A Monitoring Study to Quantify Dam Passage and Tributary Escapement of Adult Pacific Lamprey in the Rocky Reach Project Area and the Mid-Columbia River

SUBMITTED TO:

Steve Hemstrom
Public Utility District No.1 of Chelan County
327 North Wenatchee Avenue
Wenatchee, WA 98807

SUBMITTED BY:

Julie Maenhout
Blue Leaf Environmental
2301 West Dolarway Road, Suite 3
Ellensburg, Washington, 98926

PRINCIPAL PROPONENT:

Mark Timko, Blue Leaf Environmental

DRAFT

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BLUE LEAF ENVIRONMENTAL

Executive Summary

On February 19, 2009, Public Utility District No. 1 of Chelan County (Chelan PUD) filed application for a new Federal Energy Regulatory Commission (FERC) operating license for the Rocky Reach Hydroelectric Project (Project), which included a Pacific Lamprey Management Plan (PLMP) (FERC 2009). On May 1, 2009, FERC issued an "order modifying and approving" the PLMP.

The goal of the PLMP is to achieve No Net Impact (NNI) on Pacific lamprey by measuring ongoing Project-related impacts, if any, on Pacific lamprey, implementing appropriate and reasonable measures to reduce or eliminate such impacts, and implementing on-site or off-site measures to address measured unavoidable impacts. The Chelan PUD PLMP is intended to be consistent with other management plans in the mid-Columbia region.

The goals and objectives of the PLMP are to be achieved through Protection, Mitigation, and Enhancement (PME) measures when unavoidable Project effects are measured. In support of these PME's, this passage monitoring study was designed to address PME's 4.1, measure any Project-related impacts on upstream and downstream passage of adult Pacific lamprey and eliminate those impacts to the extent appropriate and reasonable; 4.1.5, evaluation of upstream passage modification; and 4.1.6, determination of any significant adult downstream passage effects.

This study used adult lamprey collected at Priest Rapids Dam (Grant PUD) and implanted with FDX-PIT tags to address the following objectives for Chelan PUD's study:

1. Continue to assess adult Pacific lamprey passage rates and behavior at Rocky Reach Dam using FDX- PIT technology to evaluate the in-fishway passage improvements Chelan PUD completed for lamprey in 2011.
2. Estimate adult Pacific lamprey passage success at Rocky Reach Dam to allow comparison to passage rates at other Projects on the Columbia River, per the PLMP.
3. Estimate the proportion of volitional escapement into mid-Columbia River tributaries.
4. Determine final return location, if possible, for the proportion of fish detected in the Wenatchee River, the Entiat River, at mid-Columbia dams upstream of Rocky Reach Dam, and for fish that are detected at Rocky Reach Dam but ultimately do not pass upstream through the dam's fishway.
5. Estimate the proportion of fish that overwinter in the mainstem Columbia River based on following-year detections of fish at mainstem dams and any following-year first detections in tributaries.
6. Assist and coordinate with Douglas PUD to provide Douglas PUD with up to 50 fish captured for Chelan PUD's study to enable Douglas to double tag lamprey (FDX-PIT tag and active acoustic tag) to assess movement through Rocky Reach Reservoir (Chelan PUD objective) and approach behavior up to and through Wells Dam tailrace and Wells Dam (Douglas PUD objective). These fish will be released upstream of Rocky Reach Dam but downstream of the confluence of the Entiat River to allow volitional escapement of lamprey into the Entiat River.

Two hundred eleven adult Pacific lampreys were collected from Priest Rapids Dam fishways during the 2016 peak migration period, implanted with full-duplex PIT tags, and released above Rock Island Dam at Kirby Billingsley Hydro Park (RM 461.8) in five release days between 3 August and 17 August. The fish were distributed approximately 90% near the right (west) bank and 10% along the left (east) bank to approximate Rock Island Dam fishway use and top of ladder exit proportions. Existing PIT tag detection infrastructure at Rocky Reach Dam, and other mainstem Columbia River dams and in tributary streams was used to monitor the migration behavior of tagged individuals in the study area. The PIT Tag Information System (PTAGIS) was queried to find detection records for tagged individuals. A detection history was created for each tagged lamprey and used to calculate metrics related to the study objectives.

Of the 211 lampreys released, 169 (80.1%) have been detected in either the adult fishway at Rocky Reach or Wells dams or in a mid-Columbia River tributary, 19 (90.5%) from the left bank releases and 150 (78.9%) from the right bank releases. As of December 31, 2016, preliminary Rocky Reach fishway passage rate was 98.8%. One hundred sixty-two of the 164 fish detected in the Rocky Reach fishway were last detected at the fishway exit and two were last detected at the lower weir antennas in the upper fishway. One fish that passed Rocky Reach Dam was last detected in the Chewuch River above Winthrop, WA. Five fish were last detected in the Wenatchee River. No lampreys from the 2016 study have been detected at Rock Island Dam. In general, lamprey last detected entering the Wenatchee River travelled slightly faster than lamprey that passed through Rocky Reach Dam. The median travel rate to reach the exit of the Rocky Reach fishway for fish released on the left bank was 5.8 rkm/day (range 1.2-23.8 rkm/day) compared to 3.4 rkm/day (range 0.4-23.3 rkm/day) for right bank releases. While the median travel rate from release to first detection in the Wenatchee River was 26.6 rkm/day (range 1.1-28.9 rkm/day). We note that this travel time comparison for lampreys passing Rocky Reach Dam versus moving into the Wenatchee River is based on a small sample size of five individuals for the Wenatchee River. Freshwater maturity time for these fish is also unknown. Therefore, at this point we caution the comparison of lamprey travel rates. There is currently 96.2% of the tagged and released lamprey potentially overwintering in the mainstem of the Columbia River, either within the Rock Island or Rocky Reach reservoirs, or in the lower Wenatchee River downstream of the FDX detection point, as indicated by their last detection site or lack of detection so far. A better estimation of the final fate of the all tagged lamprey will be available in spring 2017, and an estimation of the number fish that overwintered in the mainstem Columbia River and resume migration in spring 2017.

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1.0 INTRODUCTION

On February 19, 2009, Public Utility District No. 1 of Chelan County (Chelan PUD) filed application for a new Federal Energy Regulatory Commission (FERC) operating license for the Rocky Reach Hydroelectric Project (Project), which included a Pacific Lamprey Management Plan (PLMP) (FERC 2009). On May 1, 2009, FERC issued an "order modifying and approving" the PLMP.

The goal of the PLMP is to achieve No Net Impact (NNI) on Pacific lamprey by measuring ongoing Project-related impacts, if any, on Pacific lamprey, implementing appropriate and reasonable measures to reduce or eliminate such impacts, and implementing on-site or off-site measures to address measured unavoidable impacts. The Chelan PUD PLMP is intended to be consistent with other management plans in the mid-Columbia region.

The goals and objectives of the PLMP are to be achieved through a series of Protection, Mitigation, and Enhancement (PME) measures. In support of these PME's, this passage monitoring study was designed to address PME's 4.1, measure any Project-related impacts on upstream and downstream passage of adult Pacific lamprey and eliminate those impacts to the extent appropriate and reasonable; 4.1.5, evaluation of upstream passage modification; and 4.1.6, determination of any significant adult downstream passage effects.

1.1 Adult Lamprey Passage

Pacific Lamprey (*Entosphenus tridentatus*) numbers have declined since the 1940's as a result of many factors including spawning habitat loss, impediments to migration, changing ocean conditions, and decreased water quality (Close et al. 1995, 2002), and other potentially unrecognized conditions. Much focus over the past 10 years has been placed on studying migrating adults. Modifications have been made to many dam operations and fishway structures to improve lamprey passage. Passive tags, such as half-duplex passive integrated transponder tags (HDX- PIT), and active tags, such as radio tags (RT) or acoustic tags (i.e. Juvenile Salmonid Acoustic Transmitter System [JSATS]) have been employed to monitor adult lamprey passage primarily at dams in the lower Columbia River (Keefer et al. 2009a, Keefer et al. 2009b, Keefer et al. 2009c, Noyes et al. 2014). In 2015, a ban implemented in 2004 on the use of full-duplex PIT tags (FDX-PIT) for lamprey research was lifted by the PIT tag steering committee (PTAGIS 2015). This change made the existing FDX-PIT tag detection infrastructure common in mainstem Columbia and Snake river dams and tributaries available to lamprey researchers. One of the advantages of using FDX-PIT tags for lamprey research is the use of the PIT Tag Information System (PTAGIS) for querying detections that may occur throughout monitored sites in the Columbia and Snake river drainages. This makes it possible to imply escapement rates into tributaries or "final fate" of lamprey that are detected in spawning tributaries. Deciphering final return locations has been more difficult to quantify using other passive tag technologies.

Areas within upstream fishways can be problematic for lamprey passage (Moser et al. 2003) and as such, Chelan PUD initiated a study in 2004 using radio-telemetry to assess lamprey passage behavior and success through the Rocky Reach Dam upstream fishway. The estimated net ladder passage efficiency (NLPE), or proportion of fish that were detected in the tailrace of the dam that exited the upstream fishway was 47%, which was comparable to studies at other Columbia River dams at the time (Stevenson et al. 2005). In 2011, Chelan PUD performed

significant modifications to the Rocky Reach fishway intended to aid lamprey passage. In 2014, Chelan PUD completed a study to assess passage behavior of adult lamprey using HDX-PIT tags and found that net ladder passage, or the proportion of fish with final successful passage was estimated at 66% (Blue Leaf Environmental 2015) though the most upstream HDX antenna system in Rocky Reach fishway was compromised during a critical two-week period in the study. Although the 2004 and 2014 studies employed different tag technologies and reported slightly differing passage metrics, the studies suggest that lamprey passage through Rocky Reach Dam has improved, perhaps significantly, since the completion of in-fishway passage improvements in 2011. Due to limited detection capabilities of HDX-PIT tags in tributaries, it is unknown what proportion of fish released for the 2014 study ascended spawning tributaries. Review of total year fishway counts of lamprey passing Rock Island Dam and Rocky Reach Dam suggests that dam to dam passage conversion rates since 2011 are high for Rocky Reach (Chelan PUD 2015 unpublished data).

1.2 Study objectives

The study described herein used adult lamprey collected at Priest Rapids Dam and implanted with FDX-PIT tags to address the following objectives:

1. Continue to assess adult Pacific lamprey passage rates and behavior at Rocky Reach Dam using FDX- PIT technology to evaluate the in-fishway passage improvements Chelan PUD completed for lamprey in 2011.
2. Estimate adult Pacific lamprey passage success at Rocky Reach Dam to allow comparison to passage rates at other Projects on the Columbia River, per the PLMP.
3. Estimate the proportion of volitional escapement into mid-Columbia River tributaries.
4. Determine final return locations, if possible, for the proportion of fish detected in the Wenatchee River, the Entiat River, at mid-Columbia dams upstream of Rocky Reach Dam, and for fish that are detected at Rocky Reach Dam but ultimately do not pass upstream through the dam's fishway.
5. Estimate the proportion of fish that overwinter in the mainstem Columbia River based on following-year detections of fish at mainstem dams and any following-year first detections in tributaries.
6. Assist and coordinate with Douglas PUD to provide Douglas PUD with up to 50 fish captured for Chelan PUD's study to enable Douglas to double tag lamprey (FDX-PIT tag and active acoustic tag) to assess movement through Rocky Reach Reservoir (Chelan PUD objective) and approach behavior up to and through Wells Dam tailrace and Wells Dam (Douglas PUD objective). These fish will be released upstream of Rocky Reach Dam but downstream of the confluence of the Entiat River to allow volitional escapement of lamprey into the Entiat River.

1.3 Study Area

The study area is defined by the FERC licensed project area which includes Rocky Reach Dam and the associated tailrace area and reservoir. The project area is referenced here as the Rocky Reach Project (RRP). The Rocky Reach Reservoir spans approximately 66.6 km (41.4 miles) of the Columbia River. The Rocky Reach Reservoir has a full-pool (707.0 ft msl) surface area of approximately 8,828 acres. The RRP has only one major tributary input, the Entiat River, but both the Wenatchee River and the Entiat River were included in the study area because FDX-PIT monitoring arrays exist in both, and estimation of tributary escapement rates was desired. Both rivers were monitored for lamprey detections during the study.

2.0 STUDY METHODS

2.1 Collection

In 2016, adult Pacific lampreys were collected using mechanical fish traps located in the lower fishways at Priest Rapids Dam from 2 August to 17 August. All fish were scanned for an existing PIT tag. Previously tagged fish were released upstream of Priest Rapids Dam. All other fish were transported to a holding facility at Priest Rapids Dam left bank. Fish were placed in 20.5 gallon insulated containers (coolers) plumbed with flow-through river water, with a maximum of 15 fish per container (Figure 1).

Figure 1. Holding containers (coolers) plumbed with flow-through river water at the Priest Rapids Dam left bank holding facility.

2.2 Tagging

All lamprey were tagged with a FDX-PIT tag (12.5 mm L x 2.1 mm Dia, 0.1 g). At the beginning of each tagging and release day, the appropriate number of tags were placed in a Nolvasan (Chlorhexidine diacetate) solution for ten minutes then rinsed with distilled water. Injection needles were also disinfected in a Nolvasan solution for ten minutes and then held in trays filled with distilled water. Injection needles were disinfected and rinsed in the same manner between each fish. Physical metrics and anesthetic times for each fish were recorded on data sheets.

One lamprey at a time was transferred from a container by hand, using water soaked cotton gloves, to a heavy anesthetic bath with 120 parts per million (ppm) clove oil, until the fish lost equilibrium and swimming motion ceased (approximately 5 minutes). Start and end time (i.e., anesthetic time) was recorded. Once the lamprey was fully anesthetized, length, girth, inter-dorsal distance (IDD) to the nearest mm, and weight in grams, was measured and recorded

(Figure 2). A FDX-PIT tag was scanned into an ACCESS database. The FDX-PIT tag was then injected using a Biomark MK10 implanter and N125 injector needle above the ventral midline, in the softer, thinner part of the abdomen between the ventral midline and the muscular "rib cage". The injection site was in line with the anterior insertion of the first dorsal fin. The lamprey was then scanned to confirm PIT tag ID, and transferred to a holding/transport container on flow-through river water, labeled with the appropriate release location and number, and container number. There were no more than 12 lampreys per release container. Lamprey were held in the holding/transport containers until fully recovered from anesthetic, and released later the same day.

Figure 2. Girth was measured at the anterior insertion of the first dorsal fin. Length, inter-dorsal distance (IDD) to the nearest mm, and weight in grams, was measured and recorded before each lamprey was tagged.

2.3 Releases

After recovery, fish were transported in aerated coolers filled with river water to Kirby Billingsley Hydro Park (RM 461.8) and transferred to the custody of Chelan PUD fisheries staff. Chelan PUD staff transferred the transport coolers to a boat. The fish were released into the

Columbia River, distributed approximately 90% near the right (west) bank and 10% along the left (east) bank to approximate the number of lamprey using each of the Rock Island Dam fishways and top of ladder exit proportions based on total lamprey counts (Figure 3).

Figure 3. PIT tagged adult Pacific lamprey release sites in Rock Island Reservoir at Kirby Billingsley Hydro Park for 2016 Rocky Reach lamprey passage study. 10% (n=21) of all tagged lamprey for the study were released near the left bank and 90% (n=190) on the right bank as shown. These proportions emulate proportions of lamprey using the left bank and right bank fishways at Rock Island Dam.

2.4 Monitoring

This study employed passive FDX-PIT tags and existing FDX-PIT detection arrays installed at fixed locations (Rocky Reach Dam adult fishway, Wells Dam adult fishways, and multiple locations in the Wenatchee and Entiat rivers), to determine passage success and tributary escapement of adult Pacific lamprey in the RRP (Figure 4). Tagged fish were monitored as they moved past fixed FDX-PIT tag detection antennas located in the adult fishway at Rocky Reach and Wells dams and also in mid-Columbia River tributaries such as the Wenatchee, Entiat, and Methow rivers (Figure 5 and 6). Detections histories of study fish were assembled by querying the PTAGIS database at appropriate intervals. Queries were used to look for detections in the expected locations as well as system-wide in the event that study fish did not behave as expected.

Figure 4. Full-duplex PIT tag detection sites are located at Rock Island, Rocky Reach, and Wells dams as well as tributary detection sites in the Wenatchee and Entiat rivers. Detections of tagged lamprey released for the study were queried using the PTAGIS website (www.ptagis.org).

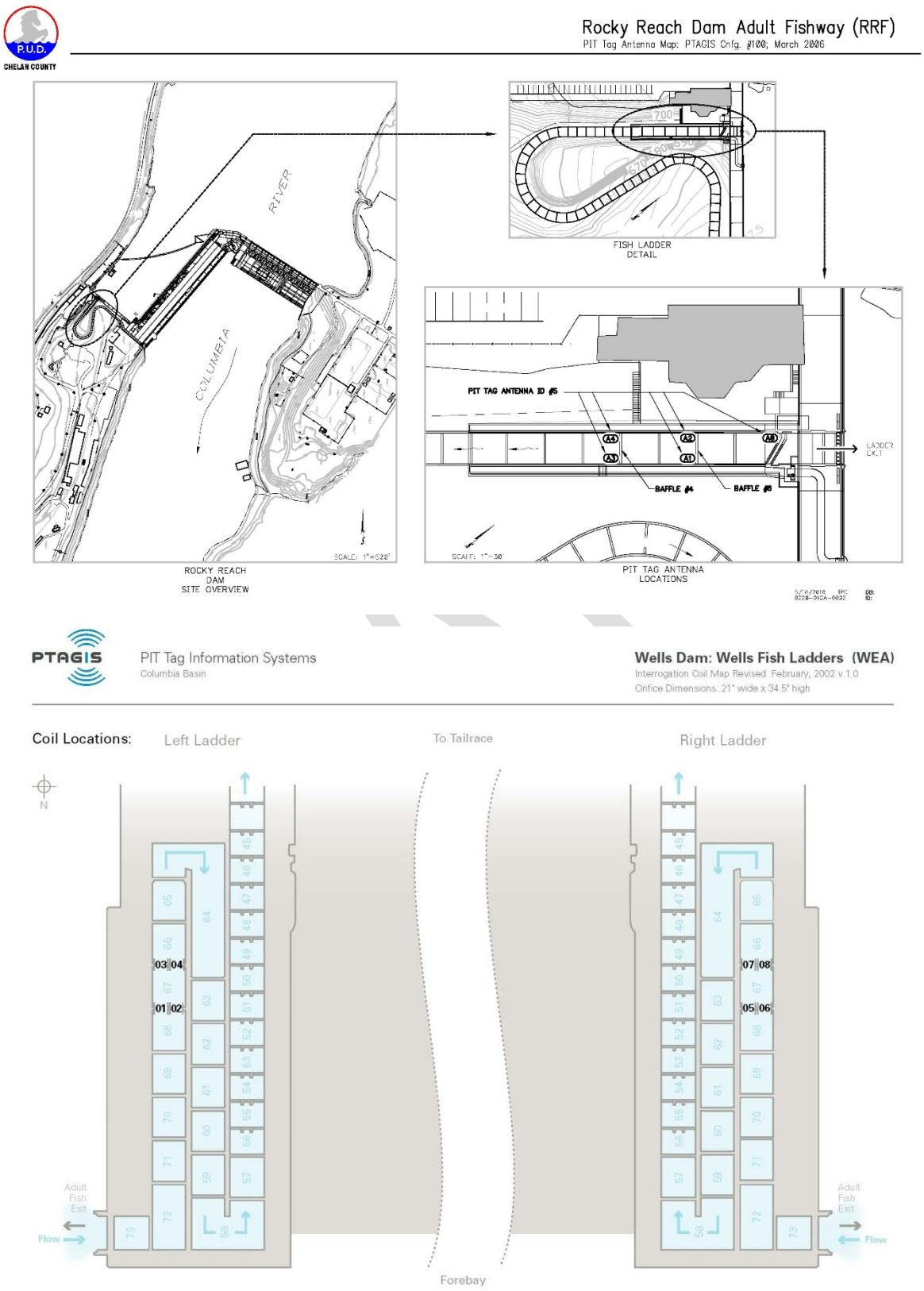
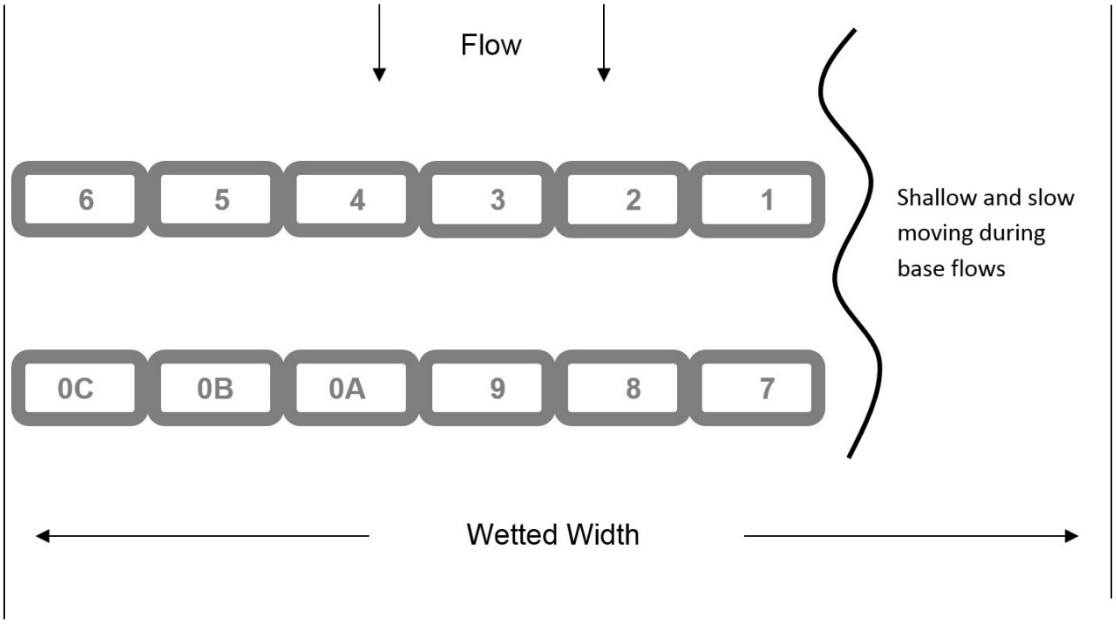


Figure 5. Detail of full-duplex PIT tag detection sites located at Rocky Reach (top) and Wells (bottom) dams. Detections of tagged lamprey released for the study were queried using the PTAGIS website (www.ptagis.org).



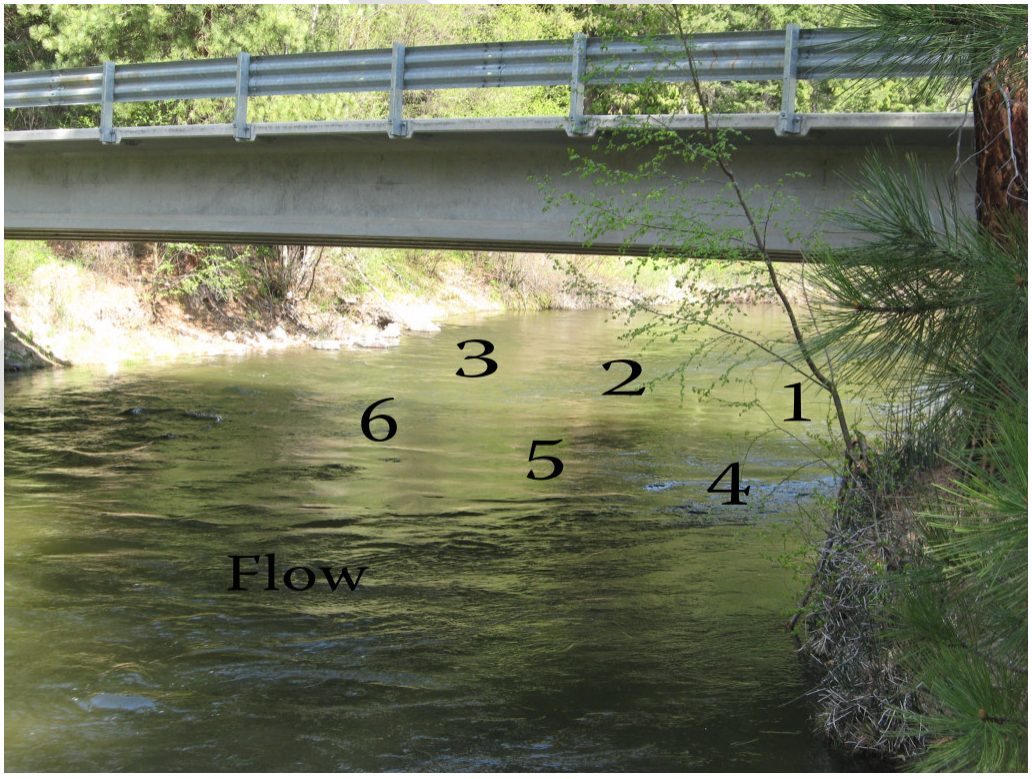


Figure 6. Detail of full-duplex PIT tag detection sites located at the lower Wenatchee (top) and Entiat (bottom) rivers. Detections of tagged lamprey released for the study were queried using the PTAGIS website (www.ptagis.org).

2.5 Detection Analysis

Detection records from the PTAGIS database were compiled in a relational database maintained by Blue Leaf Environmental (BLE) staff. A detection history was generated for each tag. Detection records were used to determine behavioral characteristics of tagged lamprey in the study area. Key metrics included the proportion of tagged fish that enter the Wenatchee or Entiat rivers, the proportion that passes through the Rocky Reach Dam adult fishway, and the proportion that is detected at or in the Wells Dam adult fishway, and in the Methow Basin. Also, the movement rate from release to detection at the above locations was estimated. Additionally, the proportion of fish that overwinter in the study area and resume movement in 2017 will be reported. This draft report only includes PTAGIS query results through 2016, the final report will include fish that may be overwintering and resume migration in spring 2017.

3.0 PRELIMINARY RESULTS

A total of 211 adult lampreys were tagged with FDX-PIT tags and released in five release days between 3 August and 17 August (Table 1). Of the 211 lampreys released, 169 (80.1%) have been detected in either the adult fishway at Rocky Reach Dam or Wells Dam, or in a mid-Columbia River tributary. Nineteen lampreys were detected (90.5%) from the left bank releases and 150 (78.9%) from the right bank releases. As of December 31, 2016, preliminary Rocky Reach fishway passage rate was 98.8%. One hundred sixty-two of the 164 fish detected in the Rocky Reach fishway were last detected at the fishway exit and two were last detected at the lower weir antennas in the upper fishway (antenna A3 and A4; Figure 5). Fish started passing Rocky Reach Dam within one day of being released and a majority (94.4%) of fish passed within the month of August (Figure 7). One fish that passed Rocky Reach Dam also passed Wells Dam, and entered the Methow River. It was last detected in the Chewuch River above Winthrop, WA. Five fish were first and last detected in the Wenatchee River (Table 2). None of these five were detected at Rocky Reach. The confluence of the Wenatchee and Columbia rivers, at RM 468.5, is 7.5 RM upstream from the release site and 4.5 RM downstream of Rocky Reach Dam.

Table 1. The total quantity of lamprey tagged and released by release date in August 2016.

Release Date	Left Bank	Right Bank	Total
8/3/2016	5	41	46
8/5/2016	6	52	58
8/10/2016	3	36	39
8/12/2016	4	33	37
8/17/2016	3	28	31
Total	21	190	211

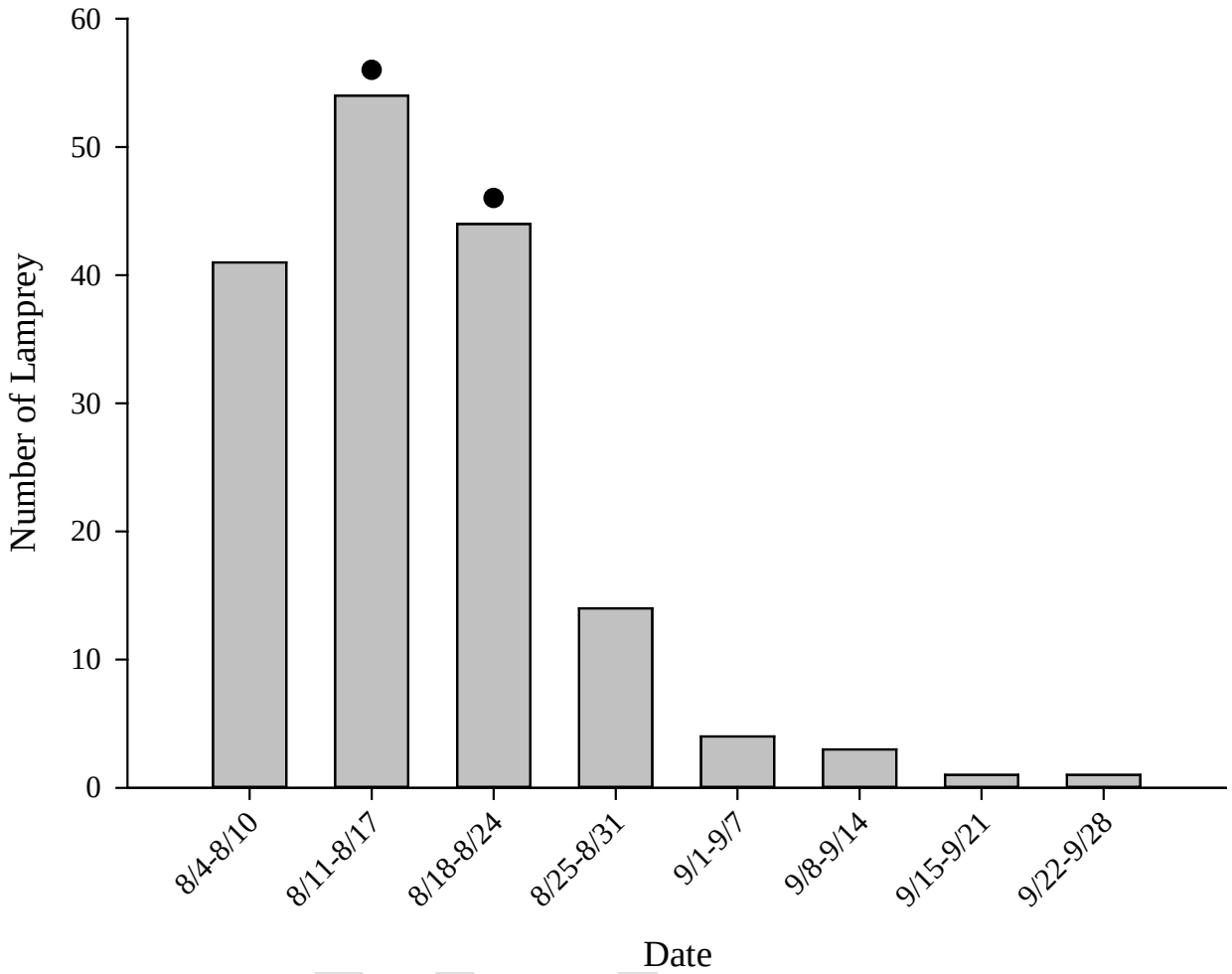


Figure 7. Number of tagged lamprey that passed Rocky Reach Dam per week in 2016. The dots represent when the only two fish that did not pass were last detected in the upper fishway.

Table 2. The last detection sites, as of December 31, 2016, of the 169 lamprey that have been detected after release.

Last Detection Site	Left Bank Release	Right Bank Release	Total
Wenatchee River	0	5	5
Rocky Reach Dam	19	144	163
Chewuch River (Methow)	0	1	1
Total	19	150	169

Travel times from release to passage through Rocky Reach Dam (last detection at the Rocky Reach fishway exit) varied by release site. Median travel times were 3.3 and 5.7 days for lamprey released on the left bank (n=19) and right bank (n=143), respectively (Table 3). The median travel rate to reach the exit of the Rocky Reach fishway for fish released on the left bank was 5.8 rkm/day (range 1.2-23.8 rkm/day) compared to 3.4 rkm/day (range 0.4-23.3 rkm/day) for

right bank releases (Table 4). The smaller sample size of left bank released fish may account for the reduced variation in travel times and rates compared to the right bank released fish. The one fish that has been detected upstream at Wells Dam, last detected in the Chewuch River, has a travel time of 18.5 days and travel rate of 4.8 rkm/day from release to first detection in the Wells Dam fishway, with an overall travel time of 32.6 days and travel rate of 5.6 rkm/day from release to detection in the Chewuch River. In general, lamprey last detected entering the Wenatchee River travelled faster than lamprey that passed through Rocky Reach Dam. The median travel time from release to detection in the Wenatchee river was 0.6 days (range 0.5-13.6 days) with a median travel rate of 26.6 rkm/day (range 1.1-28.9 rkm/day). We note that this travel time comparison for lamprey passing Rocky Reach Dam versus moving into the Wenatchee River is based on a small sample size of five individuals for the Wenatchee River. Freshwater maturity time is also unknown. Therefore, at this point we caution the comparison of lamprey travel rates.

Table 3. Travel time, in days, from release site to the last detection at the exit of the Rocky Reach Dam fishway.

		Travel Time (days)				
Release Site	n	Min	Max	Median	Mean	SD
Left Bank	19	0.8	15.7	3.3	5.1	4.1
Right Bank	143	0.8	43.4	5.7	7.9	7.4

Table 4. Travel rates, in river kilometers per day, from release site to the last detection at the exit of the Rocky Reach Dam fishway.

		Travel Rate (rkm/d)				
Release Site	n	Min	Max	Median	Mean	SD
Left Bank	19	1.2	23.8	5.8	7.2	5.8
Right Bank	143	0.4	23.3	3.4	5.3	4.4

A majority of the total travel time exhibited by tagged lampreys that passed Rocky Reach Dam is accounted for in from release to first detection within the Rocky Reach fishway, indicating lamprey spent little time in the upper portion of the fishway. The median travel time from release to first detection in the Rocky Reach fishway for fish released on the left bank was 1.8 days (19 fish, range 0.8-15.7 days) compared to 3.7 days (145 fish range 0.8-21.6 days) for right bank releases (Table 5). Travel time from first detection in the fishway to last detection in the fishway is better represented in hours due to the minimum and median travel times being less than one hour. Substantial variation was observed in times of individual fish, but the median travel time was 0.4 and 0.6 hours for left and right bank releases, respectively (Table 6).

Table 5. Travel time, in days, from release site to the first detection in the Rocky Reach Dam fishway.

		Travel Time (days)				
Release Site	n	Min	Max	Median	Mean	SD
Left Bank	19	0.8	15.7	1.8	4.4	4.1
Right Bank	145	0.8	21.6	3.7	5.6	4.9

Table 6. Travel time, in hours, from first detection to last detection in the Rocky Reach Dam fishway.

		Travel Time (hours)				
Release Site	n	Min	Max	Median	Mean	SD
Left Bank	19	0.1	141.4	0.4	17.3	38.4
Right Bank	145	0.1	882.5	0.6	56.9	134.4

4.0 DISCUSSION

Currently 96.2% of the tagged lampreys may be overwintering in the mainstem of the Columbia River or in the Wenatchee or Entiat rivers. The 161 fish last detected at the Rocky Reach Dam adult fishway exit may be overwintering in Rocky Reach Reservoir or in the lower Entiat River, and the 42 fish that have not been detected at all after release may be overwintering in the Rock Island Reservoir or the lower Wenatchee River. It is also possible that lamprey may have either moved upstream past Wells Dam undetected, or downstream through Rock Island Dam. No lampreys have been detected as yet in the Rock Island fishway.

Although tags are still being monitored, passage rates at the Rocky Reach Dam from this study are among the highest reported on the mainstem Columbia River to date, and are significantly increased from the 2004 radio telemetry estimates and 2014 half-duplex PIT tag estimates (Stevenson et al. 2005; BLE 2015). Of the lamprey detected in the Rocky Reach fishway, 98.8% were last detected at the exit. Interestingly, most recent passage estimates at the lower Columbia River dams were also among the highest estimated in previous studies as well, at 60%, 58%, and 73% for Bonneville, The Dalles, and John Day dams, respectively (Keefer et al. 2015). Lamprey travel times from release to the exit of the Rocky Reach fishway (first detection in the upper fishway for comparability) were similar to the HDX study conducted in 2014. The median travel time for the 2014 released fish was 1.7 days compared to 1.8 days and 3.7 days for left and right bank released fish, respectively (BLE 2015; Table 5).

Previous studies have reported that lamprey rarely travel long distances after overwintering to spawn (Courter et al. 2012; McIlraith et al. 2015). This indicates that the large percentage of lamprey that may be overwintering in the Rock Island or Rocky Reach reservoirs will most likely move into the Wenatchee, Entiat or Methow system in the spring to spawn. There is also some indication that lamprey may engage in mainstem spawning, particularly in the tailrace of hydropower dams where spawning habitat known to be used by fall Chinook salmon occurs (Dauble et al. 1999; McMichael et al. 2005). A better estimation of the final locations of all

tagged lamprey will be available in spring 2017, and an improved estimation of the number fish that overwintered in the mainstem Columbia River and resume migration in spring 2017.

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