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Hoh River Steelhead Project 2016 Annual Report

by John Winkowski, Mara Zimmerman, and Keith Denton

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Hoh River Steelhead Project

2016 Annual Report

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Executive Summary

The purpose of Hoh River Steelhead Project is to better explain steelhead abundance trends and how they are related to survival and diversity in marine and freshwater environment. The program is led by the Science Division at the Washington Department of Fish and Wildlife and is a collaborative effort with managers and stakeholders. In 2016, we conducted pilot studies and our work included sonar siting and operation and a volunteer angler study.

We surveyed the main stem Hoh River and identified multiple locations that may be suitable for sonar (adult monitoring) and smolt trap (smolt monitoring) operations. We further evaluated the feasibility of three potential sites with an ARIS Explorer 1800 sonar. One location was selected for future work based on the image quality, site access, site security, and ability to account for harvest above and below the location. A flow of ~4,500 cubic feet per second will be used as an upper threshold for sonar operation. Based on stream flows over the past decade, the highest frequency of sonar outages will occur between November and January (67 to 78% operational) whereas the sonar is predicted to be operational at least 85% of the time in the remaining months of the year. In 2016, the sonar was operated intermittently at three different locations and recorded data 59% of the time between February 10 and May 20, 2016. In total we observed 1,889 fish targets (> 55 cm fork length) moving upstream and 750 fish targets moving downstream. In the future, species composition sampling will be needed to apportion counts of the fish targets observed in the sonar imagery to specific species.

A volunteer angling program collected biological data including location, origin (hatchery or wild), gender, length, girth, and scales. Scales were used to describe steelhead residency in freshwater and ocean environments as well as repeat spawn rates. Steelhead averaged 73.0 cm fork length and 33.5 cm girth with males being slightly longer and wider than females. Residency of wild steelhead ranged between one and three years in freshwater and two to four years in the ocean. Five percent of females and no males were repeat spawners. Multiple years of sampling should improve understanding of how steelhead life histories are associated with time of entry and location of return. Recommendations developed for the 2017 field season include continual operation of the sonar between January and June, in-stream tangle netting to interpret species composition, continuation and expansion of the volunteer angling program with a focus on increasing the spatial coverage of the data collection to include the South Fork Hoh River and the Hoh River within Olympic National Park.

Introduction

Background

The purpose of Hoh River Steelhead Project is to better explain steelhead abundance trends and how they are related to survival and diversity in marine and freshwater environments. From this information, we aim to increase understanding of steelhead biology and ecology, fill information gaps needed for steelhead management, and improve resiliency of steelhead populations in the face of an uncertain future (i.e., climate change). To the extent that some questions are specific to the Hoh River, results will have a local contribution to conservation and management. However, results of this research will also inform steelhead management more broadly as steelhead life cycle parameters (e.g., marine survival, redds per female) are poorly documented and rarely available for river systems as large as the Hoh River. The program is led by the Science Division at the Washington Department of Fish and Wildlife and is a collaborative effort with managers and stakeholders.

A research framework for the Hoh River Steelhead Project was developed in 2015. In 2016, we conducted pilot studies that included sonar siting and operation and a volunteer angler project. The long-term purpose of the sonar is to develop an independent estimate of steelhead abundance that can be paired with existing redd count information. The long-term purpose of the volunteer angler program is to document steelhead life history diversity using a core group of citizen scientists that collect biological information from the steelhead that they catch. In the future, there are several studies envisioned to address the connection between life history diversity, entry timing and spawn timing that will be implemented once funding becomes available.

2016 Objectives

This report summarizes results from the first pilot field season. In 2016, our objectives were to:

(1) Identify potential locations for operating a sonar and smolt trap,
(2) Evaluate the feasibility of sonar operation at multiple sites,
(3) Explore potential for a volunteer angling program, and
(4) Describe the biological diversity of steelhead with respect to time and location of capture.

Methods

Siting Sonar and Smolt Trap Locations

Satellite imagery and a research float were used to site locations for operation of a sonar and smolt trap in the river. A few potential locations for operating a sonar and smolt trap were identified based on criteria associated with operation of each type of monitoring equipment. The feasibility of operating the sonar equipment was further field tested at a subset of these identified locations.

Criteria used to identify potential sonar locations included channel shape, river access, and site security. Channel shape that generates quality imagery includes a sloping gravel bar on one side of the river, lack of structure along the cross-section of the channel (i.e., no large boulders or wood debris), and a vertical bank on the far side of the river. River access ensures that equipment can be transported into and out of the river with limited staff (two people) in a time efficient and safe manner. Access was important because operation of the sonar is expected to be responsive to river flows and the equipment will be removed and reinstalled multiple times in-season given the variable flow levels experienced during the steelhead return timing. Site security was assessed based primarily on the ease of public access to the location with less access considered to be more secure.

Criteria used to identify potential smolt trap locations included a confined river channel with a defined thalweg, suitable anchor points, river access for trap installation and removal, and locations to shelter the trap during high flow events. A confined thalweg is needed to increase the proportion of outmigrating smolts that are caught in the trap. A confined thalweg generates high flow velocities that are especially important to capture steelhead smolts which are strong swimmers and the most difficult to capture among outmigrating salmonids. Suitable anchor points are needed to stabilize the trap, position the trap within the channel, and move the trap into sheltered areas during flow events. River access is needed for installing and removing equipment the size and weight of a smolt trap. Specifically, a crane may be needed to move the trap in and out of the river. Locations to shelter the trap in the river will be essential for in-season responsiveness to flow events.

Sonar Feasibility

The feasibility of sonar operation was evaluated at three locations – Oil City Spur, Lower Oxbow, and Upper Oxbow (Figure 1) – which were selected from the research floats described above. An ARIS Explorer 1800 sonar was attached to a pole mount fastened to an aluminum ladder which was anchored to the river bed with rebar (Enzenhofer and Cronkite, 2005). A cable was fastened to the ladder and pole mount and attached to a tree on the bank to act as a safety anchor. Data from the sonar array was recorded on a ruggedized laptop powered by four 12V batteries contained in a steel rigid box located on the stream bank (Figure 2). Batteries in sets of two were wired in series to create two 24-volt banks. The two banks were then wired in parallel to increase amperage (approximately 400 amp/hrs). This battery wiring allowed for roughly 5-7 days of sonar operation before the batteries needed to be exchanged. Based on cable length, the positioning of batteries and equipment was limited to a ~200 foot radius from the sonar.

The sonar was operated between the months of February and May across the three sites. Criteria used to evaluate the feasibility of sonar operation at these sites included (1) image quality, (2) site security, (3) potential for accounting for fish removed by harvest, and (4) fish behavior. High quality images were easily identified by the fish shapes on the echogram that had a strong contrast with background imagery (Figure 3). Site security was assessed primarily with respect to public access with less access considered to be more secure. The potential to account for harvested fish was highest at locations near the US-101 bridge because this location is a geographic break point in the reporting of harvested fish. The US-101 location is the upstream extent of the tribal net fishery and sport harvest upstream and downstream of this location is reported separately on the catch record cards submitted by anglers. Fish behavior conducive to sonar counts were clear, directional movements and minimal milling of individuals within the area of river channel ensonified (i.e., filled with sound) by the sonar.

Feasibility of the sonar operation was also evaluated with respect to the maximum flows under which the sonar could be safely operated in the river. During the winter and early spring, the Hoh River is subject to rapidly rising water levels accompanied by heavy debris loads that would result in substantial loss if the sonar equipment was not removed from the river. In the future, we envision having a set-up and removal process for the sonar operation that is flexible and responsive to river conditions and would allow removal (and re-installation) within a two to three hour time frame. In 2016, we identified flow levels that would serve as maximum threshold for operation used to identify the flows under which the entire unit – sonar and equipment – could be retrieved or reinstalled. The threshold was identified across sites based on flow levels at which staff could safely reach the sonar for retrieval and at which the job box with batteries and equipment remained above the high water mark. We then retrieved flow information for the past ten years on the Hoh River (USGS # 12041200) and calculated the proportion of days each month that fell below this flow threshold.

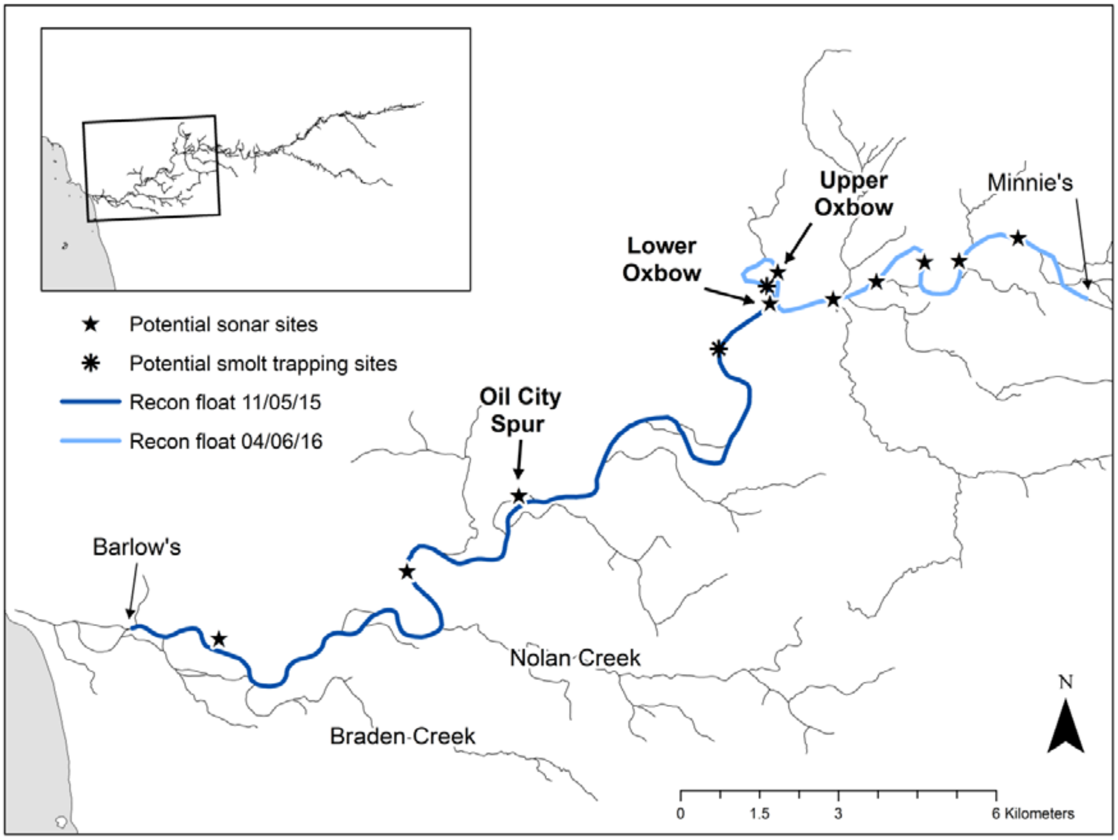


Figure 1. Potential sites for smolt trap and sonar operation on the Hoh River identified during research floats conducted in November 2015 and April 2016. In 2016, sonar equipment was installed and operated in the river to further evaluate the suitability of three locations (Oil City Spur, Lower Oxbow, and Upper Oxbow).

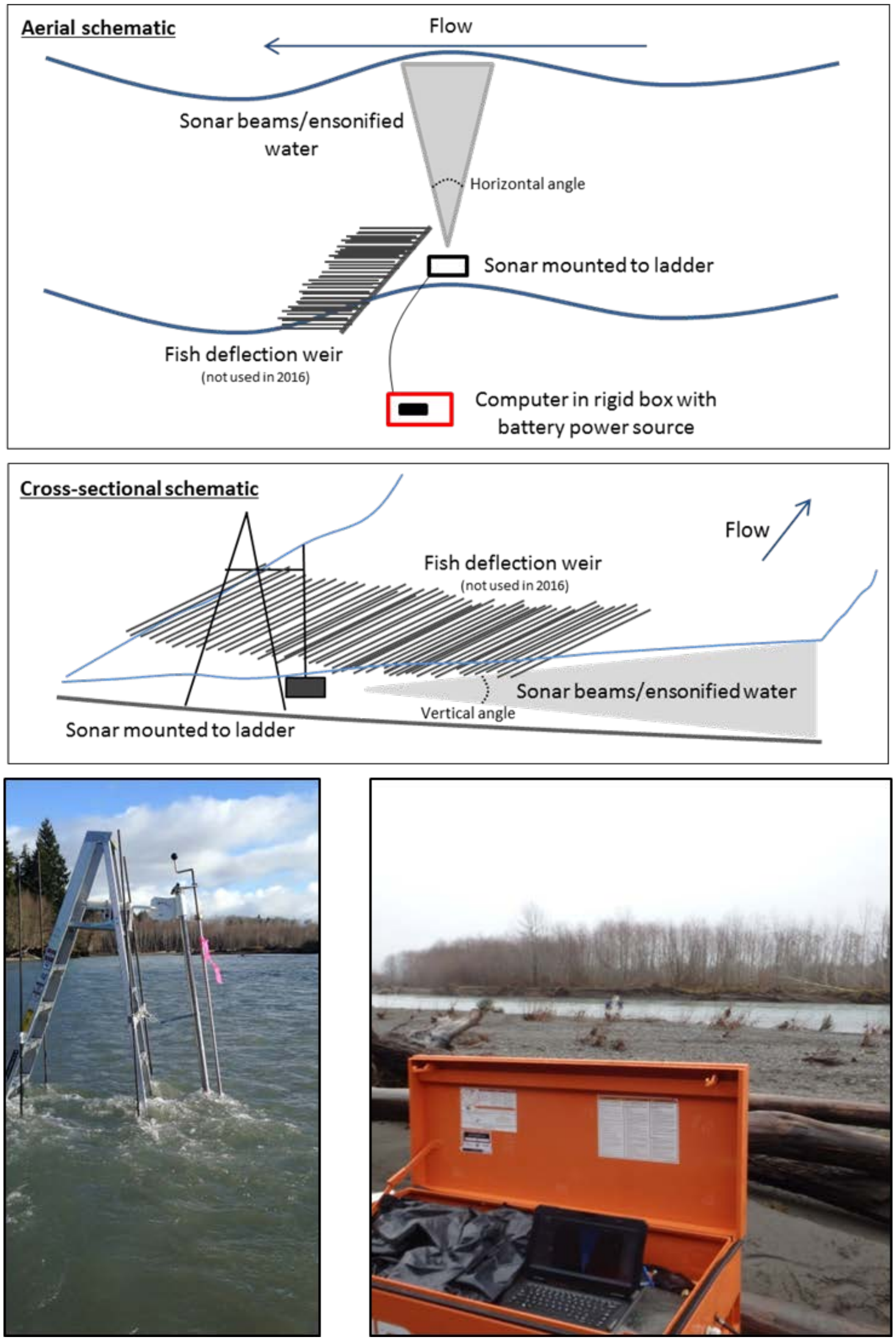


Figure 2. Schematics and photos of sonar equipment deployed at the Oil City Spur site in Hoh River, 2016. Top panel is aerial schematic showing layout of the sonar equipment in the stream channel. Middle panel is a cross-sectional schematic of the sonar equipment in the stream channel. Bottom left panel shows the ladder and pole mount (sonar is secured at base of pole mount just below the water surface). Bottom right panel shows the utility box used to contain batteries (power) and laptop computer (data storage). Notes: the fish deflection weir was not used in 2016 but is included in the diagram. The function of the fish deflection weir is to alter an upstream swimming fishes path into the optimally ensonified portion of the river as it passes the sonar. The angle of which the sonar beams spread horizontally and vertically is not to scale. The horizontal angle is always 28°. We utilized an 8°vertical concentrator lens at the Oil City site and a 14° standard lens at the other 2 sites.

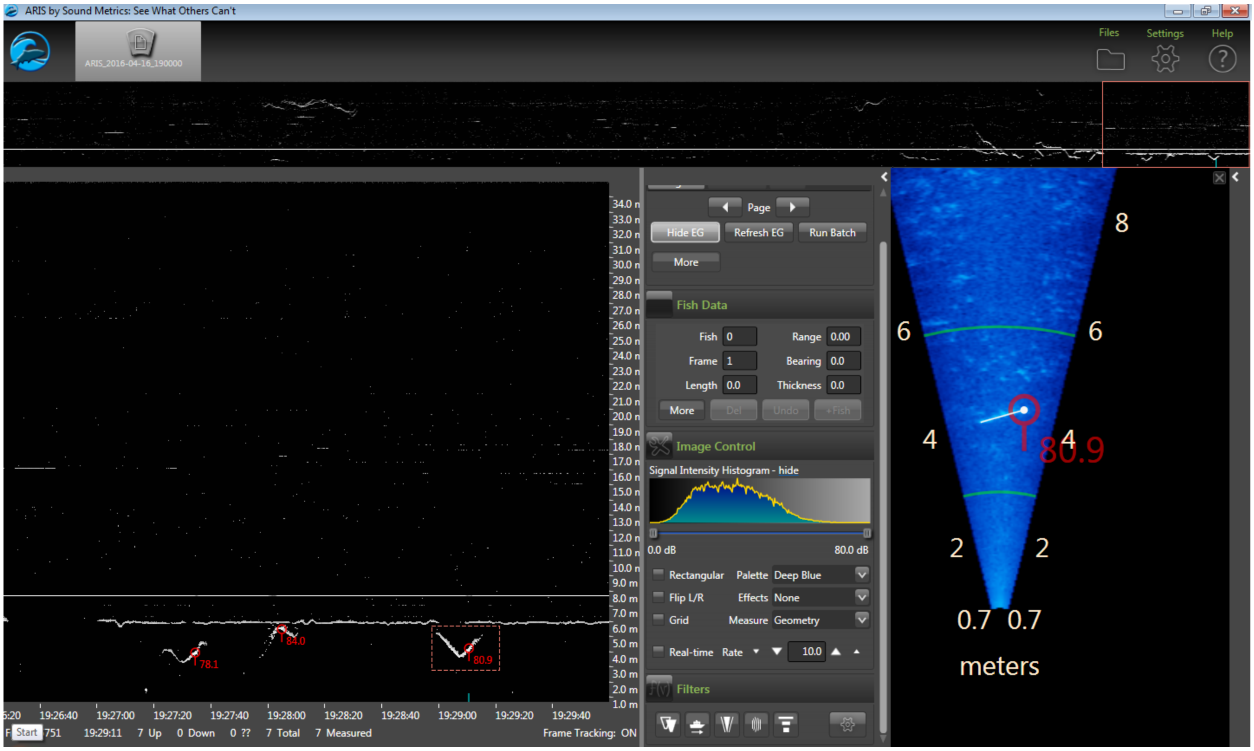


Figure 3. Example of echogram used to evaluate fish movements using the ARIS sonar. The echogram is produced by ARISFish software and is used to visualize the ARIS sonar data. The three panels shown represent different resolution of the data. Top panel represents an entire 30 min time sequence. Bottom left panel zooms into a five minute time sequence identified by the solid red frame in the top panel. Bottom right panel zooms into one frame of the raw sonar imagery identified by the small white vertical line within the dashed red frame in the left bottom panel. White markings in each panel represent a solid structure encountered by the sonar beam. Curved or squiggled white marks represent fish moving through the sonar beam. The length of the fish target and its distance from the sonar can be measured by the ARISFish software (as shown in the lower right panel).

Fish Movements Recorded by Sonar

Raw data from the sonar were recorded using ARISScope software provided by the manufacturer. Raw data files were stored in 30 minute increments (approximately 0.8 gigabytes per file) and were visualized as echograms using ARISFish software. Fish are 'visible' on the echogram as bright (or white) marks that indicate a change in density in the water column encountered by the sound-wave beams emitted and returned to the sonar. Each 30-minute echogram was reviewed in its entirety for fish targets. Information recorded for each target included date, time, direction of movement (up or downstream), distance from the sonar, body length, and observer confidence. Body length was measured in centimeters using the ARISFish software. An observer confidence of "1" indicated that the reviewer was confident that the target was a fish based on visual clarity, shape, and movement behavior and that the object traversed the entire ensonified area in the marked direction. An observer confidence of "2" indicated that the target was "probably" a fish passing all the way through the imagery in the indicated direction, or "definitely" a fish passing through the imagery in the indicated direction but only observed crossing a portion of the imagery. An observer confidence of "3" was determined by the reviewer to probably not be a fish (e.g., boat, waterfowl, etc).

Standardization of the process to identify and measure targets is critical to successful use of the sonar for fish enumeration (Holmes et al. 2006). The reliability of reviewer counts will be included as a quality control measure each year to understand the extent that observer error contributes uncertainty to the final estimate. In 2016, we had one expert and two naïve reviewers provide independent review of the same six days of sonar data files. We then compared the upstream and downstream counts and lengths measured independently by the reviewers. Because two of the reviewers were naïve to the echogram data processing, this comparison was also used as a training tool. Following each independent review, the reviewers compared results and reviewed the individual echograms to discuss discrepancies in the results. Given the pilot nature of this work, consistency of the count and length measures among reviewers is expected to be a 'worst case scenario' that will improve as staff working on this project become familiar with the echogram review process.

For the purpose of describing fish counts and directional movements over the entire data set, results from a single observer were used to summarize the data. Targets greater than or equal to 55 cm in fork length were summarized by date with upstream and downstream movements summarized separately. Fish movements in upstream and downstream directions were summarized by day over the entire study period and depicted visually.

Volunteer Angling Program

Volunteer anglers were recruited to assist in biological data collection of steelhead caught on the Hoh River. Training was required for participation in the research and was accomplished through a workshop as well as one-on-one training as needed. Anglers followed all fishing regulations with respect to gear type, location, timing, and retention. In addition, each angler was provided written letters of permission from WDFW Region 6 office and the National Park Service (NPS) to handle and collect biological samples from captured steelhead. To ensure that the data were reflective of the steelhead population, participants were required to collect biological data from all steelhead captured unless safety precluded the completion of sampling.

The training included a presentation that described the purpose of the project, the biological data to be collected, and the methods for collecting and recording data. Sampling kits were distributed to all volunteer anglers and included a tape measure, hemostats, scale envelopes, pencils, map of the study area, an example of a scale envelope completed with the data, and permission letters from WDFW and the NPS. Anglers collected data from five sections of the river that were defined by common entry and exit points for boats accessing the river (Figure 4). Section 1 was the stretch of river downstream of Oxbow campground and US-101. Sections 2 and 3 were the stretches of river upstream of Oxbow and downstream of the South Fork Hoh River confluence. Section 4 was the Hoh River upstream of the South Fork Hoh River confluence and lay entirely within Olympic National Park. Section 5 was the South Fork Hoh River; a portion of this reach was within the national park boundary.

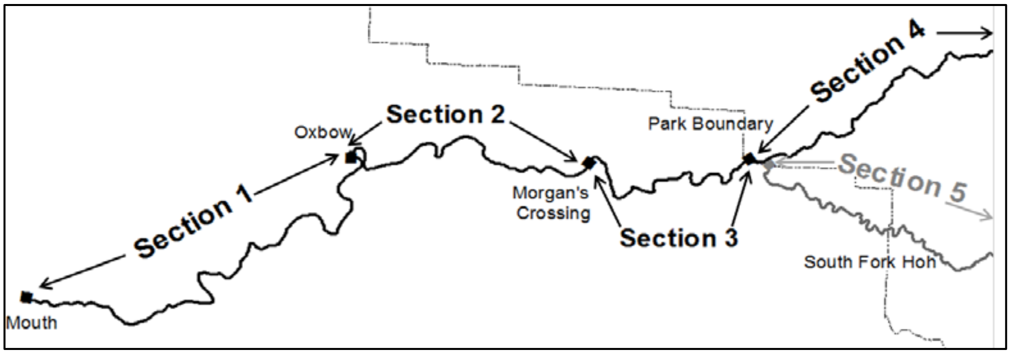


Figure 4. Study area where anglers collected biological data from steelhead caught on the Hoh River in 2015-2016. The river was divided into five sections so that biological characteristics could be compared among sections.

Biological Characteristics of Steelhead

Biological data collected from each steelhead included length, girth, and scales. Length was the fork length of the fish. Girth was the widest circumference of the fish anterior to the dorsal fin. A total of ten scales were collected (five each side) from the preferred area of the fish (Figure 5). Additional information collected included hatchery/wild origin (based on mark status), capture location (Section 1-5, see Figure 4), male/female, and additional comments (e.g., kelt, net marks, seal scrapes, lamprey wounds). Sampling was designed to take approximately 90 seconds per fish.

In the field, anglers deposited scales into the provided scale envelopes (one envelope per fish) and data from the corresponding fish were recorded on the outside of the envelope (Figure 6). Anglers transferred scale envelopes to WDFW staff throughout the season. A portion of the scales (up to six) were transferred from the envelopes to scale cards for pressing and analysis. Scale ages were assigned and the scale cards deposited with the WDFW Fish Ageing Lab. Voucher scales were retained as genetic material by the WDFW Molecular Genetics Lab and the National Park Service.

The origin of individual fish was assigned based on mark status in the field (unmarked = wild, adipose clipped = hatchery) and scale information. Scale readings provide an independent assignment of origin based on differential growth rates of wild versus hatchery fish in the freshwater environment (river vs. hatchery pond). A portion of hatchery fish do not have a visible external mark due to errors in the clipping process or fin regeneration, and the scale method (coupled with external marks) can be used to refine the origin assigned to the fish.

Data were summarized to depict the variation in body size and age structure of steelhead. Catch was summarized by section of the river and fish origin (wild, hatchery). Length, girth, age class, and repeat spawn rates were summarized for male and females. Diversity in age structure was further summarized among study sections (1-5) to describe variation in total age, freshwater age, and ocean age. Total age was the number of years between emergence from the gravel and return to the river to spawn. Freshwater age was the number of years between emergence from the gravel and smolt outmigration. Ocean age was the number of years between smolt outmigration and returning to spawn.

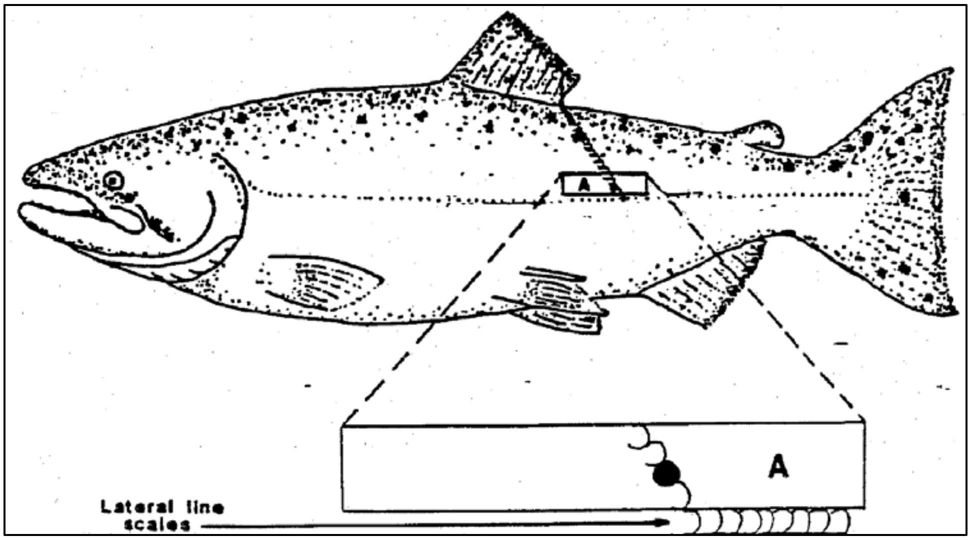
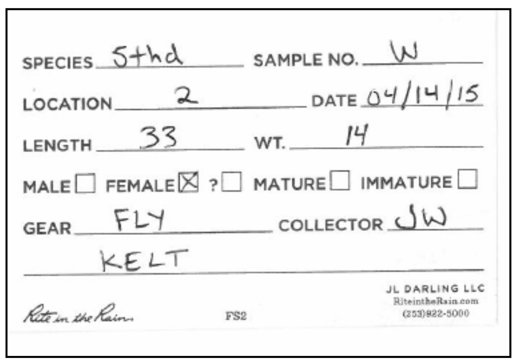


Figure 5. The preferred area for collecting scales for age and growth analysis is posterior to the dorsal fin and just above the lateral line. The area is about 15 scales wide and 5 scales high.



SPECIES Sthd SAMPLE NO. W
LOCATION 2 DATE 04/14/15
LENGTH 33 WT. 14
MALE ☐ FEMALE ☒ ? ☐ MATURE ☐ IMMATURE ☐
GEAR FLY COLLECTOR JW
KELT

Rite in the Rain FS2 JL DARLING LLC RiteintheRain.com (253)922-5000

Figure 6. Example data recorded on scale envelope. Hatchery (H) or Wild (W) was recorded in the 'Sample No.' field. Location refers to the identified river sections. Length and girth were recorded in inches (girth was recorded in the 'Wt.' field).

Results

Siting Sonar and Smolt Trap Locations

We conducted two research floats of the Hoh River. On November 5, 2015, we floated a 12.5 mile stretch of the Hoh River between Hoh Oxbow Campground and "Barlow's" (Figure 1). River flows on the day of this float were 3,000 cfs. On April 6, 2016, we floated a 5.5 mile stretch of the Hoh River between "Minnie's" and Hoh Oxbow Campground (Figure 1). River flows during this float were 2,580 cfs.

There were multiple locations with channel configurations identified as suitable for sonar operation (Figure 1). The combination of long gravel bars and hard cut banks with gravel and cobble substrate in the channel cross section provided multiple possible locations to further explore sonar feasibility.

In contrast to the good potentials for sonar operation, just two sites were identified to have the thalweg characteristics needed to effectively operate a smolt trap in the section of Hoh River main stem that was included in our floats. These sites were subsequently visited several times under different flow levels throughout the spring. Based on these additional observations, we had significant concerns regarding the suitability of both potential sites for operating a smolt trap. The first potential site, close in proximity to the Lower Oxbow (Figure 1), had suboptimal access for installation and removal of smolt trap equipment. In addition, this site was revisited during a high flow event (>10,000 cfs) where we identified a lack of suitable flow refuges during high flows. This means that trap infrastructure installed at this site will have a high likelihood of sustaining damage during spring flow events. The second potential site, near Allen's Bar roughly 1 mile downstream from Lower Oxbow (Figure 1), had water velocities that may be sub-optimal for the capture of steelhead smolts. In addition, this location was characterized by a wide floodplain which meant that anchor points (i.e., large trees) for the trap cables were too far from the river to allow the trap to be safely anchored and positioned in the channel. If smolt trap operations were to proceed at either location, interactions with boat traffic on the river will need to be considered and accommodated for in the trap operation planning. These interactions are likely to occur in the first portion of the steelhead smolt outmigration (mid-March to mid-April) but would subside once the river is closed to fishing on April 15th.

Sonar Feasibility

After considering the potential sonar sites, three locations were selected for further evaluation of sonar feasibility. The Oil City Spur and Lower Oxbow site were identified during the November 5, 2015 float. An additional site – Upper Oxbow – was identified during the April 6, 2016 float. Oil City Spur was the downstream most site selected (Figure 1).The sonar recorded data from this location for a total of 21 days. The Oil City Spur site was characterized by good imagery, poor site security, difficulty in accounting for harvest, and good directional fish movements (minimal milling, Table 1). The Lower Oxbow site was located at the downstream extent of the Hoh Oxbow (Figure 1). The sonar recorded data from this location for a total of 10 days. The Lower Oxbow site was characterized by poor imagery and poor site security, good ability to account for harvest, and good directional fish movements (Table 1). The Upper Oxbow site was located at the upstream extent of the Hoh Oxbow (Figure 1). The sonar recorded data from this location for a total of 28 days. The Upper Oxbow site was characterized by good imagery, good site security (private landowner), good ability to account for harvest, and good directional fish movements (Table 1).

Table 1. Criteria used to evaluate the feasibility of sonar operation at three locations on the Hoh River. A (+) indicates that the site met the needed criteria. A (-) indicates that the site did not meet the needed criteria.

Criteria	Oil City Spur	Lower Oxbow	Upper Oxbow
Imagery	+	-	+
Site Security	-	-	+
Account for harvest	-	+	+
Fish movements	+	+	+

A flow threshold of 4,500 cfs was identified for sonar operation based on field observations in 2016. This threshold was selected as a benchmark for projecting seasonal operation and planning operations but will likely be refined through additional experience operating the sonar in the future.

In the past twelve years (2005-2016), daily flows have exceeded 4,500 cfs in all months of the year except July and September (Figure 7A). As a result, effective sonar operation will require planning for a removal and reinstallation system that is flexible and responsive to variable river flows. Sonar operation will be the most limited in the months of November, December, and January. On average, flows during these months were suitable for sonar operation between 67 and 78% of the time (Figure 7B). During the months of February, March, and October, flows in an average year were suitable for sonar operation an average of 85 - 90% of the time. In the remaining months of the year, flows in an average year have been suitable for sonar operation more than 90% of the time. These results suggest that the sonar should be operated approximately 85% of the time given average river flows during the majority of the winter steelhead return to the river (February to May). However, more frequent outages can be expected in higher flow years and analytical solutions for estimating fish movements during the outage periods will be required to provide full season estimates of winter steelhead.

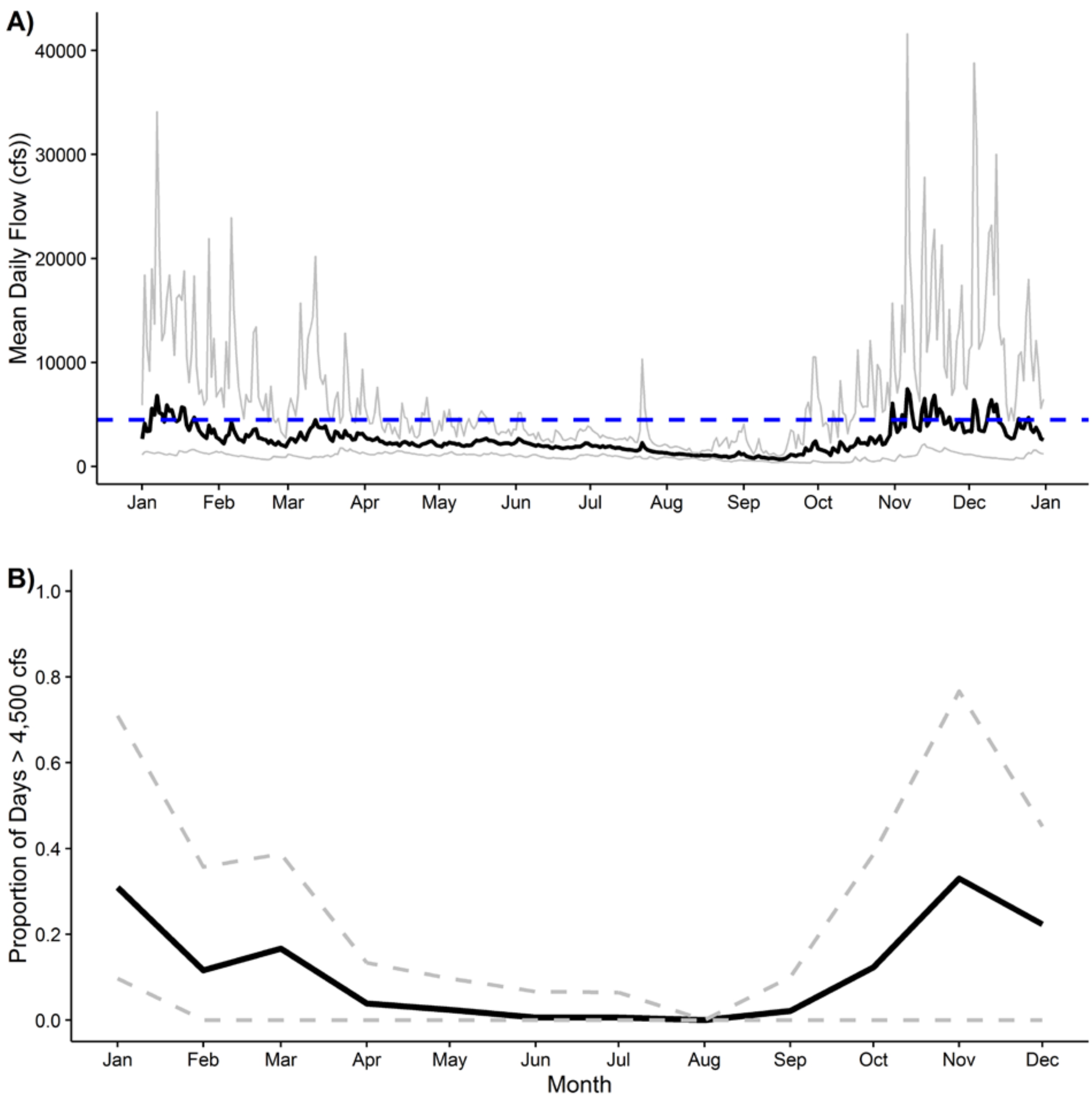


Figure 7. Hoh River flows (USGS # 12041200) summarized by month based on data between December 2004 and May 2016. Panel A shows the daily flow statistics during this period including the mean (black) and range (gray) of daily flows and the sonar operational threshold shown as the horizontal blue dashed line. Panel B shows monthly proportion of time with flows suitable for sonar operation. Graph shows mean (black) and range (gray dashed) of the monthly proportions.

Multiple Observer Analysis of Sonar Data

Three different days of data from two different sites were reviewed and counted by three different observers. An additional two days of data from an additional site were reviewed and counted by two of the observers. Observer A was the expert and Observers B and C were naïve to sonar data interpretation. Three different criteria were used to compare results among observers: 1) tally of all upstream and downstream moving fish that measured between 55 cm and 115 cm and were of observer confidence ‘1’; 2) all fish from criteria 1 in addition to fish that measured between 50 cm and 55cm, and 3) all fish from criteria 1 and 2 in addition to fish of observer confidence level ‘2’.

Across sites and analysis criteria, counts among observers varied from complete agreement to ~66% discrepancy on a given day, with greater agreement among observers generally corresponding to higher fish passage rates (Table 2). For each observer, the sum total of all upstream counts (all sites and dates) varied between 12% and 22% difference depending on the analysis criteria. A smaller variance in the total counts among observers as compared to any individual site or date differences indicates that although counts may vary on a site or date basis, systematic observer bias seems to be less of an issue.

An analysis on the number and percentage of fish targets identified as observer confidence ‘2’ can help standardize the protocol for consistent recording of confidence designations. The majority of fish targets labeled as observer confidence ‘2’ were moving downstream (Table 3). This phenomenon is typical of other sonar projects (Denton et al. 2014, 2015). The one site (Lower Oxbow) with significant numbers of upstream passage events labeled observer confidence ‘2’ had a large boulder located midstream (in addition to overall poor imagery) which compromised the ability of the sonar to record fish moving across the entire latitudinal (upstream/downstream) extent of the image.

Frequency histograms summarizing the distance of each fish target from the sonar were generated for each site to provide insight on the main path(s) of passage for both upstream and downstream moving fish at each site. Upstream moving fish tended to pass upstream closer to one of the banks while downstream moving fish were more evenly distributed across the channel (Figure 8, 9, 10). At the Lower Oxbow site, the relative lack of fish moving in either direction on the far side of the channel was likely related to the inability of the sonar to sufficiently monitor the far bank at that site (Figure 10).

In addition to the quantitative analysis presented above, qualitative observations from each site were also used in our evaluation. Overall imagery from both the Oil City site and Upper Oxbow imagery was “good” to “excellent” whereas imagery for the Lower Oxbow site was “fair” to “poor”. Milling of fish on the far bank was observed on some days at the Upper Oxbow site and increased the processing time to make accurate counts. Further, the high counts of fish targets observed at the Upper Oxbow site in April and May likely included some bull trout and spring Chinook salmon. Both bull trout and spring Chinook salmon are known to move from salt water and the lower river to upstream spawning locations throughout the spring and their lengths overlap with steelhead. Additional work will need to occur to apportion sonar targets to species.

Table 2. Number of fish counted from sonar imagery by three independent observers. Data are summarized for two length cutoffs (50 and 55 cm fork length) and two levels of confidence that the observed target was a fish (1 = high confidence, 2 = moderate confidence).

			≥ 55 cm, Quality 1			**≥ 50 cm, Quality 1**			**≥ 50 cm, Quality 1 & 2**		
Site	**Date**	**Observer**	**Up**	**Down**	**Total Upstream**	**Up**	**Down**	**Total Upstream**	**Up**	**Down**	**Total Upstream**
Upper Oxbow	4/17/2016	A	117	33	**84**	119	33	**86**	121	36	**85**
Upper Oxbow	4/17/2016	B	102	31	**71**	105	33	**72**	109	35	**74**
Upper Oxbow	4/17/2016	C	89	19	**70**	109	23	**86**	114	33	**81**
Oil City Spur	2/25/2016	A	43	5	**38**	43	5	**38**	46	7	**39**
Oil City Spur	2/25/2016	B	34	3	**31**	36	3	**33**	36	10	**26**
Oil City Spur	2/25/2016	C	36	1	**35**	45	3	**42**	45	7	**38**
Oil City Spur	4/12/2016	A	25	10	**15**	25	10	**15**	25	16	**9**
Oil City Spur	4/12/2016	B	23	7	**16**	23	7	**16**	23	13	**10**
Oil City Spur	4/12/2016	C	20	10	**10**	22	10	**12**	23	21	**2**
Lower Oxbow	3/16/2016	A	15	0	**15**	15	0	**15**	15	2	**13**
Lower Oxbow	3/16/2016	B	---	---	**---**	---	---	**---**	---	---	**---**
Lower Oxbow	3/16/2016	C	6	0	**6**	10	0	**10**	11	1	**10**
Lower Oxbow	3/20/2016	A	26	11	**14**	26	11	**14**	45	16	**29**
Lower Oxbow	3/20/2016	B	---	---	**---**	---	---	**---**	---	---	**---**
Lower Oxbow	3/20/2016	C	25	12	**13**	33	14	**19**	38	22	**16**

Table 3. Number of fish with observer confidence ‘2’ obtained from sonar imagery by three independent observers. Data are counts and total upstream passage (Up – Down) for targets ≥ 50- cm FL that were recorded with an observer confidence ‘2’.

Site	Date	Observer	Up	Down	Total Upstream
Upper Oxbow	4/17/2016	A	2	3	**-1**
Upper Oxbow	4/17/2016	B	4	2	**2**
Upper Oxbow	4/17/2016	C	5	10	**-5**
Oil City Spur	2/25/2016	A	3	2	**1**
Oil City Spur	2/25/2016	B	0	7	**-7**
Oil City Spur	2/25/2016	C	0	4	**-4**
Oil City Spur	4/12/2016	A	0	6	**-6**
Oil City Spur	4/12/2016	B	0	6	**-6**
Oil City Spur	4/12/2016	C	1	9	**-8**
Lower Oxbow	3/16/2016	A	0	2	**-2**
Lower Oxbow	3/16/2016	B	---	---	---
Lower Oxbow	3/16/2016	C	1	1	**0**
Lower Oxbow	3/20/2016	A	19	18	**1**
Lower Oxbow	3/20/2016	B	---	---	---
Lower Oxbow	3/20/2016	C	5	2	**3**

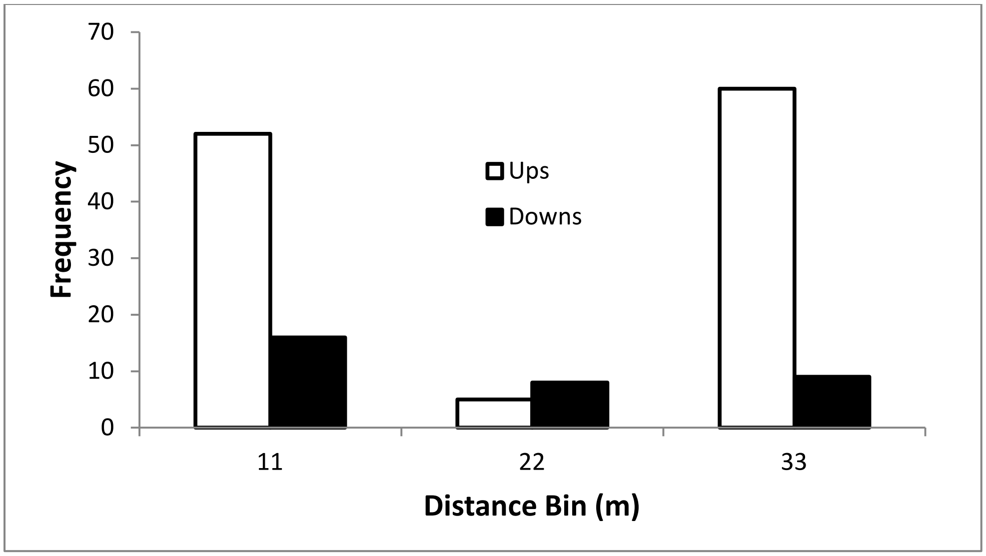


Figure 8. Histogram showing frequency of sonar counts by distance from the sonar head for all fish passage events >55 cm and observer confidence '1' as recorded by Observer A for the Upper Oxbow site on 4/17/16.

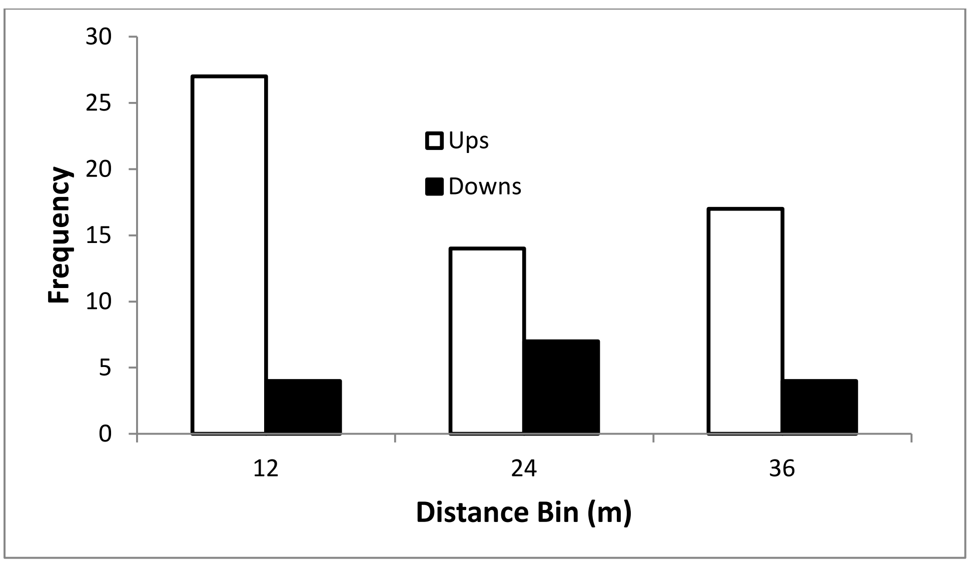


Figure 9. Histogram showing frequency of sonar counts by distance from the sonar head for all fish passage events >55 cm and observer confidence '1' as recorded by Observer A for the Oil City site on 2/25/16 and 4/12/16.

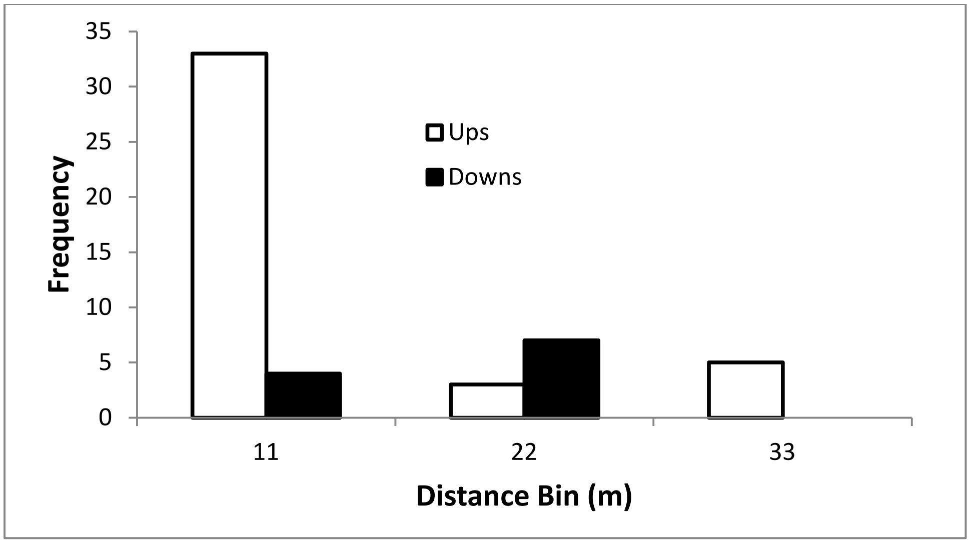


Figure 10. Histogram showing frequency of sonar counts by distance from the sonar head for all fish passage events >55 cm and observer confidence '1' as recorded by Observer A for the Lower Oxbow site on 3/16/16 and 3/20/16.

Fish Counts and Directional Movement

The sonar recorded data over a total of 67 days between February 10 and May 20, 2016. Of the recorded information, a total of 59 days were reviewed for fish movements because the sonar imagery had poor focus during an eight-day period. During this eight-day period, the sonar beams were focused too close to the sonar and fish further away from the equipment could not be distinguished from their background environment. We recorded the most imagery in April and May, 63.3 and 58.1 % of each month respectively, compared to February and March, when we recorded 35.7 and 38.7% of each month respectively (Table 4). We recorded the most imagery at Upper Oxbow (47.5% of the number of total days recorded), followed by Oil City Spur (35.6% of the number of total days recorded). We recorded the least amount of imagery at Lower Oxbow (16.9% of the number of total days recorded). Within the season, we observed poor imagery at Lower Oxbow (due to site characteristics) and thus deliberately terminated recording at this site.

A total of 2,639 passage events (1,889 upstream and 750 downstream) of fish greater than or equal to 55-cm fork length with an observer confidence of '1' were recorded (Table 4). We observed a total of 230 upstream and 27 downstream passage events in February, 143 upstream and 39 downstream passage events in March, 811 upstream and 281 downstream passage events in April, and 705 upstream and 403 downstream passage events in May. The highest proportion of total passage events (sum of upstream and downstream passage events per site as compared to the sum across all sites) was observed at Upper Oxbow (74.1 %), followed by Oil City Spur (20.7 %) and Lower Oxbow (5.2 %, Figure 11). Different proportions of upstream/downstream and total counts among sites likely reflected the duration and the seasonal timing of operation at each location rather than differences in visibility.

However, lower counts observed at Lower Oxbow site may have been further influenced by poor sonar imagery at this location.

Table 4. Summary of sonar results from pilot study on the Hoh River, 2016. Total number of upstream and downstream passage events in sonar imagery by month and the number of days (percentage) of each month recorded.

Month	***No. days recorded (%)***	***Upstream Counts***	***Downstream Counts***
February	*10 (35.7)*	*230*	*27*
March	*12 (38.7)*	*143*	*39*
April	*19 (63.3)*	*811*	*281*
May	*18 (58.1)*	*705*	*403*
Total	*59 (49.2)*	***1889***	***750***

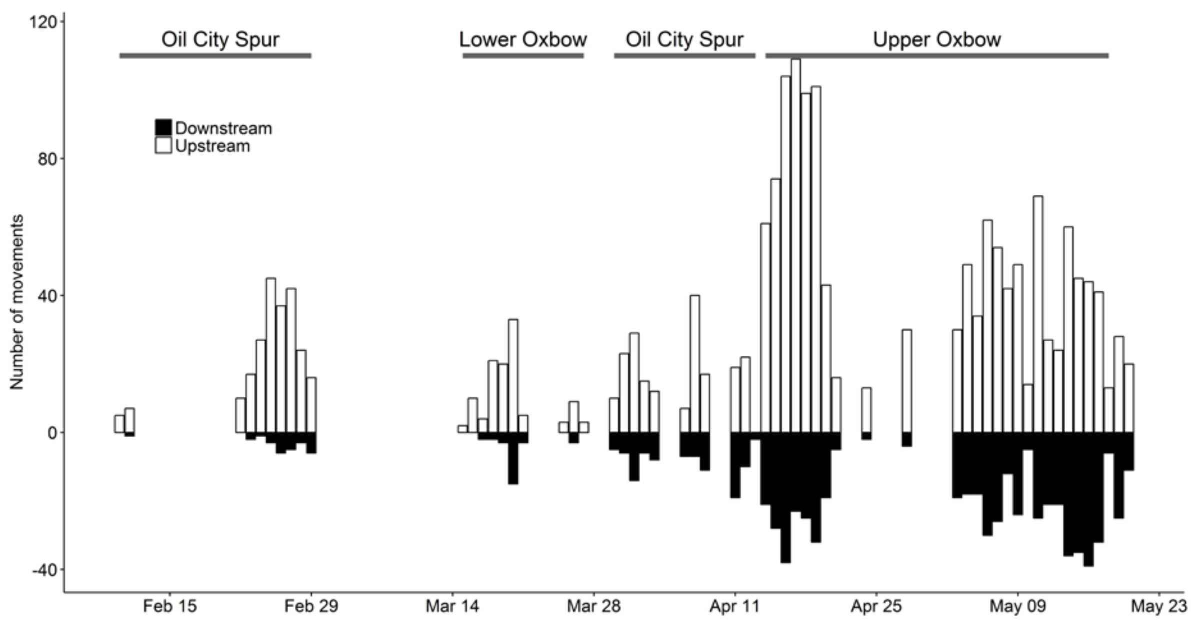


Figure 11. Directional passage events on the Hoh River, 2016 as identified by sonar imagery. Graph shows daily passage events in upstream (white bars) and downstream (black bars, negative values) direction. Horizontal bars indicate the location of the sonar during each time period.

Volunteer Angling Program

A total of 15 volunteers participated in the volunteer angling program. A volunteer training workshop was conducted on December 22, 2015 in Forks, Washington. Thirteen volunteer anglers attended the training and an additional two volunteers were trained on an individual basis throughout the season. A total of eight volunteer anglers provided biological samples representing 53% (8/15) of the volunteers who originally indicated interest in participation. In addition, two WDFW staff contributed samples to the project.

Biological data were collected from a total of 73 steelhead. Of these, 22 (30%) were caught with lures, 50 (68%) were caught with a fly, and one fish (2%) was a carcass. Complete data sets were obtained for 43 steelhead. Incomplete data sets were primarily due to no recorded girth information and uncertainty on male/female assignment.

Biological characteristics of steelhead

The majority (92%) of all steelhead were captured in the lower three sections of the river (Figure 12). Sample sizes from sections 4 and 5 were low enough that no definitive conclusions can be drawn about the composition of fish in these sections. Wild steelhead (n = 63) were captured in all three of the lower sections (as well as section 4 and 5) between the months of December and April. Hatchery steelhead (n = 10) were captured in all three lower sections but only in the month of January.

Steelhead averaged 73.0 cm fork length (± 10.1 cm standard deviation) and 33.5 cm girth (± 6.4 cm). On average, male steelhead were five cm longer than females and six cm wider in girth than females (Figure 13).

Three (3 of 63, 4.8%) of the wild steelhead were repeat spawners (Figure 14). All repeat spawners were female; two females had previously spawned once and one female had previously spawned two times. For maiden spawners (no prior spawn), males had a total of four age classes and females had a total of five age classes.

Maiden spawners had spent one to three years in freshwater and two or three years in the ocean prior to returning to the river (Figure 15). Based on one year of information, there was no discernable relationship between age diversity and the location or timing of collection.

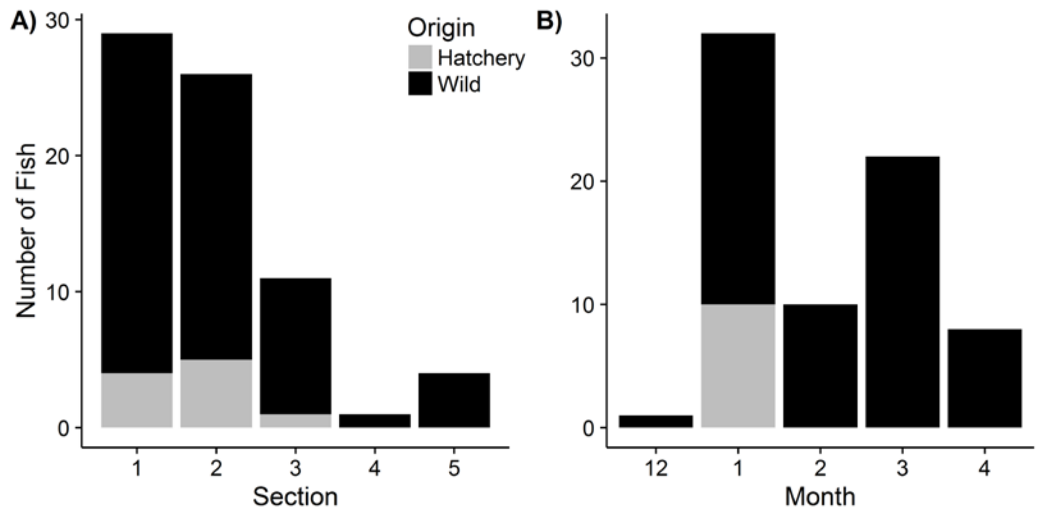


Figure 12. Catch of wild and hatchery steelhead by space (A) and time (B) on the Hoh River between December 2015 and April 2016.

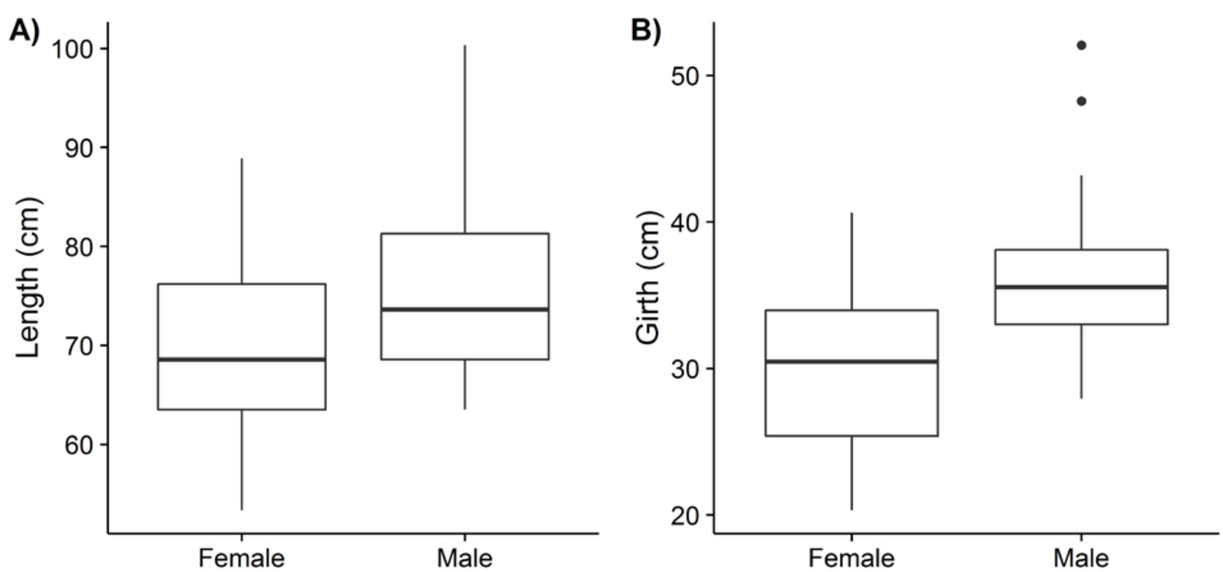


Figure 13. Fork length (A) and girth (B) of steelhead captured in the Hoh River, 2015-2016. Thick horizontal line is the median length, the rectangle is the 25% to 75% range of lengths, vertical line represents range of lengths, points represent lengths that are greater than two standard deviations from the mean.

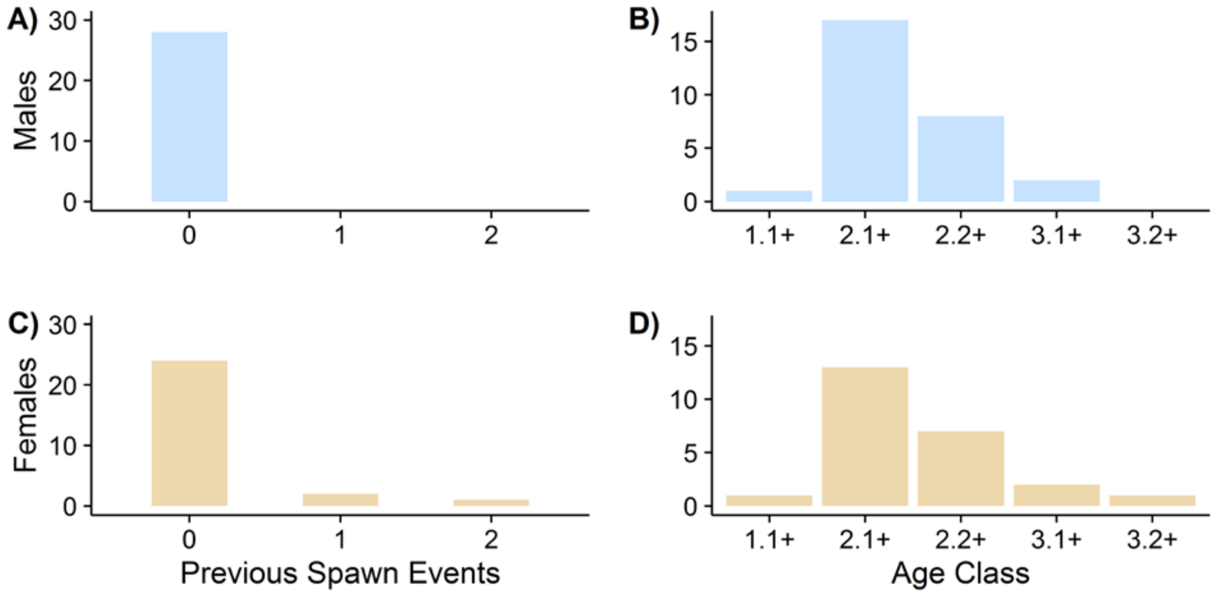


Figure 14. Number of previous spawn events (A, C) and age classes (B, D) for wild steelhead caught in the Hoh River, 2015-2016. Age class notation X.Y indicates the number of years in freshwater (X) and the number of complete winters in the ocean (Y). A '.1+' indicates a fish that has spent one winter (two summers) in the ocean and has returned to freshwater in its second winter (also called a 'two salt' fish).

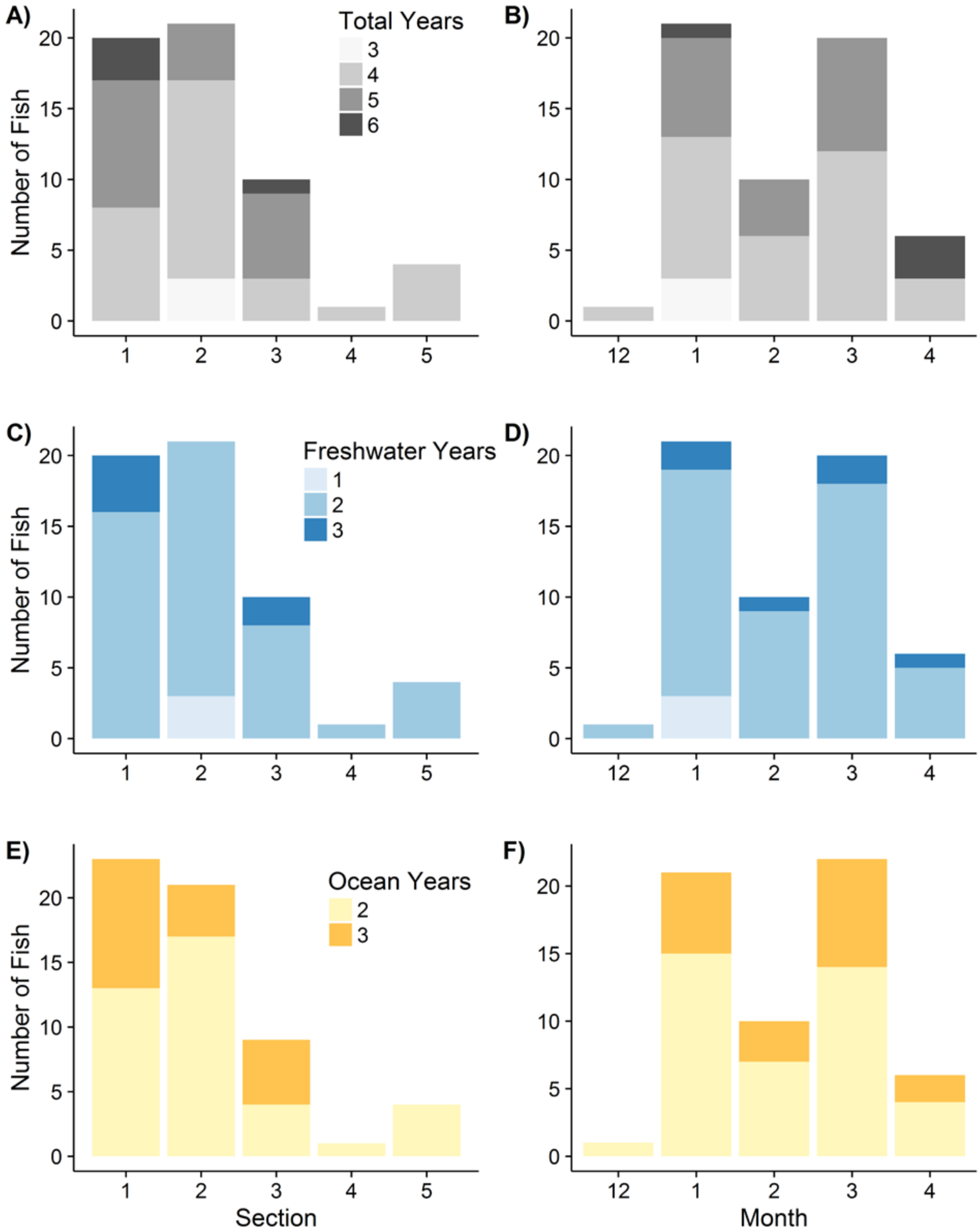


Figure 15. Age diversity of maiden (no previous spawn) wild steelhead returning to the Hoh River, 2015-2016. Age diversity is summarized by section of the river and month of capture. Age diversity shown as total years (A. B), freshwater years (C, D), and ocean years (E, F).

Discussion

We met each of the four objectives identified for the first field season of the Hoh River Steelhead Project. Based on reconnaissance of the main stem river, we identified multiple locations for operating sonar and smolt trap equipment and evaluated the feasibility of operating a sonar at a subset of these locations. We also initiated a volunteer angling program that provided an initial dataset describing steelhead biological diversity.

The wide, expansive floodplains of the Hoh River provide many potential locations to operate sonar equipment but limits locations suitable for smolt trap operation. Of the three locations where we ran the sonar, the Upper Oxbow site was the most favorable for continued study due to its image quality, site access, site security, and ability to account for harvest above and below its location. Locations identified for a smolt trap were not ideal. Given the dramatic shifts in flow observed in the Hoh River, we would recommend using a trap with steel pontoons built to sustain the impact of large debris. Aluminum pontoons, although lighter and easier to maneuver, will be easily damaged by the size of debris moved by flow events on the Hoh River. Anchoring a smolt trap in the Hoh River will be logistically difficult in most locations given that large trees (i.e., anchors) are long distances (> 0.5 km) from the river channel where the smolt trap would be located. The Lower Oxbow location has the most promise as a smolt trap location (thalweg, anchor points), but the lack of refuge during flow events at this location means that there is a high likelihood that substantial damage to trap infrastructure would occur if the trap were operated at this location. Continual need for infrastructure repair would need to be built into the long-term expectations (and funding) if we were to proceed with operating a smolt trap at this location.

The volunteer angler program returned high quality data useful for describing steelhead biological diversity. Data were correctly recorded with few exceptions indicating that the volunteers followed the protocols described during the training event. Ages were obtained from all of the collected scale samples indicating that the volunteer followed proper sampling techniques. Participants in the volunteer angling program were encouraged to follow their usual fishing patterns (gear, locations). As a result of this approach, we obtained samples from about 50% of the volunteers who initially received training with most of the samples coming from the lower three sections of the river. In the future, the study will benefit from increasing the number and spatial coverage of samples collected in a given fishing season. Increased numbers of samples could be obtained by expanding the number of volunteer participants or the number of samples collected per volunteer (seek out volunteers who spend a lot of time fishing the Hoh River). The study will also benefit from increasing spatial coverage of the sampling. Sampling from the sections within Olympic National Park may require identifying anglers who typically fish in these areas or who are willing to change some of their fishing areas to gain additional samples for this study. Total sample sizes in 2016 were relatively low and interpretation of steelhead diversity will be postponed until further information is provided by additional years of study.

Recommendations

Based on these results, the following objectives are recommended for the 2017 field season:

(1) Continually record sonar imagery at the Upper Oxbow site on all days within the identified flow threshold between the months of January and June,
(2) Fabricate and install fish deflection weir to direct fish into a favorable imagery zone in front of the sonar array and prevent fish from swimming behind the sonar array,
(3) Install solar panels to power the sonar equipment and increase efficiency of the operation by reducing time spent swapping batteries,
(4) Conduct in-stream tangle netting simultaneous with sonar operation to interpret species composition of fish moving in front of the sonar array throughout the season,
(5) Continue volunteer angling program and develop multi-year dataset of steelhead by river section and season (summer and winter run fish), and
(6) Increase sample collection effort in Section 4 and 5 to gather more information on steelhead returning to these areas of the basin.

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Denton, K., Moses, R., McHenry, M., McMillan, J., Ward, E., Stefankiv O., Wells, W. Liermann, M., Pess,G. 2014. Elwha River Steelhead escapement estimate based on DIDSON/ARIS multi-beam SONAR data. Prepared for the Lower Elwha Tribe.

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