redside<br>Shiner | Juvenile<br>Pacific<br>Lamprey | Adult<br>Pacific<br>Lamprey |
|--------|-------------|-------------|-------------|---------------|----------------|--------------------|---------|-------------------|--------------------------------|-----------------------------|
| Elwha  | 22          | 1           | 1           | 1             | 0              | 0                  | 17      | 0                 | 31                             | 0                           |
| Little | 30          | 31          | 15          | 0             | 0              | 0                  | 2       | 0                 | 0                              | 0                           |
| Indian | 219         | 521         | 512         | 8             | 8              | 7                  | 125     | 51                | 407                            | 7                           |

Table 6. Adult coho relocations and redd counts to Little River and Indian Creek 2011-2015.

|      | Indian Creek |       | Little River |       | Mainstem |              |
|------|--------------|-------|--------------|-------|----------|--------------|
|      | Transfer     | Redds | Transfer     | Redds | Transfer | Redds        |
| 2011 | 134          | 95    | 137          | -     | 326      | Not Surveyed |
| 2012 | 162          | 38    | 60           | 8     | None     | Not Surveyed |
| 2013 | 596          | 126   | 442          | 160   | None     | Not Surveyed |
| 2014 | 124          | 30    | None         | 5     | None     | Not Surveyed |
| 2015 | None         | 0*    | None         | NS*   | None     | Not Surveyed |

\* Survey conditions precluded redd surveys for coho in 2015.

## Figures

Figure 1. Elwha River smolt trap locations.

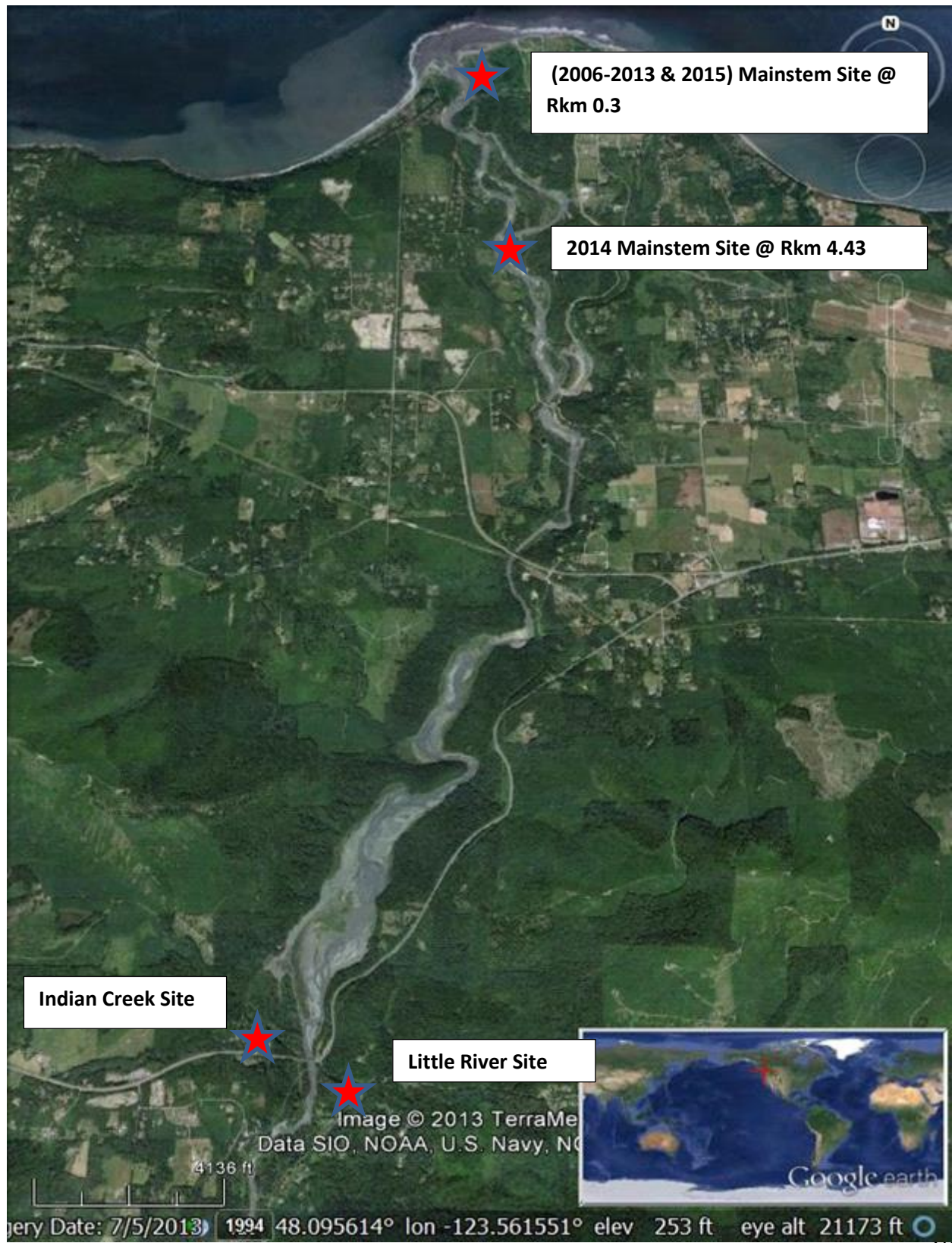


Figure 2. Elwha River 8' rotary screw trap fishing at Rkm 0.3 during the spring of 2010.



Figure 3. Elwha River 5' rotary screw trap fishing at RM 0.2, spring 2014.



Figure 4. Installing Little River screw trap, spring 2014.



Figure 5. Indian Creek 4' screw trap fishing spring 2014.



Figure 6. Elwha River flows (cfs) measured at the McDonald Gage Site, January 26 to July 31, 2015.

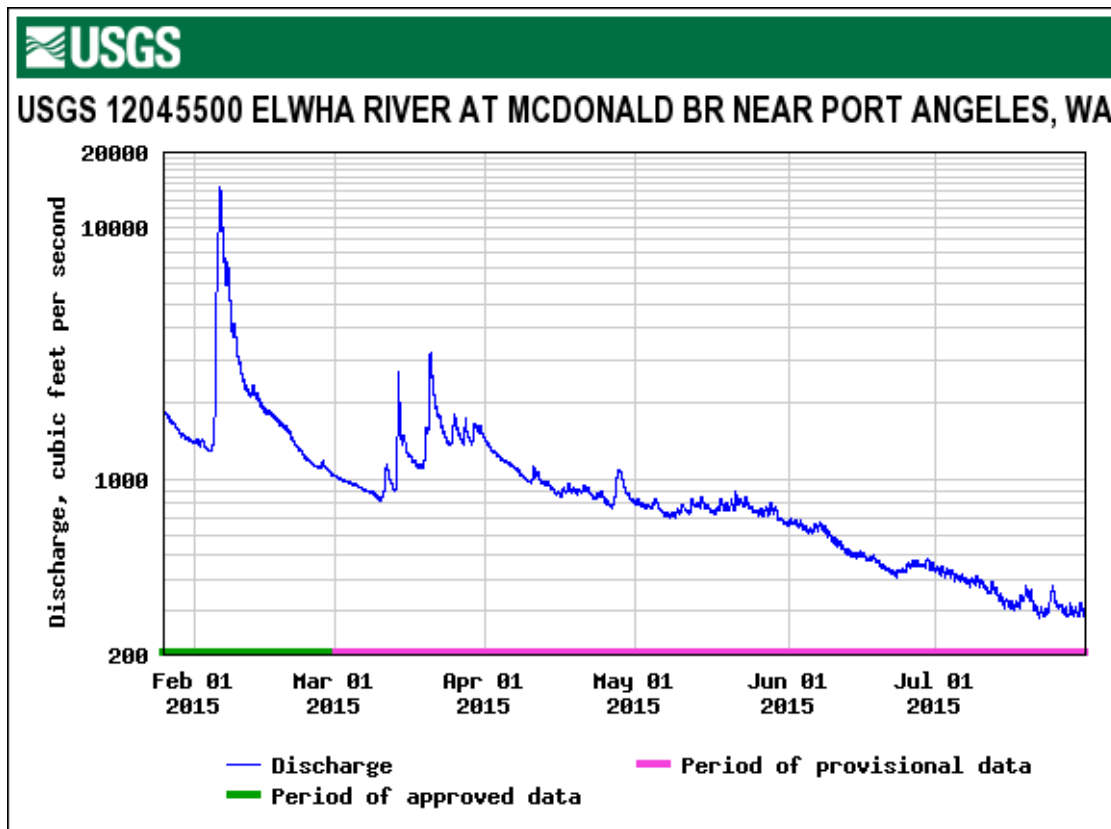
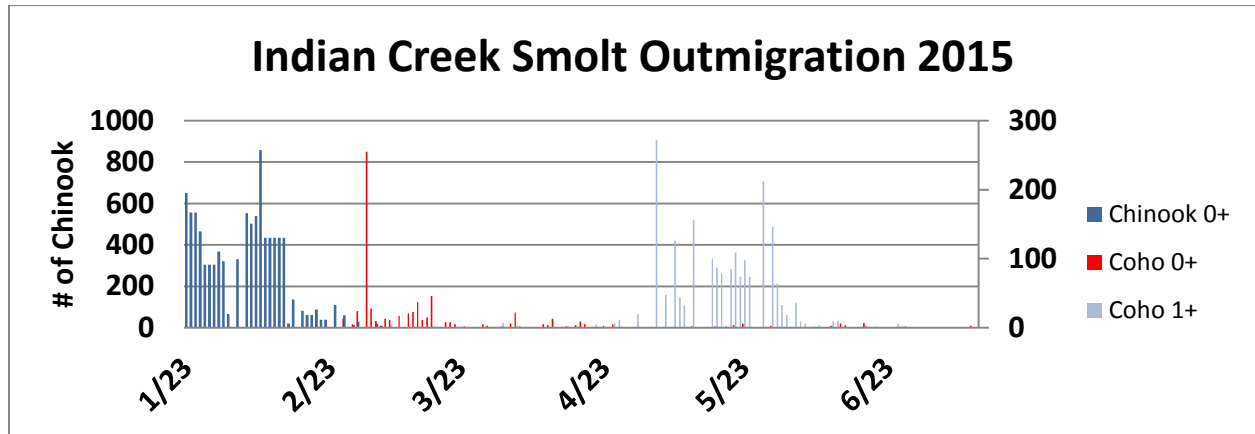


Figure 7. Bismark brown marked 1+ coho salmon for mark-recapture trap calibrations.



Figure 8. Outmigration timing for Chinook salmon 0+, Coho salmon 0+, and Coho salmon 1+ from Indian Creek (a) and Little River (b), 2015 outmigration season.

(a)



(b)

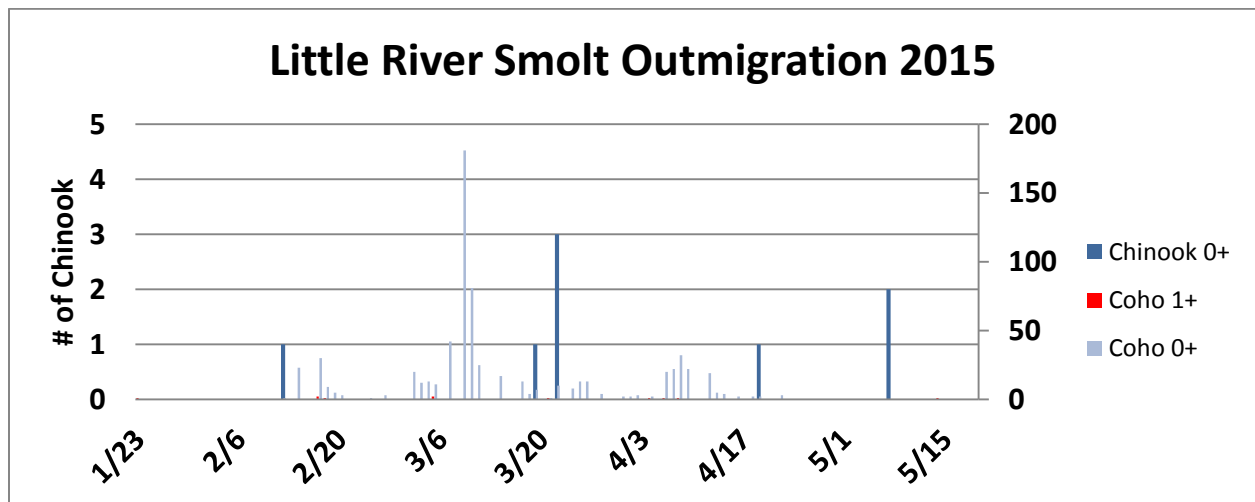


Figure 9. Sockeye salmon smolt captured at Indian Creek smolt trap, June 2015.



## 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 ( $\text{days}$ ). 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.