

2020 Elwha River Winter Steelhead Escapement Estimate Based on DIDSON/ARIS Multi-Beam SONAR Data



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Executive Summary

We used an ARIS 1800 and a DIDSON (LR) multi-beam SONAR unit to monitor winter run steelhead escapement in the Elwha River on a daily basis from February 11, 2020, through June 8th, 2020. We reviewed each hour-long file in its entirety and then adjusted these raw counts for species composition, observer error, and data gaps. This process yielded a steelhead escapement estimate above the SONAR sites of 1,985 fish; with a coefficient of variation (CV) of 4.5% (95% CI 1,765 – 2,231). This is the highest escapement of steelhead to the Elwha since the SONAR project began in 2013.

We also provide channel specific estimates of passage for the Hunt Road Channel (HRC) (647, 6.8% CV, 95% CI 563 -728) and the Old Mainstem (OM) (1,338, 5.8% CV, 95% CI 1,164 – 1,465). In addition, we calculated CV's for all three sources of uncertainty associated with estimating total escapement and passage through both channels, including gap filling (4.0%), observer error (3.0%), and species composition (0.3%).

The HRC SONAR unit was installed on February 11 and the OM SONAR unit was installed on February 12. Fish were detected migrating passed both SONAR sites on the first day of operation. Fifty-percent of the steelhead passed both SONAR sites by April 17, which was 4 days earlier than the average from 2014-2019. Species composition netting in conjunction with additional upstream net sampling indicated that between 91% and 58% of the total run, or 1,806 to 1,151 fish, were of natural-origin with the remaining 179-834 (9-42%) originating from the Lower Elwha Klallam native broodstock hatchery program. Hatchery and natural origin proportions exhibited significant spatial and temporal distribution differences with 83% (15/18) of the fish captured in the HRC (non-hatchery channel) being natural origin while 30% (9/21) of the fish captured in the Old Mainstem (hatchery channel) were natural origin. Temporal shifts ranged from 84% natural origin in March (16/19) to 42% natural origin in June (8/19). Three summer run steelhead were captured during net sampling between July 7 and July 13, but the number and timing of these samples were not representative enough to produce an escapement estimate of that distinct life history type.

Our two recommendations for next year are to perform net sampling throughout January even if the SONARs cannot be installed that early and to perform more net sampling during the presumed period when most summer steelhead pass the SONAR sites (June and July) in an effort to more accurately identify their relative abundance and timing in the overall net sampling protocol.

Introduction

One of the most important pieces of information for salmon fisheries managers is an accurate count of adults returning to spawn in a river system, hereafter referred to as escapement. Multiple methods have been used to estimate escapements of adults, including aerial surveys, counting towers, weirs, redd surveys, mark recapture, and SONAR technology (reviewed by Cousens et al., 1982). Over the years, the technology and techniques involved has remained basically static for most of these methods except SONAR, whose technology and application to escapement estimation has rapidly evolved over the last few decades (Maxwell 2008).

Single beam SONAR systems have been used to enumerate fish migration in rivers since the early 1960's. Similar technology is still being used to measure escapement in a number of commercial fisheries in Alaska (Westerman and Willette 2003; Dunbar and Pfisterer 2004; Dunbar 2001, 2003; McKinley 2002), and Canada (Levy et al. 1991, Cronkite et al. 2006). More recently, SONAR technology has greatly improved counting accuracy by incorporating multiple high frequency beams, producing "movie" quality images while also providing detailed data on several other fish characteristics including direction of travel, range, length, and swimming speed (Belcher et al. 2001, 2002). The main unit in use for fisheries applications today is the **D**ual-frequency **I**Dentification **S**ONar (DIDSON) and its newer version, the **A**daptive **R**esolution **I**maging **S**onar (ARIS).

Several studies have compared sonar counts of adult salmon derived from DIDSON imaging systems to other enumeration methods such as weir passage (Holmes et al. 2006), visual counts (Enzenhofer et al. 1998), and mark-recapture (Cronkite et al. 2006, Holmes et al. 2006). These studies have shown that SONAR counts were more accurate (insignificant error calculations) when compared to more traditional methods. It is important to note; however, that almost all of the fisheries applications of SONAR are focused on large salmon runs that transpire over the course of only a few weeks, which requires large technical staffs and operating budgets (eg. Lilja et al. 2008, Enzenhofer et al. 2010). In this study, we enumerate a small, protracted run of steelhead using multi-beam imaging SONAR.

SONAR is used to enumerate winter-timed steelhead (*Oncorhynchus mykiss*) and summer/fall Chinook salmon (*O. tshawytscha*) in the Elwha River, Washington from early January/early February through late September. This report only covers steelhead enumeration from late January through mid-July (see Denton et al., 2010-2018 for reports and data on Chinook salmon). It should be noted that historically the Elwha River had different life histories of steelhead that entered the river throughout the year (Personal Communication, Dick Goin, 2014). Following dam construction and subsequent development of hatchery steelhead programs, the diversity of entry timings and life histories of steelhead were simplified over time. At the time of dam removal, steelhead populations consisted of an early timed non-native hatchery run (Chambers Creek) and a remnant winter population with a later run timing, although the two overlapped from late December through March (Winter, 1989). The Chambers Creek program has been terminated and a native broodstock program initiated which aims to mimic the life history patterns of natural-origin fish. These programs had their last and first outplants, respectively, in 2011. Additionally, monitoring following dam removal has identified a growing summer steelhead run with adults being identified in the lower, middle and upper

river during the summer months (Duda et al., in press). Over the last 50 years, the summer run steelhead population in the Elwha was at a very low abundance. Small (~20,000 fish/year) outplants of Skamania stock summer timed steelhead were made during the last few decades of the 20th century, but they were discontinued well before dam removal.

The Elwha River, located on the north Olympic Peninsula in Washington State, provides a unique opportunity for fish enumeration using a multi-beam sonar system. Two dams had blocked fish passage to nearly 146 KM of main stem and tributary habitat since 1911, but removal of both dams began in September 2011 (Elwha River Fisheries and Ecosystem Restoration Act, 1992). The lower dam (Elwha) was completely removed by the spring of 2012. Large scale removal operations were completed at the upper dam (Glines) in August of 2014, but a subsequent rockfall in the fall of 2014 impeded passage at that site. Systematic blasting of the in-stream boulders resulting from the rockfall occurred in the summers of 2015 and 2016 and passage conditions appear to be improving, with multiple observations of a variety of fish species, including steelhead, upstream of the former dam site.

Annual adult abundance estimates are critical for evaluating the success and rate of recolonization of anadromous fish during and after dam removal (Peters et al. 2014). While the major goal of the Elwha and Glines dam removals is to eventually increase salmon and steelhead populations, the act of removing the dams has released large amounts of trapped sediment. The resultant turbidity severely limits visibility and makes the use of traditional enumeration methods (i.e. redd surveys) for specific species and time periods nearly impossible (Magirl et al. 2014). In addition, the removal of both dams opens up access to approximately 90% of the watershed that was previously inaccessible to anadromous fish (Pess et al. 2008). Much of this area is located in roadless wilderness area that is difficult to access. Therefore, SONAR is the best technique for producing basin-wide escapement estimates for anadromous salmon populations during and after dam removal.

Due to their ESA listing status of “threatened” and chronically low adult abundance, Elwha River steelhead recovery is important (Brenkman et al. 2008). Estimating adult steelhead returns on the Elwha River presents both a unique and common set of challenges. First, and unique to the Elwha River, is maintaining in-stream infrastructure in a constantly shifting environment due to the extreme sediment loads created by dam removal operations. Second, and applicable to many streams in the Pacific Northwest, is that due to highly variable streamflows during the steelhead migration upstream, the SONAR sites require constant maintenance, including removal and re-installation to avoid loss or damage to the equipment. Lastly, like other Puget Sound rivers, the Elwha River mainstem has an anastomosing or forested island morphology resulting in multiple channels for fish to migrate through (Beechie et al. 2006). Adult steelhead may migrate up one of two distinct channels that split near the mouth of the river, and as a result, each channel must be monitored with independent SONAR devices. When the flow is consolidated into a single channel near the mouth, it is too wide to accurately monitor with a SONAR unit. The sediment loads and dynamic, multiple channels provide a unique opportunity to evaluate the performance of SONAR to estimate adult escapements and run timing, examine sources of estimation error, and increase our understanding of SONAR in future monitoring efforts. To that end, the objectives of this study are to: 1) provide an estimate of winter run steelhead escapement to the Elwha River; 2) provide run timing information; 3) incorporate and describe various sources of error in

the estimate; 4) determine the proportion of steelhead and other species of salmon in the river during the course of the run; 5) provide an estimate of the proportion of natural to hatchery-origin steelhead in the river; and 6) make recommendations on how to improve the use of SONAR to enumerate adult salmon in the Elwha River in the future.

Methods

Data Collection

Continually changing river conditions and two distinct stream channels (migratory pathways) in the lower Elwha River necessitated two separate SONAR installations to accurately detect steelhead passage in 2020 (Fig. 1). The primary enumeration site was located in the Old Mainstem (OM, also referred to as the East channel) while a secondary site was located in the Hunt Road Channel (HRC, also referred to as the West Channel). Both sites were located at approximately RKM 0.8. While current data does not exist on the proportion of flow down each channel, during the flows experienced during the majority of the steelhead run, approximately 30% of the flow is transported down the HRC, with the remaining 70% traveling down the OM (Personal communication, Mike McHenry 2018). Two different SONAR units were used during the course of this study; a DIDSON LR (long range, 0.7/1.1 MHz, provided by NOAA Fisheries) and an ARIS 1800 (1.1/1.8 Mhz, provided by the National Park Service – Olympic National Park).

Site selection was based on four criteria: 1) almost all fish would pass the site; 2) the location was downstream of the majority of steelhead spawning habitat; 3) the river channel was sufficiently narrow to accommodate the effective range of the SONAR; and 4) fish movement was primarily directed upstream with little milling in the location of the SONAR. Depending on stream flow, the HRC site was between 15 and 20 m across and 1.8 meters deep in the thalweg, while the OM site was 15-28 meters wide and 2.2 meters deep in the thalweg.

Each SONAR was attached to a pole mount (Enzenhofer and Cronkite 2005) that was mounted on a reinforced aluminum step-ladder. The SONAR and ladder were positioned just under the surface of the water with a downward angle of approximately 4-6° (Fig. 2). The goal of this placement was to ensonify the bottom of the river across the entire width of the channel in addition to clearly identify the far bank (see Enzenhofer et al. 2010 for details on aiming the beam).

We constructed a picket weir approximately three meters downstream of the DIDSON that extended from the bank to 3 m beyond the SONAR (Fig. 3). This weir directed fish to an area of the channel more effectively covered by the sonar beams, producing greatly improved imagery and minimizing the possibility of fish passing directly underneath the beam and avoiding detection.

The HRC site was connected to line power, which ensured a constant power supply. The OM site was powered by a 24-volt, 200 amp hour battery bank that was continually charged by an array of solar panels. A weir was also constructed at the OM site to direct upstream passage of adult fish (Fig 4).

Winter steelhead passage was recorded at the OM site from February 12 through June 8, 2020. There were three short data gaps during this time period totaling 4 days (Fig 5a). Steelhead passage was

recorded at the HRC site from February 11 through June 8. There was one two day gap during this time period (Fig 5b).

The SONARs were also in operation after June 8, 2020, to record Chinook salmon passage. Data, analysis, and an estimate of Chinook passage for this time period is available in the project's Chinook report (Denton et al., 2021).

Species Composition

We conducted fourteen tangle net surveys between February 18 and June 8, 2020, to capture live adult salmonids at ten different sites in the lower five kilometers of the river. We did this to differentiate species of salmonids over the course of the run timing, to determine the end of the steelhead run and to estimate hatchery:natural proportions (or pHOS, the percentage of hatchery origin spawners). Captured fish were measured for fork length and qualitatively categorized as “new” if they appeared to have entered the river within the previous 2 weeks, “holding” if they appeared to have been in the river for more than 2 weeks, or “spawned out” if they appeared to have initiated or completed spawning. The tangle-net was designed to snare fish from the jaw not the gills in order to reduce encounter effects. The net was approximately 18 m long and 3 m deep with loosely hung 10 cm stretch mesh.

We also used the in-stream netting data to determine a minimal threshold for SONAR measured targets to be included in the final escapement estimation by comparing the lengths of steelhead to bull trout and SONAR measured fish (Fig 6). Additionally, species composition data was used to determine the sex ratio of steelhead. Fish captured during species composition netting in conjunction with fish captured during additional sampling at supplemental upstream sites were used to determine hatchery and native origin proportions for the entire run. PHOS showed significant variability both temporally and spatially. To combat this, additional sampling occurred this year and in 2019 to correct for biases introduced in pre-2019 sampling that relied on significant sampling near the LEKT hatchery during the peak of the hatchery return. We sampled an additional 6 sites on 10 different dates upstream of the traditional species composition sites in order to better characterize variability in pHOS and thereby provide a more accurate measure of the percentage of natural origin fish. Not all sites were sampled on all days. See Peters et al. 2021 for methods, data, and analysis of this portion of the project.

Data Analysis

Post Processing

All DIDSON data was processed using DIDSON proprietary software (V5.25.26). There were 24 hour long files for each day of operation. The entire hour of each file was reviewed. Raw data was transformed in a four step process that enabled empty periods of time to be efficiently reviewed, while still highlighting fish passage events for closer inspection. Files were background subtracted, using the default parameters, to remove rocks and make it easier to discern moving objects, such as migrating fish. Subsequently, each file was transformed into an echogram using the default parameters, with the exception that all 96 beams were included rather than only the center beam. This dramatically increases the probability that any fish entering the ensonified area was detected in the echogram.

An echogram is a graph of the data with distance from the SONAR head on the y-axis and time on the x-axis. If no targets are present, the echogram is blank. If a fish swims through the ensonified area, the echogram has a series of targets connected along the x-axis, whose overall length correlates with the length of time it took the fish to pass through the ensonified area. The string of targets along the x-axis may trend up or down along the y-axis if the fish was swimming diagonally away or towards the sonar head during its passage. To count fish passage events, target echograms were simultaneously reviewed along with the raw video file. This enabled the reviewer to quickly scan through an echogram until a target pattern that could potentially represent a fish was encountered. The raw video imagery was then reviewed to ensure identified targets were indeed fish.

The procedure for processing ARIS data was the same (background subtraction, echogram formation, manual review of likely targets), except ARIS data is processed with its own software, ARISFish (v.1.5). After determining that a pattern on the echogram was indeed a fish, we noted several variables, including the date, time, direction (upstream or downstream), distance from SONAR head, length (mm) and observer confidence. Length was measured in centimeters using software specific procedures. Observer confidence was a qualitative value about the likelihood that the target was indeed a fish. The reviewer recorded a 1 if they were extremely confident that the target was indeed a fish passing in the specified direction or a 2 if they are not confident that the target was a fish passing in the specified direction.

Escapement Estimation and Uncertainty Tabulation

Basic fish passage is tabulated by simply subtracting downstream passage events from upstream passage events (Xie et al. 2005):

$$N = U - D$$

Where N is the net upstream movement of fish for a given period of time, U is the sum of upstream fish for that time period and D is the sum of downstream moving fish for that time period.

In order to sum the upstream and downstream passage events for each hour long file, we first had to determine which passage events to include in our analysis, namely the minimum length threshold and which observer confidence categories. A length frequency histogram of the in-stream netting data revealed that steelhead were between 560 mm and 850 mm (Fig. 6). Five bull trout were captured during species composition sampling measuring between 330 mm and 480 mm, all of which were smaller than the smallest steelhead. Based on this data, only SONAR targets recorded as 500 mm or greater were included in the final escapement analysis. We only used passage events of observer confidence level 1 in the final escapement analysis. Twenty percent of all upstream passage events that met the length criteria were recorded as observer confidence level 2 (734/3,736). Most of these targets were determined to be beavers moving in very shallow water on the far bank. Forty-two percent of all downstream passage events were recorded as observer confidence level 2 (882/1,220).

Raw targets meeting the above criteria were then aggregated into channel specific six-hour chunks, four per day. Each channel specific six hour chunk was then put through a three step adjustment simulation to determine the final escapement. This simulation used collected data to correct

raw counts for the three major adjustments that make up the total escapement estimate: 1) down weighting the raw counts to reflect the proportion of SONAR targets that were steelhead; 2) adjusting the steelhead counts to account for observer error; and 3) filling in passage data for gaps in the corrected steelhead data.

We used a simulation based approach and replicated this simulation procedure a large number of times (10,000) for each channel individually. We initialized the values in each cell (508 rows, representing each of the 6-hour chunks and 10,000 columns, representing the iterations) to the net passage based on the raw counts from the files. During each of the three steps in the adjustment procedure described below, we were able to generate updated channel specific estimates of escapement, and at varying temporal scales (6-hour estimates, daily estimates, and annual estimates). Each step of this process was done for each channel and then the channel data was summed to provide total estimates and a coefficient of variation (CV). To determine the coefficient of variation for the final escapement, the standard deviation of all 10,000 estimates was divided by the mean of all 10,000 estimates. To generate CV estimates for each of the four individual adjustment procedures, we also applied each step of the procedure individually to the raw six-hour chunk counts from each channel.

Species Composition

Calculation of the 2020 winter steelhead escapement only included SONAR targets recorded through June 8 based on findings of the species composition sampling. No “new” or “holding” winter steelhead were captured in our sampling after June 8. Three additional steelhead were captured at the species composition sites after June 8, one on June 22 and two on July 20. All three were spawned out and of hatchery origin. In addition, four “new” Chinook were captured on June 8 and seven more were captured throughout June with at least one captured every week, indicating that most of the large bodied salmonids migrating past the SONAR sites after June 8 were likely Chinook salmon (although see discussion about the possibility of summer run steelhead migrating passed the sites in June).

In-river netting also provided the necessary data to adjust the raw counts to reflect just the number of steelhead moving past the SONAR sites (Table 1). Because of the low numbers of fish caught during some of the sampling events, we summed fish between adjacent events to arrive at daily totals of “all fish” versus steelhead caught. For each channel, we simulated the proportion of steelhead for a given iteration and day as:

$$p_{i,j,k} = \text{Binomial}\left(\frac{N_{i,j,k}^{\text{steelhead}}}{N_{i,j,k}^{\text{total}}}, N_{i,j,k}^{\text{total}}\right) / N_{i,j,k}^{\text{total}}$$

where i represents the iteration (1 – 10,000), j indexes the 6-hour chunk (1 – 476) and k indexes the channel. The total number of fish, $N_{i,j,k}^{\text{total}}$, and total number of steelhead, $N_{i,j,k}^{\text{steelhead}}$, were available on a daily basis, so the four six-hour chunks from each day were assumed to have the same species composition.

We then adjusted each of the raw counts for the proportion that were steelhead as a random

draw from a Binomial distribution:

$$X_{i,j,k}^{steelhead} \sim \text{Binomial}(p_{i,j,k}, X_{i,j,k}^{total})$$

where X is the number of steelhead and total number of fish for each six-hour chunk.

The CV for escapement for this step was calculated by performing the correction directly on the net passage data. Then the counts of all 6-hour chunks were summed for each iteration, yielding 10,000 estimates. Finally, the standard deviation of all 10,000 estimates was divided by the mean of all 10,000 estimates.

Observer Error

We quantified observation error by comparing counts for 28 six hour chunks between the primary technician and a more experienced, “expert” counter. Six hour total passage counts by the expert counter were considered to be a measure of “actual” passage and were compared to the technicians “predicted” counts (Fig. 7). A trend line was fitted to the data with an intercept of 0 and then a vector of observer error residuals was generated. Each cell of the steelhead matrix was then adjusted by multiplying it by the coefficient from the regression trend line and adding a random residual. The CV for escapement for this step was calculated by performing the correction directly on the net passage data as opposed to the species composition adjusted data used by the simulation. Then the counts of each 6- hour chunks were summed for each iteration, yielding 10,000 estimates. Then the standard deviation of all 10,000 estimates was divided by the mean of all 10,000 estimates.

Filling Data Gaps

As stated above, there were three data gaps for the OM after initial deployment totaling 4 days. There was one two day gap for the HRC after initial deployment. To fill in these gaps, we used a generalized additive modeling (GAM) approach to fill in missing values, because this approach also allowed us to include uncertainty estimates (gam in the ‘mgcv’ package in R). We fit a spline over time (days), which allowed both a flexible shape of return timing, and uncertainty to increase as the spline moved further away from data. For each iteration of the simulation, we first fit the GAM to fill in the data gaps, then for each day drew a random number from a normal distribution centered on the fitted value estimated from the GAM, with corresponding standard error. This approach ignores autocorrelation in missing values, but also represents upper bounds of uncertainty estimates.

Results

Between February 11 and June 8, 2020, 2,856 hours (119 days) of data were recorded on the HRC, and 2,760 hours (115 days) were recorded on the OM which represented 98% of the total possible hours in this year’s steelhead run. At least one of the channels was monitored for 100% of the run. During this time period, 5,976 fish passage events were recorded and analyzed. The best estimate for the steelhead escapement to the Elwha River in 2020 was 1,985 fish with a coefficient of variation (CV) of 4.5% (95% CI 1,765 – 2,231) (Tables 2 and 3). A total of 647 steelhead (CV 6.8%, 95% CI 563–728)

went up the HRC, while the remaining 1,338 (5.8% CV, 95% CI 1,164 -1,465) steelhead went up the OM (Figure 8). In order of decreasing variance, the largest sources of error were (1) filling in data for missing time periods (4.0%), (2) the observer error correction (3.0%), and (3) uncertainty associated with species composition (0.3%) (Table 3).

The nature of the SONAR data in combination with in-stream species composition netting provides detailed information on run timing. Fish passage was detected passed both sites on the first day of deployment. We initiated species composition sampling on February 18 and caught five steelhead. Weekly species composition sampling through June indicated that winter steelhead ceased migrating past the SONAR sites by June 8. Twenty-five, 50 and 75% of the run had passed the SONAR sites on March 23, April 17, and May 5, respectively (Figs. 11 and 12). Twenty-five, 50, and 75% of the run had passed the HRC by March 31, April 24, and May 8, respectively, and by March 19, April 14, and May 3 for the OM, respectively (Figs. 9 and 10).

In general, daily passage seemed to be independent of flow, but interestingly significant entry appeared to begin in early March when the hydrograph was near the lowest of the season (Figs. 13). The hydrograph was variable over the course of the study, reaching a high of 3,000 cfs on May 27 and a low of 600 cfs on March 27.

Sampling at the species composition sites and additional upstream sites captured 106 winter run steelhead. Forty-two of these fish were adipose clipped (hatchery origin) while the other 64 were natural origin. There were significant differences in the pHOS both spatially and temporally (Table 4a and 4b). Most of the spatial variability in pHOS can be attributed to sampling proximity to the LEKT hatchery, whereby sites near the hatchery had a pHOS of 70% (21/30) and sites on the channel that bypasses the hatchery had a pHOS of 17% (3/18). Sites located below the channel split, which is theoretically before fish disproportionately bifurcate, had a pHOS of 15% (3/20) (Table 4a). PHOS also varied temporally, with natural origin fish comprising a greater proportion of the early portion of the run and hatchery origin fish dominating the later portion of the run (Table 4b). After accounting for variable capture probabilities depending on location of capture, as detailed in Peters et al. (in prep), the best estimate for pHOS for the entire run was between 9% and 42%. Assuming this represents an unbiased sample of the total run, approximately 1,806 – 1,151 of the 1,986 total returning steelhead were natural-origin recruits (NOR), while the remaining 179 - 834 were hatchery-origin recruits (HOR). Net sampling from all sites indicated a male:female sex ratio of approximately 0.7:1 (43 male, 62 female).

Additionally, three summer run steelhead were captured on July 7 (2), and July 13 all of which were natural origin. Unfortunately, this small sample size precluded deriving a summer run steelhead escapement estimate using SONAR data for 2020.

Discussion

Our estimate of 1,986 winter steelhead represents a robust measure of steelhead escapement to the Elwha River for several reasons. Most importantly, we collected data over what was likely the majority of the temporal period of the run. Although it is likely some steelhead moved past the SONAR

sites before installation on February 12 based on the observance of fish passage on the first day of recording at both sites, daily passage at the beginning of the run was relatively small for the first week of operation. Species composition netting throughout the months of May and June confirmed that we accurately identified the end of the run. We were able to encompass the major sources of uncertainty in our final estimate and thereby provided a robust range of possible escapement totals, giving managers and stakeholder's reliable information upon which to base management decisions. This uncertainty comes from three main sources, (1) filling in gaps for missing time periods (CV, 4.0%), (2) observer error (CV 3.0%), and (3) correcting for species composition (CV 0.3%).

The largest source of uncertainty (CV 4.0%) was associated with filling the data gaps that occurred over the course of the study. Once each SONAR site was installed there were very few data gaps, totaling only 5 days. A relatively mild late winter/early spring storm season in 2020 enabled us to keep both SONARs in the water and recording for almost the entire run. It is important to note that, as in 2019, fish passage was detected on the first day of installation for both channels, indicating that steelhead almost certainly moved passed the SONARs before installation. The gap filling procedure makes no attempt to account for fish that passed by before SONAR installation. Given that 13 and 43 steelhead passed by the HRC and OM SONARs, respectively, during the first week of operation, it is plausible that more than 100 steelhead passed by before installation that were not part of our ~2,000 fish estimate. Historically, winter steelhead entered the Elwha River in significant numbers throughout December and January and then entry slowed down during the month of February until the run built again in March and April (Dick Goin, personal communication, 7/16/05). While it is unlikely that the historical run timing of winter steelhead in the Elwha is still intact or will recover in the near future, it is worth noting that it is difficult to predict the number of fish entering the Elwha before SONAR installation based solely on passage shortly after installation. See recommendations below for methods to collect data on early timed winter steelhead.

The second highest source of uncertainty was the observer error correction (CV 3.0%). The regression coefficient (1.01) was essentially the same as a 1:1 relationship between technician and expert counts and the r^2 (.82) indicated a good fit of the regression. The project has employed the same technician for several years, resulting in reliable and accurate data review.

The final and smallest source of uncertainty was associated with the species composition (CV 0.3%). The low level of uncertainty associated with this source is attributed to the fact that net sampling indicated that almost all fish passing by the SONAR sites during the course of the study were steelhead. Although five bulltrout were captured, the largest one, 480 mm, was much smaller than the smallest steelhead, 560 mm, so none of the captured bulltrout affected the model adjustment. The uncertainty that does exist from this adjustment is due to the overlap at the end of the steelhead run and the beginning of the Chinook run. Both species were concurrently actively migrating for only one week, minimizing the effect of this correction on the total number of steelhead estimated.

Although there is no other independent estimate of steelhead escapement on the Elwha, our estimate can be put into context with redd surveys conducted in several tributaries and the main stem channel during the 2020 season. Moses et al. (2020) observed 172 steelhead redds from the river

mouth to the upstream end of Geyser Valley (RKM 19.9). Using a redd to fish multiplier of 1.8, gives a redd based estimate of 310 fish. When the hatchery collection of 91 fish is added, the total of 401 fish only amounts to about 20% of the SONAR based escapement. This disagreement is not unexpected for multiple reasons. First, due to visibility issues, limited main stem surveys were conducted in 2020. Secondly, survey effort was opportunistic, not all areas were surveyed (namely the entire upper watershed upstream of Geyser Valley) and some surveyed areas were not visited consistently. Finally, it appears as though the spatial distribution of observed steelhead redds is moving upstream and survey effort upstream of the former Lake Mills reservoir is very limited. Taken together, there is a high likelihood that numerous redds were uncaptured during these surveys.

We also put this year's steelhead escapement estimate in context with the last five years' SONAR derived estimates (Denton et al. 2013, 2014, 2015, 2016, 2017, 2018, 2019). The escapement estimate has varied from a low of 385 (2013) to a high of 1,625 (2018) while the proportion of natural origin (NOR) fish has ranged from a low of 13% (2015) to a high of 75% (2013) (Table 4). Our escapement estimate of 1,985 steelhead this year marks the highest return of steelhead to the Elwha since the start of the SONAR project in 2013. The number of NOR steelhead in 2020, 1,806 – 1,151, is double the previous highest estimate of NOR fish (2019: 875 – 1,020).

Similar to 2019, extensive effort was made this year to produce an unbiased estimate of the proportion of hatchery fish (HOR). In 2020, as in 2019, we attempted to sample over both a longer spatial distance (mouth of the river to former Lake Mills) and a longer temporal scale (early March through end of June). Unfortunately, due to COVID precautions, only limited sampling occurred upstream of the former dam sites, resulting in only one NOR spawned out male sampled in the middle river on June 18. We were able to expand our sampling temporally in 2020, starting on February 18. It is important to note that the species composition sampling protocol of previous years was not designed to provide an unbiased sample of natural vs. hatchery-origin ratios, so numbers prior to 2019 should be used with caution and comparisons of previous years to 2019 or 2020 are not advisable. This is particularly true of the 2013 and 2015 data. In 2013 species composition sampling only occurred in June solely as an effort to differentiate steelhead from Chinook. In 2015, most of the sampled steelhead were captured within 500 m of the LEKT hatchery and therefore the proportion of natural origin fish is almost certainly biased low. In 2020, significant variability was shown to exist in the proportion of hatchery fish both temporally and spatially (Table 4a and 4b). HOR:NOR proportions were highest close to the LEKT hatchery facility that raises and releases winter timed steelhead. HOR:NOR proportions were lowest at sites on the HRC channel (17%) and at sites below the location of the HRC/OM channel split (15%). The HRC channel bypasses the LEKT hatchery facility and therefore would presumably not contain olfactory cues for HOR fish, although one small overflow channel connects the OM with the bottom 100m of the HRC.

The date at which 50% of the run had passed the SONAR sites in 2020, April 17, was similar to most other years except 2019 and 2013. 2013 was the final return year for the LEKT hatchery early timed winter steelhead program (Chamber's Creek fish) which likely pushed entry timing earlier for that year. Netting did not occur during the steelhead season in 2013 so it is unclear what the NOR:HOR proportions were. In 2020, as in 2019, approximately one hundred fish moved passed the SONARs

during the first week of operation. In contrast to 2019, the record run size in 2020 eventually pushed the 50% date back towards the average from 2014-2018, April 15. It is important to note that SONAR installation in 2020, February 11, was the latest of the project due to flow conditions. It is likely that if the SONARs had been installed in late January or earlier, the total run size estimate may have increased by more than one hundred fish and the 50% passage date may have shifted earlier by approximately one week. Species composition netting indicated an end of the winter steelhead run (June 8) very similar to the 2014-2019 average of June 10. However, net sampling occurred throughout June and July in conjunction with the Chinook project and six additional winter run steelhead were captured, including two HOR fish on July 20. All six of these fish were spawned out, but the existence of winter run steelhead in any condition in the river on July 20 indicates that some active migration of fresh steelhead may have occurred after the last fresh fish was captured in net sampling on June 8.

Snorkel surveys conducted in the upper watershed in late September of 2017 recorded approximately 60 summer run steelhead. Similar surveys in 2018, 2019, and 2020 recorded 216 and 341 summer run steelhead, respectively (Duda et al., in press). In 2018, we captured nine summer run steelhead over a period of six weeks from May 22 to July 10 and were able to generate an escapement estimate for this distinct timed run. In 2019, we only captured three summer run steelhead between June 24 and July 17. In 2020, we captured only four summer run steelhead, two on July 7, one on July 13, and one on July 27. As in 2019, the low sample size precluded us from making a SONAR based run size estimate for this distinct run.

The increased life history diversity of steelhead as evidenced by protracting run timing and the presence of summer run fish bodes well for steelhead recovery in the Elwha River, but does pose new monitoring challenges. While we miss some portion of the total run by installing the SONAR in late January (or even early February, as happened in 2020), low passage in the days immediately after installation for year's 2014-2018 gave us confidence that we were not missing many early fish. This year however, similar to 2019, passage up both channels was evident soon after installation (Fig 9). If this trend continues, we may have to consider installing the SONAR earlier in January or even December if possible. Historically a significant portion of the run was thought to enter the river in December and January (Dick Goin, pers. comm. 7/16/05). Finally, if the project intends to monitor summer steelhead populations, additional work will need to occur, as described in the recommendations section.

Recommendations

It is becoming apparent that the run timing of winter steelhead in the Elwha is becoming more protracted, with migrating fish being detected immediately after SONAR installation. The project generally always installs the SONARs as early as possible in January/February so earlier installation is likely not possible. However, it is possible that a flow window would allow for some net sampling in early January even though the SONARs may not be installed. Therefore, even if the SONARs are not yet installed, we recommend net sampling at least once in early January.

We need to repeat the second of last year's recommendations in regards to increasing sampling effort for summer run steelhead. In order to provide a better estimate of the summer-run steelhead population, more species composition sampling should occur from mid-May through mid-July. Additionally, resources need to be committed to dealing with the increased analyses required to devise

a statistically defensible method for dealing with the effects of downstream migrating kelts during this time period.

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Table 1. Total number of “new” and “holding” steelhead and Chinook captured by date at ten species composition sites during in-river netting operations.

Date	Steelhead	Chinook	% Steelhead
2/18/2020	5	0	100%
2/24/2020	6	0	100%
3/10/2020	8	0	100%
3/16/2020	4	0	100%
3/23/2020	8	0	100%
4/7/2020	8	0	100%
4/13/2020	12	0	100%
4/16/2020	7	0	100%
4/20/2020	8	0	100%
4/28/2020	6	0	100%
5/5/2020	6	0	100%
5/25/2020	0	0	NA
6/3/2020	1	1	50%
6/8/2020	2	4	33%

Table 2. Channel specific and total estimates of steelhead passage on the Elwha River in 2019. Each step is an adjustment of the previous step, i.e. they are not stand alone estimates except for the final one.

Type of Count (Adjustment)	HRC	OM	Total
Raw Passage	568	1,214	1,782
Species Composition	565	1,194	1,759
Observer Error	588	1,229	1,817
Gap Fill (Final)	647	1,338	1,985

Table 3. Channel and source specific coefficients of variation (CV) for the three sources of uncertainty individually and for all of them combined. The individual source CV's are the result of applying each correction to the raw data while the total CV reflects the total CV from all sources.

Source	HRC	OM	Total
Species Comp	0.4%	0.3%	0.3%
Observer Error	6.5%	3.1%	3.0%
Gap Fill	1.2%	5.7%	4.0%
Total	6.8%	5.8%	4.5%

Table 4a. Number and proportion of natural and hatchery origin steelhead in different sampling areas of the lower Elwha River in 2020. The river splits at RKM 0.5, with one channel passing by the LEKT hatchery facility (OM) that releases winter run steelhead and the other channel by-passing the facility (HRC). The hatchery site refers to three sites within 100 meters of the hatchery facility while the OM (hatchery channel) refers to all sites in that channel. All sites include an additional 22 steelhead that were captured upstream of the two channel's reconnection (~RKM 5.0)

Sites	Natural	Hatchery	% Hatchery
All	64	42	40%
Below split	17	3	15%
Hatchery	9	21	70%
HRC (non-hatchery channel)	15	3	17%
OM (hatchery channel)	19	27	59%

Table 4b. Number and proportion of natural and hatchery origin winter run steelhead caught by month in the lower Elwha River in 2020.

Month	Natural	Hatchery	% Hatchery
February	8	3	27%
March	16	3	16%
April	29	19	40%
May	3	4	57%
June	8	11	58%

Table 5. Yearly escapement estimates for Elwha River steelhead with 95% confidence intervals and number of natural-origin recruits (NOR) and hatchery-origin recruits (HOR) based on species composition sampling, except for 2019 and 2020 which was based on a more robust sampling protocol intended to estimate %NOR fish. %NOR estimates prior to 2019 should be used with caution and likely do not accurately represent true NOR:HOR proportions.

Year	Estimate	95% CI	NOR	HOR	% NOR
2013	385	NA	290	95	75%
2014	1,200	1,140 - 1,250	400	800	33%
2015	1,450	1,220 - 1,675	190	1,260	13%
2016	890	810 - 976	320	570	36%
2017	1,130	1,060 - 1,226	375	755	33%
2018	1,625	1,489 - 1,768	731	894	45%
2019	1,458	1,260 - 1,666	875 - 1,020	437 - 583	60 - 70%
2020	1,985	1,765 - 2,231	1,151 - 1,806	175 - 834	91 - 58%



Figure 1. Map of the lower Elwha. The former Elwha dam site is located at the bottom of the figure, with the Strait of Juan de Fuca at the top. White oval depicts the location of the Hunt Road Side Channel DIDSON site. The Old Mainstem site is located approximately adjacent to the upper right hand portion of the white oval.



Figure 2. Photo of the HRC DIDSON site showing the picket weir and the ladder on which the DIDSON is mounted.



Figure 3. Ladder and pole mounted DIDSON multi-beam imaging SONAR. The SONAR is housed in the black silt box at the bottom of the pole.



Figure 4. Old Mainstem SONAR site. The SONAR itself is attached to the pole mount which is in turn attached to the ladder. The PVC picket weir immediately downstream from the ladder directs fish away from the bank so they pass at least 3 m from the SONAR head.

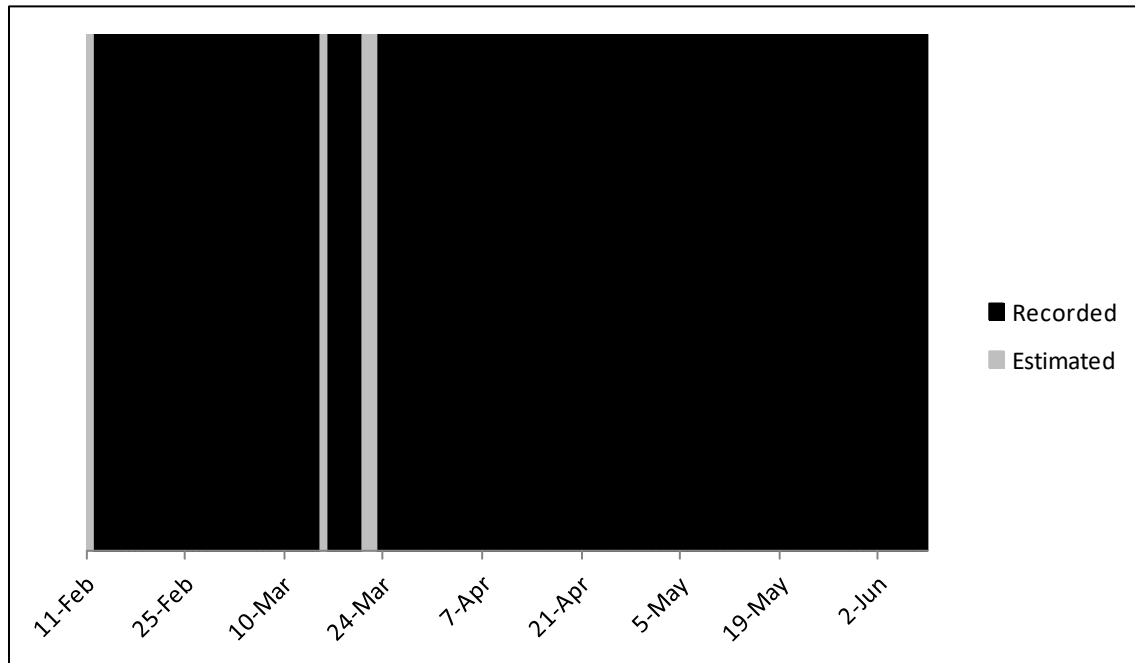


Figure 5a. Dates which had data recorded, black bars, or estimated, grey bars, for the Old Mainstem of the Elwha River in 2020.

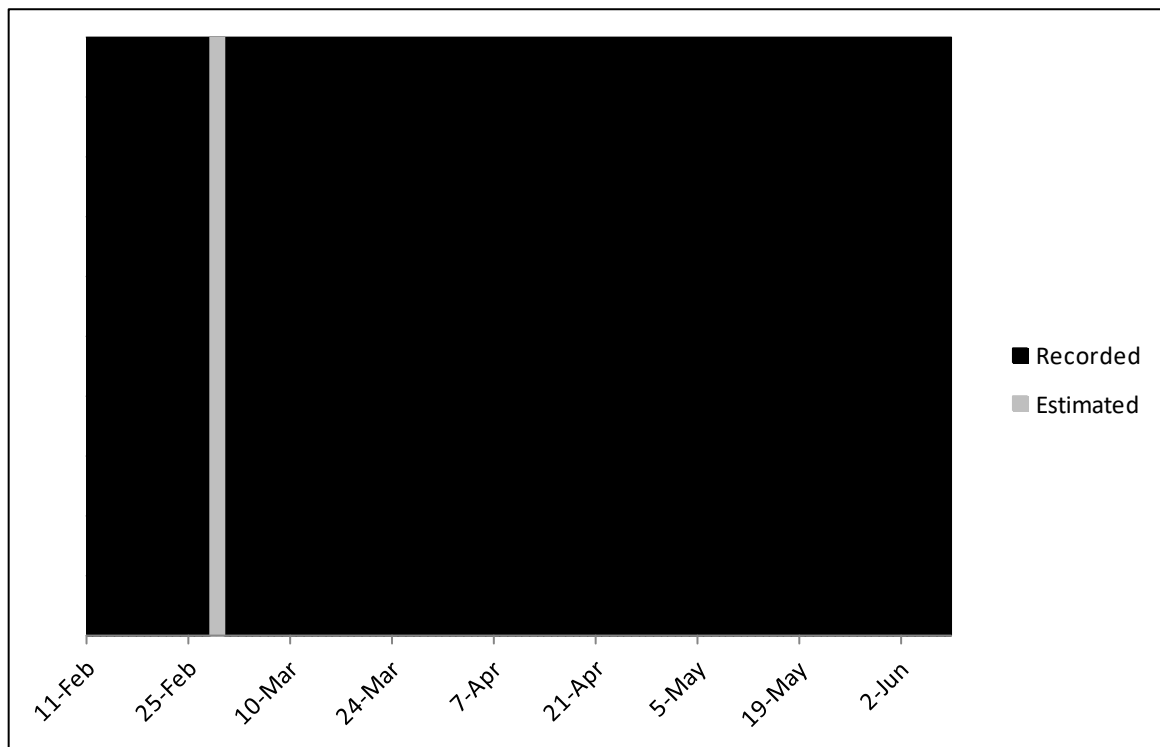


Figure 5b. Dates which had data recorded, black bars, or estimated, grey bars, for the Hunt Road Channel of the Elwha River in 2020.

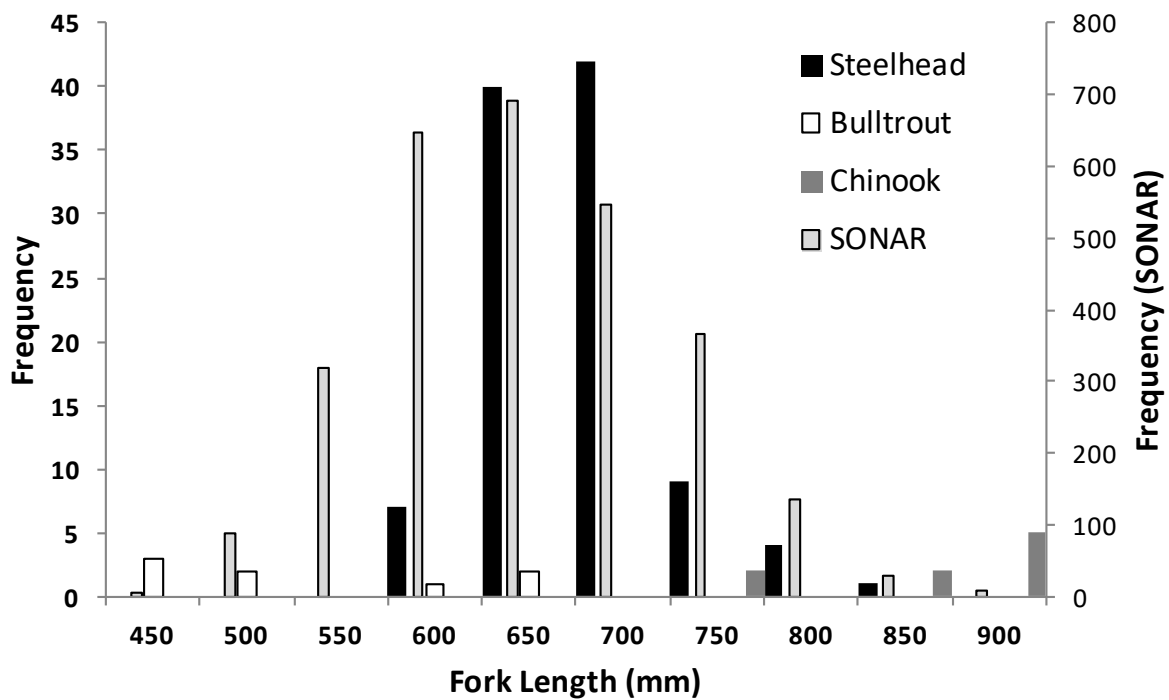


Figure 6. Length frequency histogram of all fish captured during netting operations at eleven locations on the lower Elwha River between February 18 and June 8, 2020 (left hand y-axis). Length frequency histogram of all SONAR measured targets of observer quality 1 (right hand y-axis). One Chinook was captured June 3 and four Chinook salmon were captured on June 8, 2020.

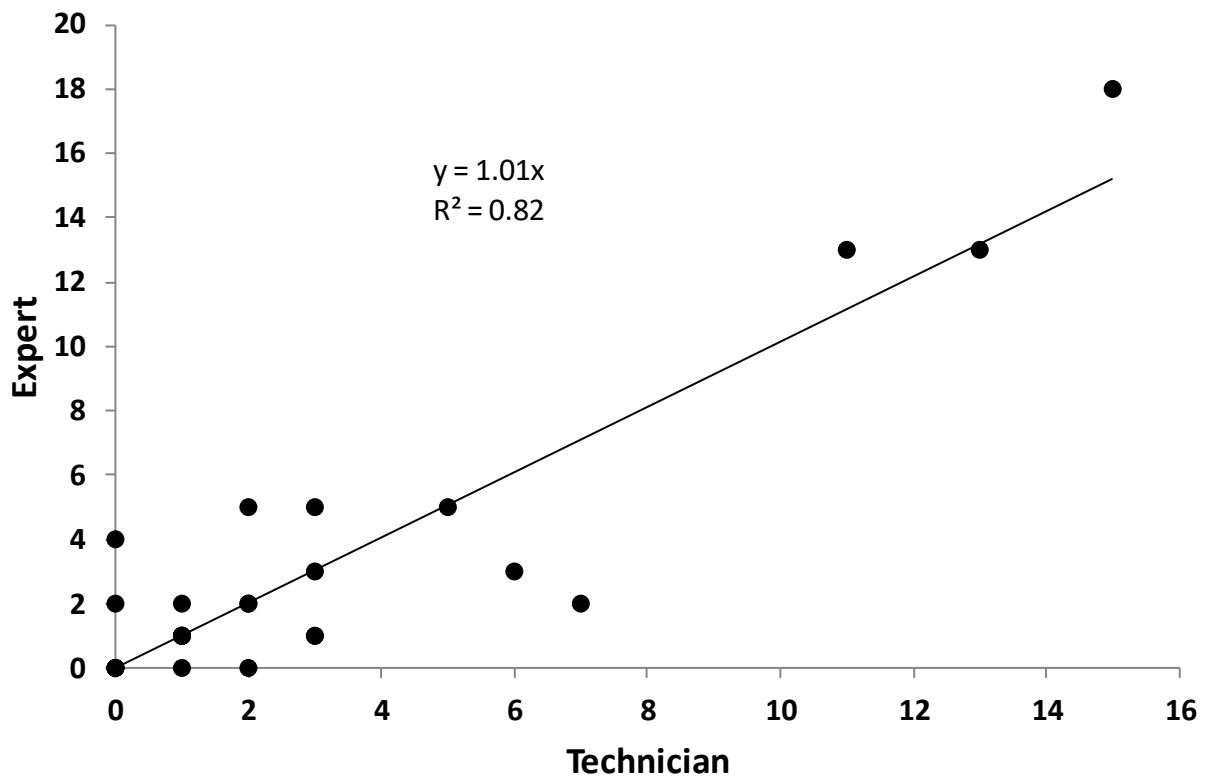


Figure 7. Total upstream passage counted by a technician and an expert for 28 six hour chunks. Points (0,0) and (1,1) each have four data points and point (2,2) has two data points.

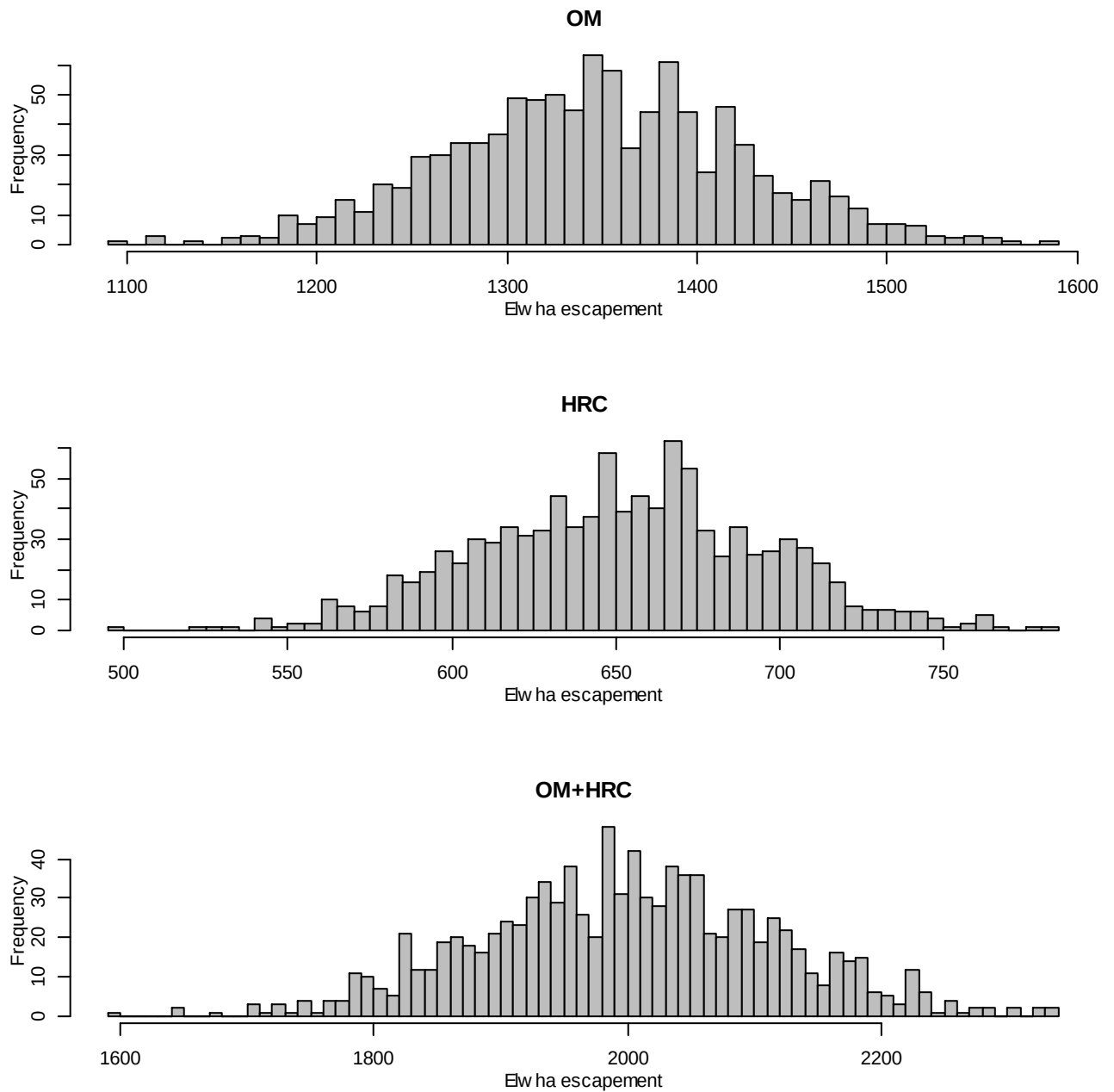


Figure 8. Run size frequency histograms for the steelhead in the Old Mainstem (OM), Hunt Road Channel (HRC) and combined run (OM + HRC) for the Elwha River in 2020.

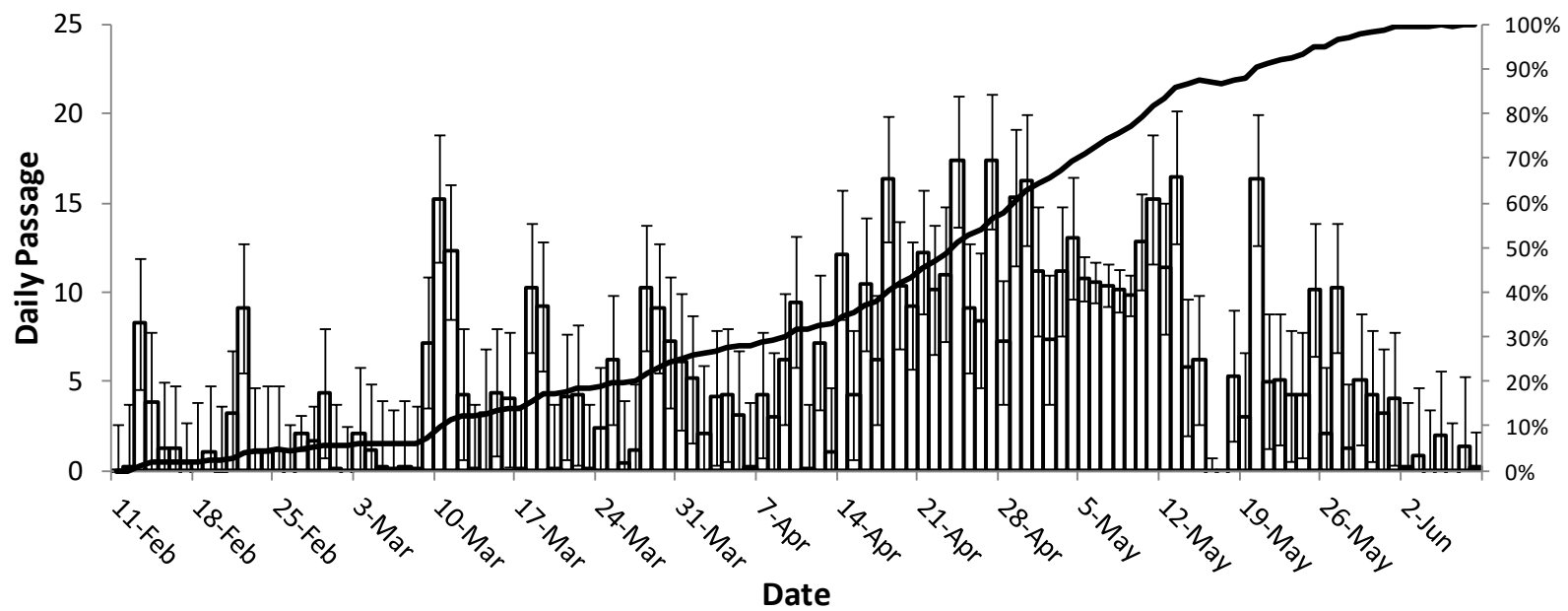


Figure 9. Daily passage estimates for steelhead, with standard deviations, and cumulative percent of run for the Hunt Road Channel (or West Channel) of the Elwha River in 2020. Total passage for this channel was 647 steelhead.

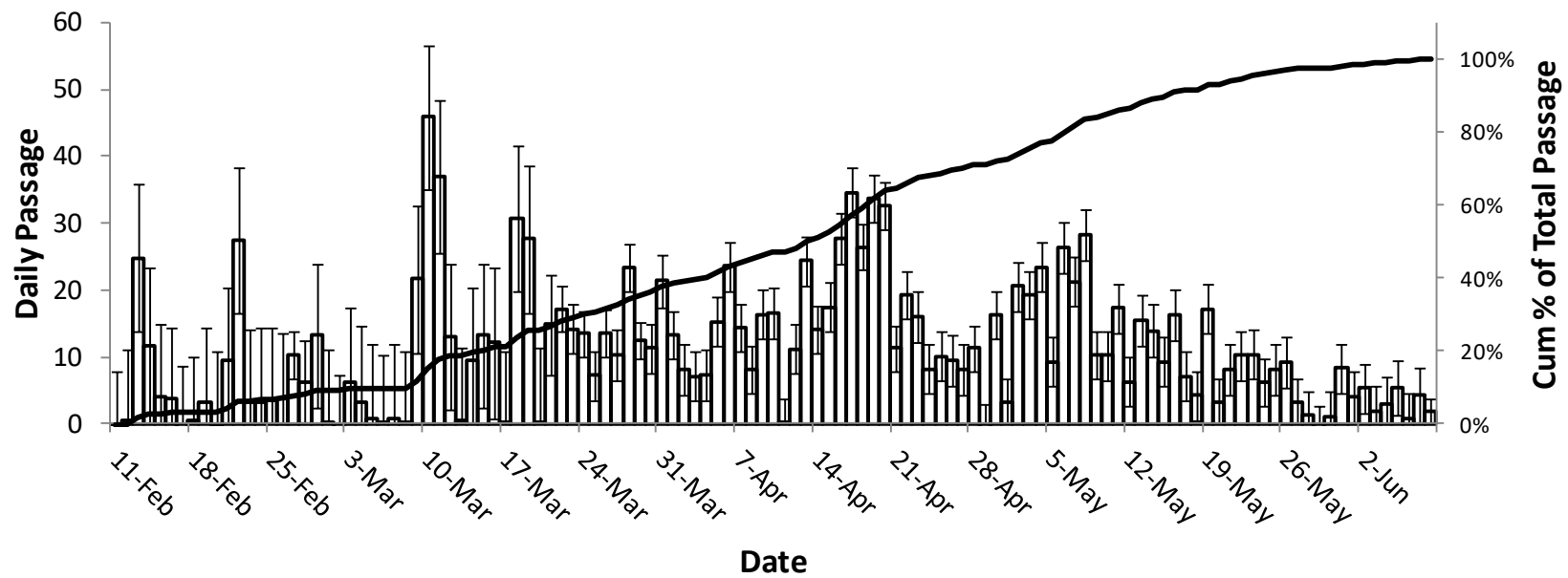


Figure 10. Daily passage estimates for steelhead, with standard deviations, and cumulative percent of run for the Old Mainstem (or East Channel) of the Elwha River in 2020. Total passage for this channel was 1,338 steelhead.

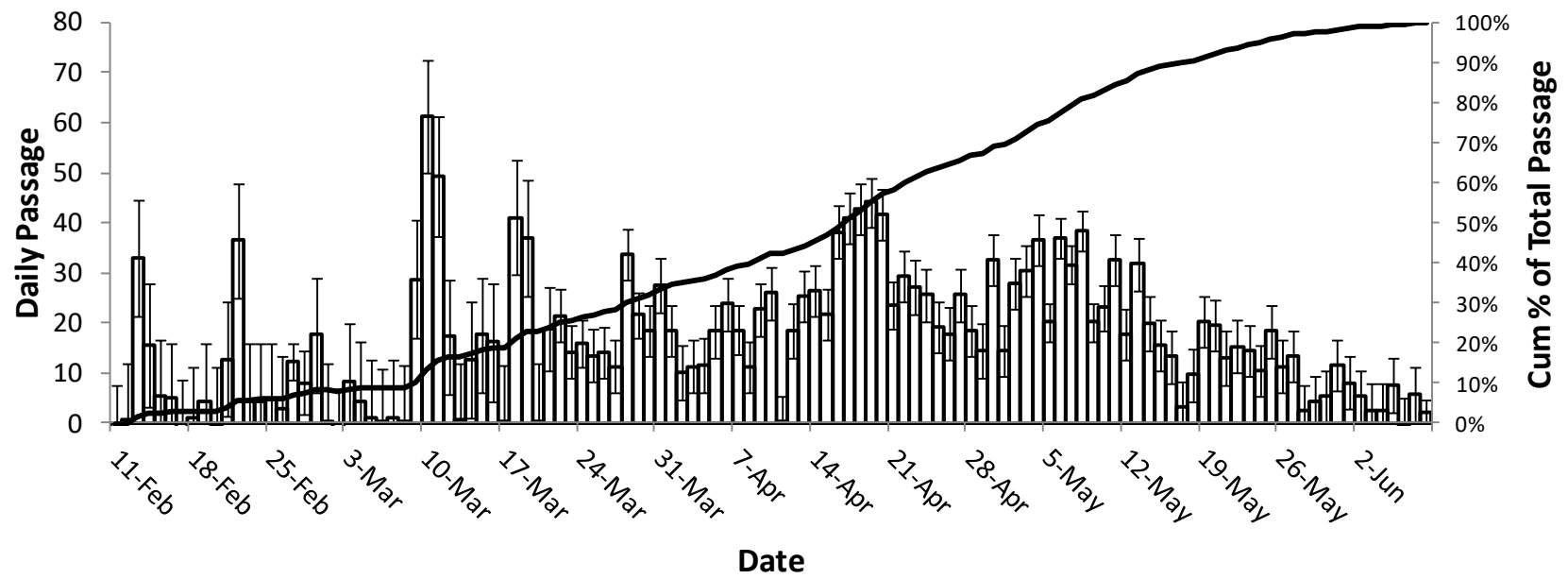


Figure 11. Daily passage estimates for steelhead, with standard deviations, and cumulative percent of run for both channels the Elwha River in 2020. Total passage estimate was 1,985 steelhead.

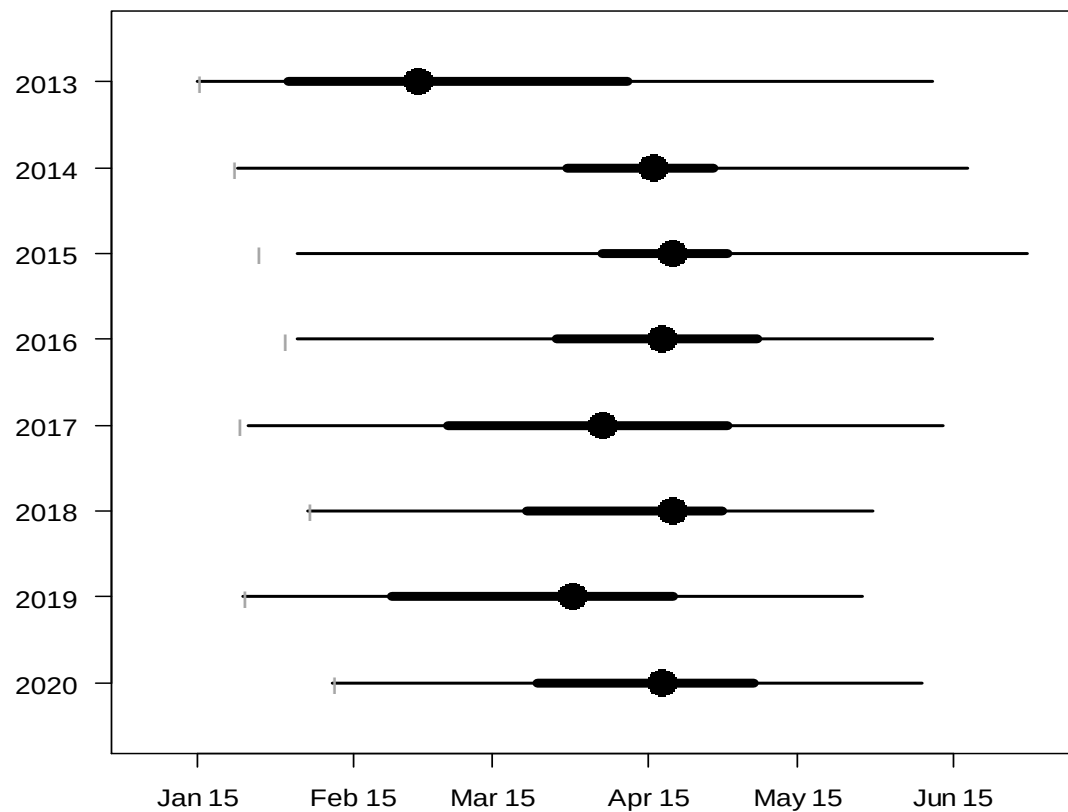


Figure 12. Run timing of steelhead in the Elwha River from 2013 to 2020. For each year the small vertical gray line shows the install date, the long thin black line encompasses the first fish detection until the end of the run. The thick black line shows the time period during which 25% to 75% of the run passed the SONAR sites. The black dot shows when 50% of the run had passed.

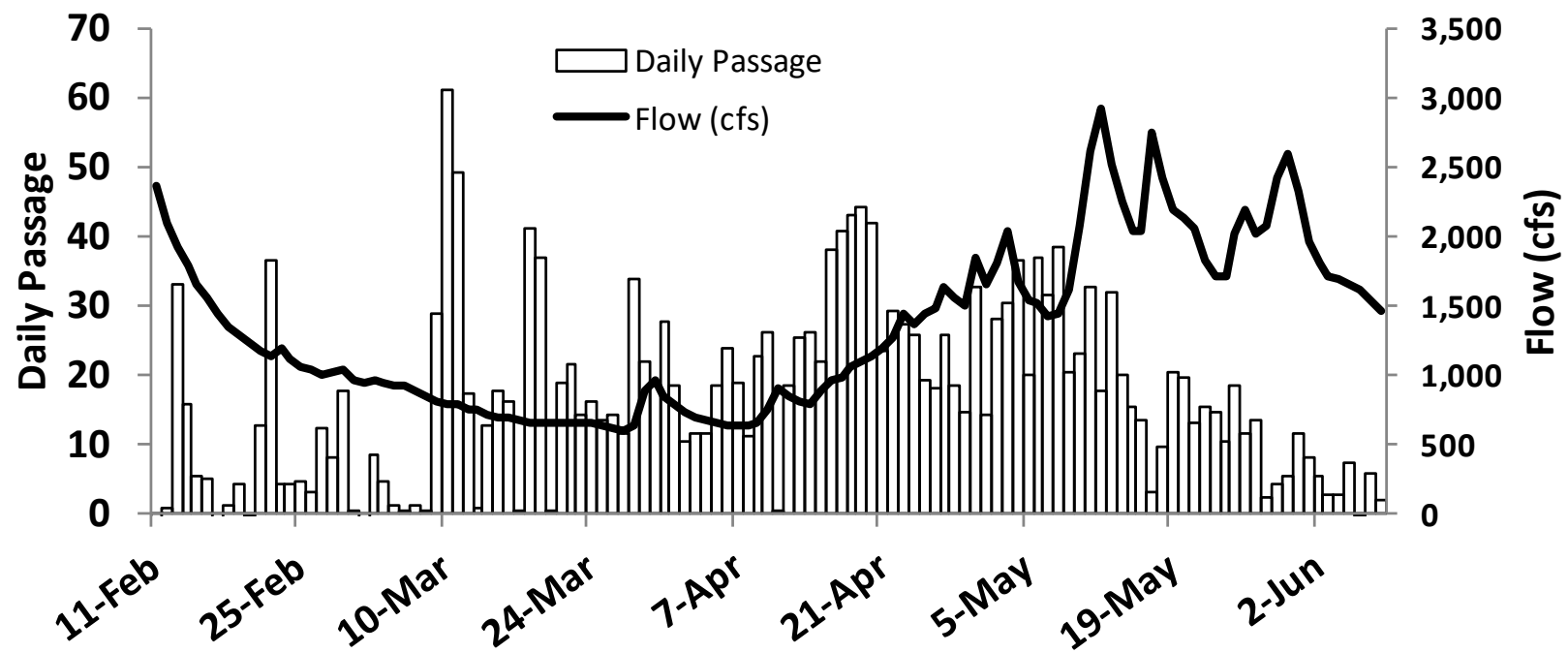


Figure 13. Daily passage of steelhead and flow (cfs) in the Elwha River in 2020.

