RECLAMATION
Managing Water in the West

Pacific Lamprey 2012 Annual Report and 2013 Plan

Columbia/Snake River Salmon Recovery Office
Pacific Northwest Region

U.S. Department of the Interior
Bureau of Reclamation
Pacific Northwest Region
Boise, Idaho

September 2013

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Mission of the Bureau of Reclamation

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

Cover Photograph: Pacific lamprey climbing bedrock at the base of Prosser Dam on the Yakima River, Washington.

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Pacific Northwest Region

Prepared to document and communicate Reclamation's actions in calendar year 2012 pertaining to Pacific Lamprey under the commitments in the 2008 Columbia River Fish Accords.

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for Columbia/Snake Salmon Recovery Office
Pacific Northwest Region

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Table of Contents

List of Figures

List of Tables

Photographs

Table of Contents (Continued)

Introduction

Bonneville Power Administration (BPA), U.S. Army Corps of Engineers (Corps), and the Bureau of Reclamation (Reclamation) (collectively known as the Action Agencies) operate the Federal Columbia River Power System (FCRPS). In 2008, the Action Agencies entered into a Memorandum of Agreements with several Columbia River Basin states and Tribes, known as the 2008 Columbia River Basin Fish Accords (Accords). The Accords include agreements to implement and fund numerous fisheries and habitat-related actions to improve fish survival in addition to those already prescribed in the Reasonable and Prudent Alternative in the 2008 Biological Opinion on the FCRPS (NOAA Fisheries 2008). There were several actions in one of the Accords that dealt specifically with Pacific lamprey.

In that agreement, the Action Agencies each agreed to pursue or implement actions to address and potentially reverse the recent decline in Pacific lamprey numbers in the basin. Reclamation's commitments are as follows:

1. Beginning in 2008 and concluding in 2010, Reclamation will conduct a study, in consultation with the Tribes, to identify all Reclamation projects in the Columbia River Basin that may affect lamprey. The study will also investigate potential effects of Reclamation facilities on adult and juvenile lamprey, and where appropriate, make recommendations for either further study or for actions that may be taken to reduce effects on lamprey. The priority focus of the study will be the Umatilla and Yakima projects and related facilities.

2. Beginning in 2008, Reclamation and the Tribes will jointly develop a lamprey implementation plan for Reclamation projects as informed by the study above, the tribal draft restoration plan, and other available information. The plan will include priority actions and identification of authority and funding issues. It will be updated annually based on the most recent information. Reclamation will seek to implement recommended actions from the implementation plan (2008 River Basin Fish Accords, Memorandum of Agreement between the Three Treaty Tribes and FCRPS Action Agencies, May 2008).

The purpose of this annual report is to document and communicate Reclamation's actions under these commitments. The 2011 Annual Report, published in March 2012, reported updates on all activities since the signing of the Accords in 2008 through 2011. That report also included the final Assessment of U.S. Bureau of Reclamation Projects in the Columbia River Basin: Effects on Pacific Lamprey (*Lampetra tridentata*) (Assessment), fulfilling the first commitment of the Accords.

This 2012 annual report communicates activity through the calendar year 2012 and Reclamation's plans for 2013. These activities continue to be guided by the Assessment and adapted to evolving knowledge.

Partners

Reclamation's lead office for Pacific lamprey activities is the Pacific Northwest Regional Office (PNRO). Other Reclamation offices include:

Columbia-Cascades Area Office (CCAO)
Yakima Field Office (YFO)
Umatilla Field Office (UFO)
Technical Service Center (TSC)

Reclamation partners with a variety of agencies and organizations for Pacific lamprey activities, including:

Columbia River Inter-Tribal Fish Commission (CRITFC)
Yakama Nation (YN)
Confederated Tribes of the Umatilla Indian Reservation (CTUIR)
U.S. Fish and Wildlife Service (USFWS)
National Oceanic and Atmospheric Administration, Fisheries (NOAA Fisheries)
U.S. Geological Survey (USGS)
U.S. Army Corps of Engineers (USACE)
Lamprey Technical Working Group (LTWG)

2012 Lamprey Status Update

Overall numbers of adult lamprey returning to the Columbia River Basin, counted at Bonneville Dam in 2012 was 93,456, including day (29,224) and night (64,232) counts. This is the highest return since 2003, but it is important to consider the changes in counting effort at Bonneville Dam. Prior to 2010 lamprey were only counted during daytime. The majority of lamprey move at night, so many of them went uncounted in those years. However, a comparison of daytime only counts from 1999 to 2012 provides an index of lamprey return trend. These daytime only counts are represented in Figures 1, 2, and 3.

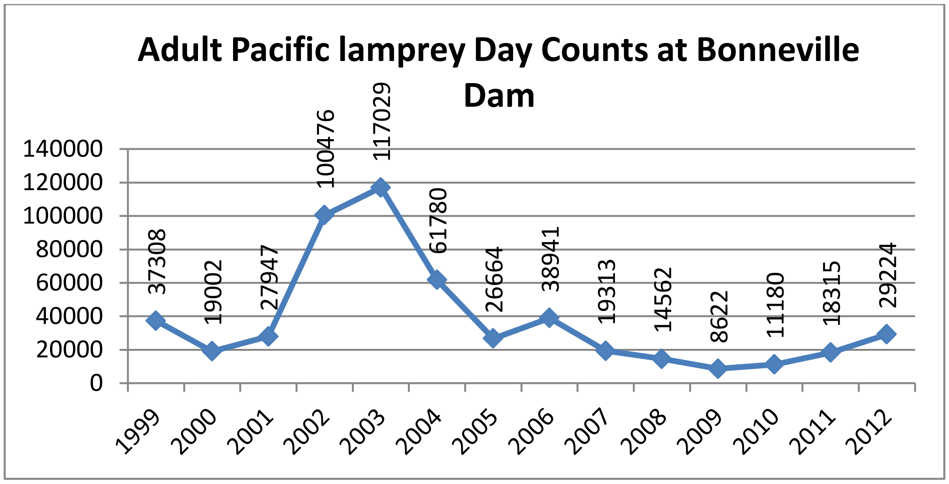


Figure 1. Adult Pacific lamprey daytime counts at Bonneville Dam.

Similarly, though still fairly low numbers overall, there have been record returns of lamprey adults to Three Mile Falls Dam in the Umatilla River, with over 100 lamprey in each of the past two years compared to less than 20 in each of the previous years since counting began in 1999. Note: there was an apparent loss in Lamprey Passage System function in September of 2012; actual returns were likely equal or above 2011. The recent increase is likely due to restoration efforts by CTUIR.

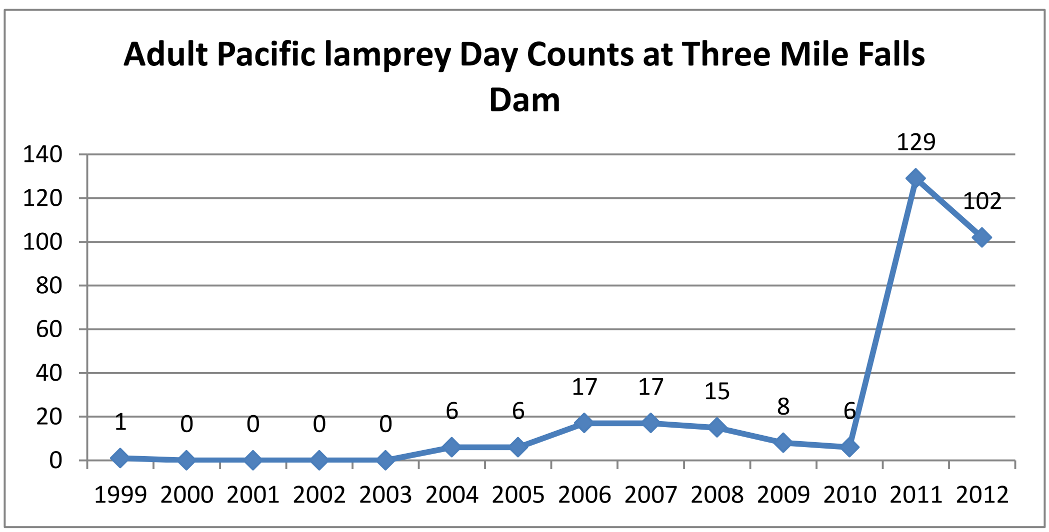


Figure 2. Adult Pacific lamprey returns to the Three Mile Falls Dam.

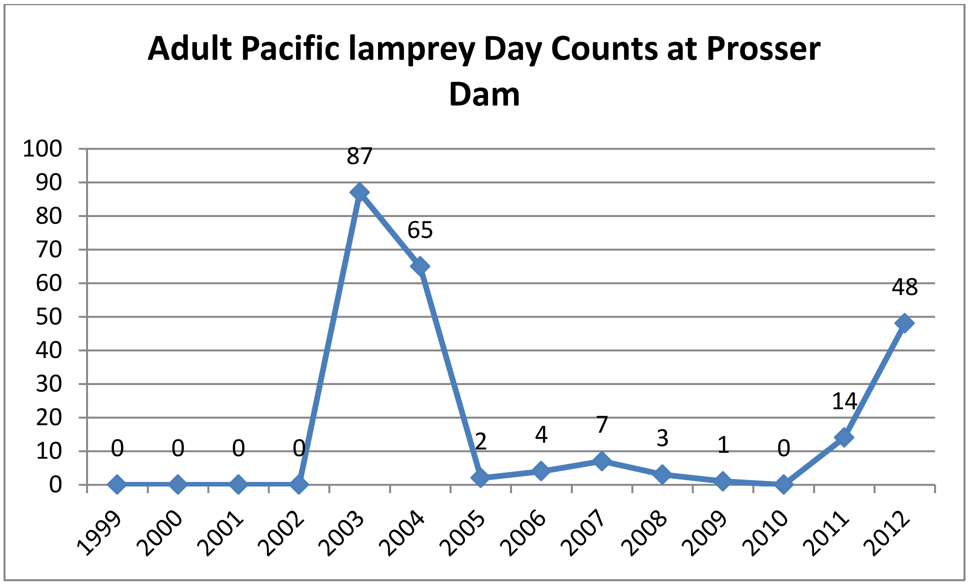


Figure 3. Adult Pacific lamprey returns to Prosser Dam.

A recent study (Murauskas et al 2013) linked return trends of Pacific lamprey with the population indicators of several of their host species in the ocean. It is difficult to determine if the recent upward trend in the Columbia River Basin is due to improvements for lamprey in the freshwater habitats, influenced by the availability of food for adult lamprey in the ocean, other factors, or a combination of these.

2012 Collaboration Activities

Reclamation staff and managers attended a variety of site visits, meetings, conferences, workshops, and other functions in 2012 to support Pacific lamprey activities in a cooperative and collaborative manner. These are listed below:

- PNRO, CCAO, and YFO staff attended site visits with YN, CRITFC, CTUIR, NOAA Fisheries, and USGS biologists to participate in "Rapid Assessment" (see Activities Updates) at Yakima Basin projects (January and March).
- PNRO participated in Lamprey Technical Working Group meetings (March and November).
- PNRO participated and presented at Lamprey Summit III in Portland, OR (June).
- Reclamation signed Pacific Lamprey Conservation Agreement (June)
- PNRO Participated in Federal Lamprey Coordination Group meeting with Corps, BPA, FWS (September).

- PNRO and CCAO participated in site visit with YN and FWS at Prosser Diversion Dam to explore options for lamprey passage (November).

- PNRO, TSC, CCAO and YN participated in a site visit at Sunnyside Diversion Dam to brainstorm monitoring strategies to further investigate lamprey entrainment issues (November).

Reclamation worked to develop and execute agreements to provide funding to partners working on lamprey activities pertaining to Reclamation projects. Activities funded under these agreements provide additional information about Reclamation Project effects on Pacific Lamprey.

- Yakama Nation Cooperative Agreement R11AC17069 – Reclamation staff continued to work with YN to administer and implement a 4-year, $420,000 agreement for lamprey work in the Yakima Basin. Activities under this agreement include canal sampling for juvenile entrainment, assisting with monitoring adult movements in the Yakima basin in relation to Reclamation's projects, water quality sampling, and other agreement tasks.

- CTUIR Cooperative Agreement R12AC10024 – Reclamation staff worked with CTUIR to develop a Scope of Work and administrative requirements to implement a 4-year, $358,000 agreement for lamprey work in the Umatilla basin. In addition, Reclamation purchased supplies and equipment for this work. Lamprey activities include monitoring adult movements in relation to Reclamation projects in the Umatilla River, assisting with canal surveys and other studies investigating possible entrainment of juveniles in Reclamation canals.

- USFWS Interagency Agreement R10PG10402 – Reclamation continued to implement an interagency agreement with USFWS to monitor movements of adult Pacific lamprey into and throughout the Yakima River basin with an emphasis on providing data for determining passage needs and facilitating designs for lamprey passage at Reclamation facilities.

- USGS Interagency Agreement R10PG17414 – Reclamation continued to implement this agreement with USGS for evaluation of different screen materials for Pacific lamprey entrainment protection.

Lamprey Activity Summaries

Reclamation has been involved in or supported a number of studies and activities since the Accords were signed in 2008. Reclamation completed an assessment of Reclamation projects in 2011 with recommendations for a number of further studies or actions. Many of these actions are being implemented through collaboration with partners. This section provides a brief summary of each of these activities. In many cases Reclamation is one of several partners collaborating on a study or activity, and information is reported from the primary researcher. For each study, the "Background" section outlines the needs and objectives for the study and the extent of Reclamation involvement. The "Update" is either an abstract, executive summary, or narrative summary of the work to date with an emphasis on work accomplished in 2012. If a report has been submitted by the study lead, that report is attached as an appendix and the abstract or executive summary is used for the "Study Update" section. Finally, the "Future Plan" is a brief narrative describing Reclamation's plan relative to that particular study or activity.

Umatilla Basin Passage Structures

Background

CTUIR has been actively working to restore Pacific lamprey populations to the Umatilla River basin through translocation, and led the effort to enhance passage throughout the Umatilla basin for adult lamprey. Reclamation involvement includes providing funding and technical support for passage at Reclamation structures, as well as cooperative funding agreement to monitor adult lamprey movements in the basin related to these structures. NOAA Fisheries has also provided technical expertise and personnel. Adult lamprey passage structures have been installed on all three of Reclamation's diversions in the Umatilla River basin. CTUIR and NOAA Fisheries collaborated to install a Lamprey Passage System (LPS) at Three Mile Falls Diversion in 2009. A flat plate was added to Maxwell Diversion Dam in 2010 to enhance passage for Pacific lamprey. An LPS was installed at Feed Diversion Dam in 2010.

Update

Monitoring

An interim research report prepared by CTUIR and NOAA Fisheries for Reclamation is included as Attachment A – *Identification of low-elevation impediments to adult Pacific lamprey (Lampetra tridentata) migration in the Umatilla River, Oregon and installation of aids to lamprey passage, 2012*. A summary of findings from that report relevant to Reclamation structures is provided below:

Forty radio-tagged fish were released in April, 2012 into the Umatilla River basin. Fifteen were released below Three Mile Falls Dam, ten near Maxwell Dam, and fifteen below Feed Diversion Dam. Of the fifteen released below Three Mile Falls, all approached the dam and eight passed successfully. Two were documented to use the LPS and six used unknown passage routes. Seven of the eight fish that passed Three Mile Falls continued upstream to approach Maxwell Dam, with five passing successfully after an average delay of 1.6 days. Of the ten lamprey released below Maxwell, eight passed Maxwell Dam, with an average delay of

Photograph 1. LPS at Feed Diversion Dam.

2.9 days. Of the fifteen fish released below Feed Diversion Dam, one had a non-working transmitter, and two immediately fell back downstream and then eventually came back up and passed Feed Diversion Dam. Twelve of these fish immediately approached Feed Diversion Dam and four (33 percent) passed with relatively short delay time (average 11.6 hours at the dam) either through the existing fish ladder (one fish) or other routes at the dam (three fish). Eight lamprey were not successful in passing Feed Diversion Dam and spent an average of 19.1 days below the dam exploring, and appeared to move into the fish ladder and slot but were unable to pass. No lamprey were detected attempting to use the LPS at Feed Diversion Dam.

From a basin-wide perspective, lamprey that were able to pass all dams (including several non-Reclamation structures) continued on to spawning areas, but they often did not reach these sites until early June when water temperatures exceeded optimal egg development temperatures. Delays at Reclamation structures may contribute to the cumulative effects of delays at all structures throughout the basin affecting the timing and success of spawning.

Adaptive Management Actions

A vibration and noise issue at the Feed Dam LPS was brought to Reclamation's attention in 2012 that potentially could hamper lamprey use of the lamprey passage structure. Reclamation's Umatilla Field Office responded with modifications to insulate the pumps from the passage structure material, resulting in quieter operation and reduced vibration.

Future Plan

CTUIR and NOAA Fisheries will continue to lead adult lamprey passage monitoring in the Umatilla basin. Reclamation will continue to provide funding as identified in cooperative (CTUIR) and interagency agreements to evaluate efficiency of passage at Reclamation structures. As issues are identified that could hamper lamprey passage at these structures, Reclamation will continue to work with CTUIR and other partners to develop solutions to address them.

Umatilla Projects Juvenile Lamprey Sampling

Study Lead – Reclamation Technical Service Center
Zachary Sutphin
Fish Biologist
Fisheries and Wildlife Resources Group
Denver, Colorado

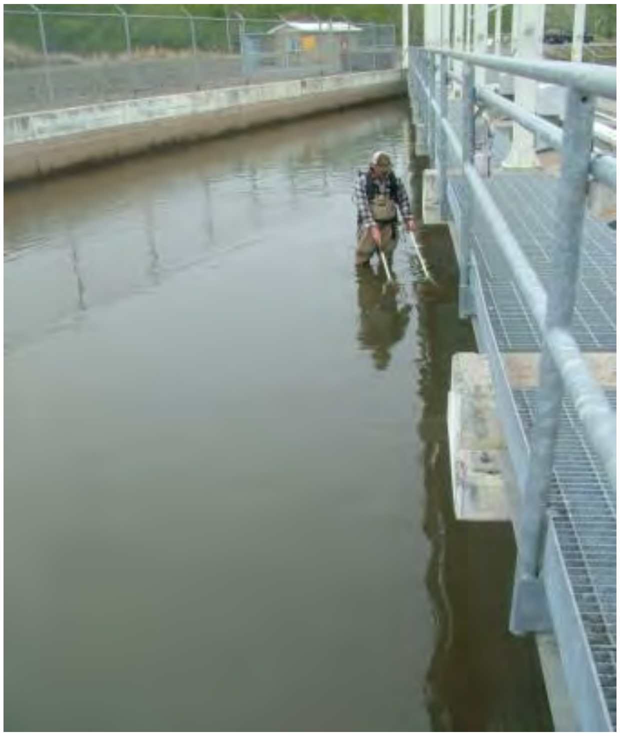
Background

Reclamation worked with CTUIR to begin implementing recommendations from the Assessment. One of these recommendations was to systematically sample Reclamation canals shortly after water delivery shutdowns to estimate the effect of juvenile lamprey being entrained through fish screens and being left stranded in canals. The primary objective was to complete short-term data collection efforts to estimate entrainment loss at Feed, Maxwell, and West Extension Canals, shortly after dewatering. Reclamation's TSC and PNRO staff worked with CTUIR to implement this study, with CTUIR providing equipment and training. Reclamation is the lead on this study. Feed Diversion, West Extension, and Maxwell canals were all sampled in 2011 with very few lamprey captured, and no lamprey were found below any of the screen structures in that initial year of study.

Update

The Year 2 (2012) Annual Report is attached as Attachment B, with a summary provided below:

Presence of Early Life-Stages of Pacific Lamprey Above and Below Water Intake Screens in Bureau of Reclamation Canals in the Umatilla River Basin: Year 2
Zachary Sutphin, Eric Best, Susan Camp



Photograph 2. Lamprey sampling below Feed Diversion screen structure.

For the second consecutive year, Feed, Maxwell, and West Extension canals were sampled by backpack electrofisher and other methods to search for stranded lamprey both in front of and behind the screens, including down the length of the canals. Entire sampling efforts (above/below screens in minutes) for Feed, Maxwell, and West Extension canals was 351/660 min, 384/275 min, and 160/361 min, respectively. In this second year of systematic sampling, a total of 33 Pacific lamprey were collected: 14 in Feed Canal, zero in Maxwell Canal, and 19 in West Extension Canal. No lamprey were collected below the screens in Feed or Maxwell canals. However, two juvenile lamprey (macropthalmia life stage) were captured below the screen at West Extension Canal, and an additional four lamprey were collected in the vicinity of the screen structure after the screen was raised for annual maintenance.

Table 1. Summary of 2012 lamprey sampling results in Umatilla basin canals.

Canal	Dewater Date	Sampling Dates	Sampling Effort Minutes (Above/Below Screens)	Lamprey Collected			
				Above Screens	Below Screens	Unknown	Total
Feed Canal	Apr 18, 2012	Apr 18-19, + Nov. 7, 2012	351/660	14	0	0	14
WEID Canal	Oct. 31, 2012	Nov. 6-7, 2012	384/275	13	2	4	19
Maxwell Canal	Oct. 26, 2012	Nov. 7-8, 2012	160/361	0	0	0	0

CTUIR, with Reclamation support, is also beginning to use PIT tags to learn more about juvenile migration patterns and entrainment susceptibility. Almost 700 juveniles were tagged in the Umatilla River in 2012 and their downstream migrations were tracked. Thirteen of these fish have been detected at juvenile bypass detectors at John Day Dam on the mainstem Columbia River.

Future Plan

Systematic sampling in 2011 of all three Reclamation canals on the Umatilla River yielded very few lamprey overall, and no lamprey were found beyond the screen structures at any of the facilities. Sampling in 2012 still found relatively few lamprey in canal structures, although two were sampled below screens in the West Extension Irrigation District Canal. Further work may be warranted to better understand the interactions of lamprey larvae and juveniles with project structures.

Reclamation plans to continue this effort of sampling for stranded lamprey in canals of the Umatilla projects in 2013, then will evaluate the value of continued sampling. Additionally, other sampling methods and experiments are being explored to provide a more complete picture by allowing for the quantification of lamprey actively entrained into diversions and past screening structures. In 2012, Reclamation worked with CTUIR and developed a pilot study to test PIT tagged individual juveniles exposed to the headworks structures, and also developed study plans for a possible entrainment netting apparatus at West Extension Diversion. Reclamation will also continue to provide funding as identified in cooperative agreements with CTUIR to perform PIT tag studies in relation to juvenile entrainment at Reclamation facilities.

Yakima Radiotelemetry Study

Study Lead – U.S. Fish and Wildlife Service

RD Nelle
Mid-Columbia River Fishery Resource Office
Leavenworth, Washington
Intergency Agreement R10PG10402

Background

Reclamation is providing partial funding to USFWS for a cooperative radiotelemetry study determining the movements of adult Pacific lamprey into and through the Yakima River Basin. Other contributers to this study include YN, BPA, and USACE. The objectives of this study are to determine adult Pacific lamprey passage at the Yakima River diversion dams, including approach timing, residence time downstream of dams, passage routes, time in the fishways, total time spent at the dams, and migration rates between dams. In addition, areas where Pacific lamprey over-winter and spawn in the Yakima River will be located if possible. This information will further develop our understanding of how Reclamation diversions (and other diversions) may affect the migration of adult lamprey and provide information for prioritization, conceptualization, and design of possible lamprey passage structures.

Update

The Abstract from *Passage of Radio-tagged Adult Pacific Lamprey at Yakima River Diversions - 2012 Annual Report* by Andy Johnsen, Mark Nelson, and RD Nelle is provided here to give a basin-wide view of the study results, followed by a more detailed discussion of the information specific to Reclamation projects, including Prosser, Sunnyside, and Roza dams. The full 2012 Annual Report is attached as Attachment C and provides similar site-specific details on non-Reclamation projects such as Wanawish and Wapato diversion dams.

Abstract – The Pacific lamprey *Entosphenus tridentata* is an anadromous fish native to the Pacific Northwest. Information about Pacific lampreys in the Yakima River is very limited. Several irrigation diversion dams exist on the Yakima River that may prevent or delay the upstream migration of adult Pacific lampreys; however, the total impact of these dams on adult Pacific lamprey migration and spawning is not known. We used radio telemetry to determine approach timing, residence time, fishway routes, other passage routes, and migration rates at the diversion dams on the lower Yakima River. Wanawish, Prosser, Sunnyside, and Wapato dams were equipped with multiple antenna telemetry stations. Seven additional stations were established to monitor tributaries and the boundaries of the study area. Seventy-six Pacific lampreys, collected from lower Columbia River dams in summer 2011, were radio-tagged and released near Wanawish and Prosser Dams on October 4, 2011 and March 28, 2012. Seventy-four lampreys made upstream movements with sixty-eight approaching at least one dam. Overall passage success at the dams varied from a low of 39 percent at Sunnyside Dam to a high of 62 percent at Wanawish Dam. Only two lampreys passed all four dams. All passage events occurred in October and April through June. At all four dams combined, the average residence time for lampreys that passed in the fall was 5.45 days with a fishway passage time of 2.2 hours. Lampreys that passed in the spring had an average residence time of 23.7 days and a fishway passage time of 3.4 hours. Fall passage occurred during discharges between 500 and 2,500 ft^3/s. Average discharge during spring passage events was highest at Wanawish with 8,300 ft^3/s and lowest at Prosser Dam with 5,200 ft^3/s. The majority (78 percent) of passage occurred when water temperatures were between 12 and 15°C. The average migration rate between dams was 10.1 km/day with most movements past stations occurring at night. Fishway entrance velocities at all four dams ranged between -4.61 and 10.09 ft/s. To date, our results indicate the diversion dams on the Yakima River are impeding the upstream migration of Pacific lampreys. We suggest several different modifications that may increase lamprey passage including a lamprey passage system (LPS), reduced fishway velocities, and modifications to fishway entrances.

Prosser Diversion Dam – Prosser Dam had an overall approach rate of 84 percent, including lamprey released immediately below Prosser as well as those that successfully passed Wanawish dam further downstream. Of these lamprey that approached Prosser Dam, 48 percent were able to pass the dam successfully, and those that passed were delayed by the dam to varying degrees. Lamprey that successfully passed in the fall were delayed an average of 0.5 days. Unsuccessful fall migrants either moved downstream before overwintering or spent the winter near the dam. Lamprey released in the spring that passed the dam spent an average of 27.4 days at the dam, but this residence time was highly variable with a range of 0.04 to 93 days. Those spring lamprey not successful at passage spent an average of 81.6 days at the dam.

First approaches were made near the left bank 62 percent of the time and the right bank 34 percent of the time. Only two lampreys were first detected on the downstream antenna on the center island.

Lampreys were detected on all three stations at Prosser Dam while they searched for upstream passage with the greatest number occurring on the left island antennas. Lampreys spent little time near the face of Prosser Dam during holding periods or daylight hours, residing instead just downstream of the bedrock ledge the dam was built upon. The greatest concentration occurred in a pool along the left bank (Photograph 3). This area included a boulder filled pool and areas of whitewater coming off the face of the dam. Pacific lampreys were consistently detected in this area during both day and night hours. Night observations during July showed tagged lampreys attempting to climb over the dam using the bedrock at face of the dam along the left bank (Photograph 4). High velocities over the dam and the overhanging crest prevented these lampreys from being successful in their attempts.

Photograph 3. Pool and whitewater along left bank of Prosser Dam where the majority of lamprey are held.

Photograph 4. Two radio tagged Pacific lamprey attempting to climb over exposed bedrock in pool along left bank.

A total of 23 tagged lampreys passed Prosser Dam. Five lampreys (22 percent) passed in October, two of which used the right bank fishway during adult salmonid trapping operations. Both lampreys successfully moved up the ladder and around or through the picket gate used to direct salmon into the denil and trapping facility. The remaining eighteen (78 percent) passed the dam between April 10 and July 14. Thirteen of the 23 (57 percent) passage events occurred in the right bank fishway. Four lampreys used the center island fishway and four were known to have used the left island fishway. An additional two lampreys passed the dam during a power outage and were believed to have used the left fishway. Two separate lamprey were detected attempting to use the fishways to pass but were unsuccessful due to the fishway headgates being closed (Photograph 5).

Photograph 5. Pacific lamprey attempting to exit the right bank fishway by climbing the closed headgate on April 30, 2012.

In summary, Prosser Diversion has a 48 percent passage success rate, variable residence time for lamprey searching for passage, and only intermittent use of fishways that appears to be dependent upon velocities and ability for lamprey to locate entrances. The data collected this year identified a strong preference for the pool and whitewater along the left bank of the dam. This area would be the ideal location for lamprey passage improvement at Prosser. Additionally, this study indicated possible concepts to increase fishway passage efficiency by managing velocities, improving passage conditions within the fishway by rounding corners, and improving entrances with mounds to more smoothly connect the river bottom to the fishway.

Sunnyside Diversion Dam – Thirty-one lampreys had either been released above Prosser Dam or had successfully passed above Prosser Dam, 18 migrated upstream to Sunnyside Dam and seven (39 percent) successfully passed Sunnyside Dam. The first detections at Sunnyside Dam were all on the aerial antennas of the center island station. Three lampreys first approached the dam in October 2011. Approaches made during the spring months occurred from March 28 to July 3, 2012 with the majority in April.

Pacific lampreys that were successful in passing Sunnyside Dam had an average residency of 9.3 days before entering a fishway. The shortest residency occurred on June 16, 2012, and lasted just over 2.5 hours while the longest was 20.7 days. The average residency time for those individuals who were not successful and ultimately moved downstream was 40 days (range 0.1 to 112.7 days). Only one lamprey (code 34) over-wintered at Sunnyside Dam. It attempted to find passage from its arrival on October 24 until December 29. It then over-wintered for 90 days until it began moving again on March 28. Its spring residence at the dam lasted for 81 days until June 17 when it stopped moving. It is not known if the tag was shed, the lamprey died, or it was still holding. Lampreys utilized holding areas across the width of the river downstream of the dam; however, the majority of lampreys used the area between the center island and the right bank for holding during daylight hours. A large log stuck on the face of the dam provided a break in the flow over the dam and lampreys were routinely detected beneath it.

Seven of the eighteen (39 percent) lampreys that approached Sunnyside Dam successfully passed upstream using one of the fishways, and passage through the fishways ranged between 0.27 to 3.85 hours with an average of 1.09 hours. Of successful passages, five lamprey were detected using the right bank fishway, one was deduced to have used the right bank fishway, and one successfully passed using the center island fishway. With only one exception, most lamprey that successfully passed Sunnyside Diversion continued on upstream within a few minutes of passage.

Roza Dam – The study focused on the diversion dams in the lower Yakima River, although a single telemetry station was placed at Roza Dam to detect if any lamprey moved up that far. No lamprey approached Roza Dam. This study is planned to continue in 2013 and lamprey will be released further upstream to evaluate their movements in relation to Roza Dam.

Future Plan

Reclamation plans to continue funding this study in FY2013 and outyears as determined by the results. This phase of the study will involve releasing lamprey further up in the basin with more intensive radiotelemetry networks (similar to Prosser and Sunnyside dams described above) at Roza Dam.

Results in 2012 indicated diversions in the Yakima basin appeared to be impeding lamprey passage to varying degrees and provided valuable information for development and prioritization for lamprey passage improvements throughout the basin. Reclamation will continue to use this information to inform efforts for lamprey passage improvements at Reclamation facilities.

Yakima Project Canals Juvenile Lamprey Sampling

Study Lead – Yakama Nation
Cooperative Agreement R11AC17069

Background

Reclamation continued working with YN to further investigate projects in the Yakima basin. One study was to systematically sample Reclamation canals shortly after dewatering to estimate the effect of juvenile lamprey being entrained through fish screens and being left stranded in canals. With Reclamation support, YN performed a pilot sampling effort in 2011, sampling both Reclamation and non-Reclamation canals. Some Yakima basin canals were previously sampled in 2010 for the presence of lamprey. This sampling continued in 2012.

Update

The full 2012 report, "*Assessment of Lamprey Presence in Irrigation Diversions and Canals in the Yakima Basin*" is included as Attachment D. A summary of results is provided here:

Reclamation projects sampled include Prosser, Sunnyside, and Roza diversions on the Yakima River, and Wapatox Diversion on the Naches River, and Yakima-Tieton on the Tieton River. A number of non-Reclamation facilities were also sampled and reported in the same study, funded by other partners. Reclamation has operation and maintenance agreements and/or ownership of fish screen facilities at some of these non-Reclamation diversions. Surveys were done using standard lamprey electrofishing protocols and took place as canals were dewatered.

In the Yakima River Basin, Western brook lamprey (*Lampetra richardsoni*) are a common, non-anadromous species that is very similar in appearance to Pacific lamprey as ammocoetes. At very early life stages, such as captured in the canals, they are indistinguishable in field identification. Electrofishing surveys captured lamprey at some diversions sampled (Reclamation and non-Reclamation). From these surveys areas behind fish screens have been found with considerable numbers of lamprey, consisting primarily of Western brook lamprey and limited numbers of Pacific lamprey in some of the sites (however, many of the captured lamprey cannot be positively identified to species due to its smaller size).

The total number of lamprey captured at each Reclamation diversion in 2010, 2011, and 2012 is shown in Table 1, with the numbers captured in front of the screens and behind the screens listed. It should be noted that these numbers are not directly comparable as there was much more habitat available throughout the length of the canal downstream of the screens than what was available in front of the screens, so there was much more effort behind the screens. Suitable habitat for lamprey juveniles was found and targeted at all locations; locations where suitable habitat did not exist no sampling was conducted (indicated with N/A).

Table 2. Number of lamprey (Pacific and Western Brook combined) captured at Reclamation's Yakima basin diversions.

	2010		2011		2012	
	Front	Behind	Front	Behind	Front	Behind
Prosser/Chandler	0	0	0	0	0	0
Sunnyside	0	1292	0	224	201	365
Roza	0	24	29	0	98	125
Yakima-Tieton					0	N/A
Wapatox	N/A	0	98	0	87	52

Canal sampling resulted in identifying Sunnyside Diversion dam as a priority for further work to determine entrainment mechanism and population effects. A field visit to Sunnyside Diversion was made by Reclamation (Sue Camp, Zach Sutphin, and Eric Best) and Yakama Nation (Ralph Lampman and Patrick Luke) partners on November 5, 2012. During this visit, several monitoring strategies that may be applicable to this particular site were brainstormed and discussed. There was no one solution that would address all the identified questions, but there are multiple specific monitoring tools (such as small-mesh fyke net and rotary screw traps) that could answer at least one aspect of the entrainment dynamics, and specific locations were discussed where these types of gear could be employed. Means to monitor whether juvenile lamprey are "rolling over" the drum screens were also discussed. Because rotary smolt traps provide more general information, such as timing and general magnitude of migration, installing these both above and below the diversion appeared to be a suitable approach at least for the first year of investigation.

Future Plan

Electrofishing surveys of Reclamation canals found some lamprey both above and behind screens; many of these were Western Brook lamprey, with a few Pacific lamprey and some of unknown species. Reclamation plans to continue funding YN to do electrofishing surveys of canals as they are dewatered to determine the presence/absence of Pacific lamprey and to gather more detailed entrainment information at Sunnyside Diversion Dam.

Yakima Basin "Rapid Assessments"

Background

Reclamation engaged in initial discussions with YN regarding the need to assess diversion structures in the Yakima basin for lamprey adult passage and juvenile protection concepts. These "Rapid Assessments" would entail the development of a team of lamprey and fish passage/protection experts participating in site visits to project facilities in the Yakima basin with the goal of developing site-specific concepts that could be implemented to provide passage for adult Pacific lamprey and protect juveniles from entrainment.

Update

On March 14 and 15, 2012 the Yakama Nation (YN), CTUIR, the Columbia River Inter-Tribal Fish Commission (CRITFC) and Reclamation sponsored a pilot investigation at Prosser and Sunnyside Diversion dams on the Yakima River. Participants represented the above organizations as well as USFWS, USGS, NOAA Fisheries, and the Yakima Basin Environmental Education Project. This investigation focused on developing a process, by a technical working group of lamprey passage experts, to rapidly assess irrigation diversion dams in relation to potential lamprey passage issues. Assessment at Prosser Diversion Dam focused on upstream passage for adult lamprey, while Sunnyside Diversion Dam was used as an example for developing information related to juvenile lamprey entrainment issues. After conclusion of the Rapid Assessment site visit, Reclamation continued to develop passage concepts for Prosser Diversion Dam. In addition, USFWS suggested concepts to enhance passage at Prosser Diversion Dam in their report of the Yakima radiotelemetry study. These included a rock fishway in the area where Pacific lamprey attempted to climb bedrock near the left bank of the dam, a lamprey passage system in this same area, and/or enhancing passage through existing fishways by mounding up the approaches to allow lamprey easier access to them and managing nighttime velocities in fishways to allow lamprey to pass.

Future Plan

In 2013, Reclamation will continue to develop and evaluate designs to be considered for adult lamprey passage at Prosser Diversion Dam. As data comes available to support and inform implementation at other locations the rapid assessment approach may be used to develop improvements for lamprey at other project locations.

Fish Screen Materials Evaluation

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Interagency Agreement R10PG17414

Background

Reclamation is one of several funding partner agencies contributing to a USGS-led study of how juvenile lamprey move through diversion systems, what factors influence entrainment and entrapment of juveniles, and to provide information for the development of criteria for passage and protection of lamprey. Other partner funding agencies include FWS, USGS, CTUIR, and CRITFC. In addition, YN, CTUIR, and CRITFC have encouraged Reclamation to continue funding this study as part of Fish Accords commitments.

The study objectives are: 1) document the general passage characteristics of juvenile lamprey over selected screen types in the laboratory; 2) estimate the rate of entrainment of juvenile lamprey at various screen sites in the field; 3) document the general passage characteristics of juvenile lamprey experimentally released over screens in the field; and 4) develop velocity and operational criteria for the safe and effective passage of juvenile lamprey at different types of diversion screens in the Columbia River Basin.

USGS began work on this study in April, 2010. Personnel were put in place, supplies and materials purchased, and experiments focusing on the first part of Objective 1 conducted. Entrainment, impingement, and injury of ammocoetes exposed to different screen panels at an approach velocity of 0.4 ft/s (current salmonid screening criteria) were evaluated. No sweeping velocity component was used in this initial work.

Update

A report of the initial work was completed in 2011 and published in 2012. This was included in Reclamation's 2011 Annual Report.

In 2012, USGS and partners completed design and construction of laboratory facilities to evaluate screen materials in a more realistic environment with the addition of approach and sweeping velocities as well as varied screen angles. No additional testing was done so there is no new report in 2012.

Future Plan

Reclamation intends to continue contributing to this study through funding identified in an interagency agreement to evaluate screen effectiveness with the newly constructed facilities.

Reclamation Lamprey Plan

Background

Paraphrasing from the Accords, Reclamation agreed to jointly, with the Tribes, develop a lamprey implementation plan for Reclamation projects, and the plan will include priority actions and identification of authority and funding issues. It will be updated annually based on the most recent information, and Reclamation will seek to implement recommended actions from the implementation plan.

Implementation Plan

Reclamation is working with CTUIR, YN, and other partners to implement recommendations in the Assessment for further study or actions that may be taken to reduce effects to Pacific lamprey. First, further studies, as described in this report, are in progress to better understand the effects of Reclamation projects on lamprey. As these studies increase our knowledge, an implementation plan is being developed in collaboration with partners to identify and prioritize actions needed to address Pacific lamprey effects.

Reclamation identified funds of approximately $400,000 for Fiscal Year (FY) 2013, for lamprey activities. Activities have been identified for FY2014 to FY2016 for similar funding levels, but actual out-year funding will depend upon appropriations, activity identification and prioritization, and other factors. Several agreements with partners are in place for continuing work on the activities as summarized in the "Lamprey Activities Summary", and additional mechanisms to conduct lamprey work are continuously being refined through collaboration with the tribes and other partners as opportunities develop. This plan will be revised with input from YN, CTUIR, and CRITFC annually as our knowledge develops.

In the Yakima River Basin, we are still in the stage of identifying and investigating basic issues. Some of this work has identified high priority actions for implementation, but in other areas additional questions need to be investigated. The current focus is on the furthermost downstream facilities (below Roza Dam) for more intensive study in the near term and we anticipate doing more work in the upper basin in out years. Reclamation plans to continue supporting YN and working collaboratively to conduct canal surveys and additional investigations and to provide support to lamprey activities through the existing cooperative agreement. The interagency agreement with FWS will continue to be funded through 2013 and beyond to continue to monitor adult and juvenile lamprey movements relative to Reclamation facilities. Rapid Assessments may be continued in 2013 to develop a process for evaluating concepts to provide adult lamprey passage and entrainment protection as determined necessary by the results of these studies. Information from ongoing studies will be used to prioritize projects for adult passage and to develop lamprey passage designs and placement. In addition, Reclamation will provide technical support through staff time from the various Reclamation offices involved in these efforts.

Specifically, data indicates a priority for passage improvements at Prosser Diversion Dam and sufficient information is available to support passage designs. Reclamation will complete planning and design for this location in 2013 and will seek to implement it as soon as possible.

In the Umatilla River Basin, Reclamation plans to continue to work closely with CTUIR to accomplish continued canal surveys/salvage, and to monitor adult movements and adult passage efficiency. Additional entrainment studies will focus on better understanding juvenile migration patterns and behaviors in the basin with a focus on implications for Reclamation projects. To address reliability issues, Feed Dam LPS will be modified with different pumps and a warning system to send email alerts if the LPS quits operating. In out years, modifications and/or design/implementation of passage and entrainment protection measures will be planned as appropriate to address issues as identified through studies.

From a Regional perspective, Reclamation will continue to fund the USGS study to study the effects of diversions on Pacific lamprey. Collaboration will continue to tie this laboratory study to field studies, which will facilitate a better understanding of the mechanism of juvenile lamprey entrainment and identify possible solutions where needed. Reclamation also remains committed to continued planning, administration, coordination, and collaboration on Pacific lamprey issues through development and administration of funding agreements, participation in interagency meetings and Pacific lamprey workgroup meetings, field studies, continued communications with all partners, and other activities. Reclamation will continue outreach and education efforts to our customers, such as the irrigation districts and municipalities that operate/maintain Reclamation facilities or that have contracts for water, so that they are considered more active partners in our lamprey activities.

Finally, an opportunity exists within Reclamation to augment programmed funding with additional money from Reclamations Science and Technology (S&T) program. This program is a Reclamation-wide competitive, merit-based research and development program that is focused on innovative solutions for issues facing Reclamation water and facility managers and western water stakeholders. Funding is available on an annual basis through application to the program; applications are submitted by Reclamation personnel but are highly focused on effective partnerships. Research proposals may be developed and submitted as other areas are identified where collaborative research would be a good fit for this program to leverage additional funding. Any additional research funded from the S&T Program would be performed by TSC and our research partners.

Authority and Funding Issues

The previous section outlines Reclamation's 2013 plan to continue working with partners to understand effects to Pacific lamprey from Reclamation projects and to seek to develop solutions to address those effects. This section is a discussion of authority and funding issues which may affect implementation of the plan.

Reclamation's authority for lamprey activities is primarily through **The Fish and Wildlife Coordination Act, 16 U.S.C. § 661:** "For the purpose of recognizing the vital contribution of our wildlife resources to the Nation, the increasing public interest and significance thereof due to expansion of our national economy and other factors, and to provide that wildlife conservation shall receive equal consideration and be coordinated with other features of water-resource development programs through the effectual and harmonious planning, development, maintenance, and coordination of wildlife conservation and rehabilitation for the purposes of sections 661 to 666c of this title in the United States, its Territories and possessions, the Secretary of the Interior is authorized (1) to provide assistance to, and cooperate with, Federal, State, and public or private agencies and organizations in the development, protection, rearing, and stocking of all species of wildlife, resources thereof, and their habitat, in controlling losses of the same from disease or other causes…."

Reclamation is using this authority to carry out studies and planning of Pacific lamprey issues at Reclamation projects. Reclamation does not have authority to make any operational or structural modification decisions at non-Reclamation facilities.

Additional authority exists for implementation in the Yakima River basin through Sec. 109 [Fish passage facilities in Yakima River basin] of the 1984 Hoover Powerplant Act, which authorizes the Secretary of the Interior to design, construct, operate, and maintain fish passage facilities within the Yakima River Basin, and to accept funds from any entity to do so.

Activities such as studies, research, and planning (including most lamprey activities in this report) are primarily funded by Reclamation's Columbia/Snake Salmon Recovery Office (CSRO) in the Pacific Northwest Regional Office in Boise, Idaho. Reclamation's field offices in the Umatilla and Yakima River basins have also contributed funding and other support. Reclamation's CSRO is responsible for Reclamation's commitments under the Federal Columbia River Power System (FCRPS) Biological Opinion and Fish Accords such as assessment of projects, studies, and planning. Funding for these lamprey activities is identified from the same budgets as Reclamation's commitments to the Endangered Species Act (ESA) listed species covered under the FCRPS Biological Opinion (salmon and steelhead species), and as such are subject to prioritization for listed species, if necessary. As projects are developed for implementation at individual Reclamation projects, the actual costs of implementation will be considered on a case-by-case basis. Implementation costs are expected to transition towards being project costs and will be subject to budget availability.

Summary

Since the Fish Accords were signed in 2008, Reclamation has been working with YN, CTUIR, CRITFC, and other partners to learn more about how Reclamation projects may affect Pacific lamprey, identify issues, and begin developing and implementing solutions. This report summarizes the Pacific lamprey work completed in 2012.

In calendar year 2012 Reclamation participated in a number of collaborative activities such as meetings with CRITFC, YN, and CTUIR at staff and management levels, participated in lamprey information sharing opportunities with the USACE to enhance interagency cooperation, made efforts to educate water user groups and irrigation districts on lamprey issues, and participated actively with the LTWG. Reclamation also participated in Lamprey Summit III and signed the Pacific Lamprey Conservation Agreement. Updates are provided on studies and/or activities in which Reclamation is a participating partner such as Umatilla basin passage structures, juvenile sampling efforts in both Umatilla basin and Yakima basin canals, the Yakima basin adult lamprey radiotelemetry study, Yakima basin rapid assessments, the fish screen materials evaluation study, and propogation efforts.

Reclamation plans to continue this work through various instruments of funding and technical participation to implement studies and activities for Pacific lamprey. Reclamation plans to collaborate with YN, CTUIR, and CRITFC to update this plan annually to continue meeting Pacific lamprey commitments as specified in the Accords.

Literature Cited

Murauskas, Joshua G., Alexei M. Orlov & Kevin A. Siwicke. 2013. Relationships between the Abundance of Pacific Lamprey in the Columbia River and their Common Hosts in the Marine Environment, Transactions of the American Fisheries Society, 142:1, 143-155.

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Attachments

Attachment A

Identification of Low-Elevation Impediments to Adult Pacific Lamprey (Lampetra tridentata) Migration in the Umatilla River, Oregon and Installation of Aids to Lamprey Passage, 2012

Identification of low-elevation impediments to adult Pacific lamprey (*Lampetra tridentata*) migration in the Umatilla River, Oregon and installation of aids to lamprey passage, 2012.

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Draft Report of Research

April 2013

Introduction

Diminishing lamprey abundance in the Columbia River drainage has resulted in fewer tribal harvest opportunities and the potential loss of a cultural mainstay. In recent years, the number of adult lamprey counted in the mainstem Columbia River has reached record lows (USACE 2008). Consequently, tribal harvest is now restricted to extremely limited areas. Lamprey are considered a "first food" of indigenous peoples of the interior Columbia River Basin, meaning that they are a primary traditional source of nutrition and must be protected. In addition, lamprey are used for medicinal and ceremonial purposes, and have legendary status among these tribes (Close et al. 2004). The danger now exists that younger generations of tribal people may have no exposure to this important fishery resource.

Translocation of adult lamprey to suitable spawning habitat is one tool being used to promote lamprey production and restore damaged or extirpated populations. Lamprey losses have occurred in many tributaries of the Columbia and Snake Rivers. Reasons for these losses include blocked access to spawning and rearing habitats, purposeful extermination, and habitat degradation (Renaud 1997). In fact, control measures for sea lamprey in the Laurentian Great lakes have included the use of low barriers to spawning habitat (GLFC 2006). To restore extirpated or severely depressed populations, the Confederated Tribes of the Umatilla Indian Reservation have undertaken restoration programs to achieve self-sustaining and harvestable lamprey populations in their ceded lands (Close et al. 2009).

A key element of this effort is the provision of habitat connectivity so that all life stages of lamprey can thrive. As is the case for most anadromous, parasitic lampreys, Pacific lamprey spawn in freshwater streams having clean gravel and cobble substrate**.** After hatching, the larvae drift downstream to silty substrate, burrow in the sediment, and begin a 4-7 year period of filter-feeding as ammocoetes. After this period, the ammocoetes metamorphose (becoming macrophthalmia) and begin a seaward migration. Upon reaching the marine environment, Pacific lamprey begin a parasitic phase that is thought to last 2-3 years. Thereafter, the adults embark on a free-swimming spawning migration (migratory phase), entering the Columbia River in spring (April-May). During the next year they proceed upstream and spawn in the Umatilla River and other tributaries of the Columbia Basin in summer between June and August (spawning phase).

There are many potential obstacles to adult lamprey migrants, including physical barriers, poor water quality, low water volume, and extremely high temperatures. To date, research has focused on the effects of large, mainstem hydropower dams that represent formidable obstacles to lamprey migrants (Moser et al. 2002; Keefer et al. 2012). However, smaller structures in tributaries could also block access to spawning habitat. These include irrigation diversion dams, weirs, and culverts (Moser and Mesa 2009). The fact that lamprey reproduction is low in the upper reaches of some rivers (above such structures) indicates that this might be the case (Moser and Close 2003). Moreover, radiotelemetry studies have shown that relatively low-elevation structures (< 5 m) can obstruct or delay migration of sea lamprey (*Petromyzon marinus*) (Almeida et al. 2002; GLFC 2006).

Due to the large number of low-elevation structures in western landscapes, the preservation of migratory corridors for adult Pacific lamprey is a primary regional concern (CRBLTW 2005). To assess the effects of small dams, we examined the passage success of adult lamprey at irrigation diversion dams in The Umatilla River located in northeastern Oregon. These dams function to back up rivers and allow water to be diverted for irrigation. There are many similar irrigation diversions in the Columbia River drainage (Figure 1).

In 2005, we initiated a radiotelemetry study to document lamprey migration behavior in the Umatilla River and to assess the effects of low elevation structures on adult lamprey passage.

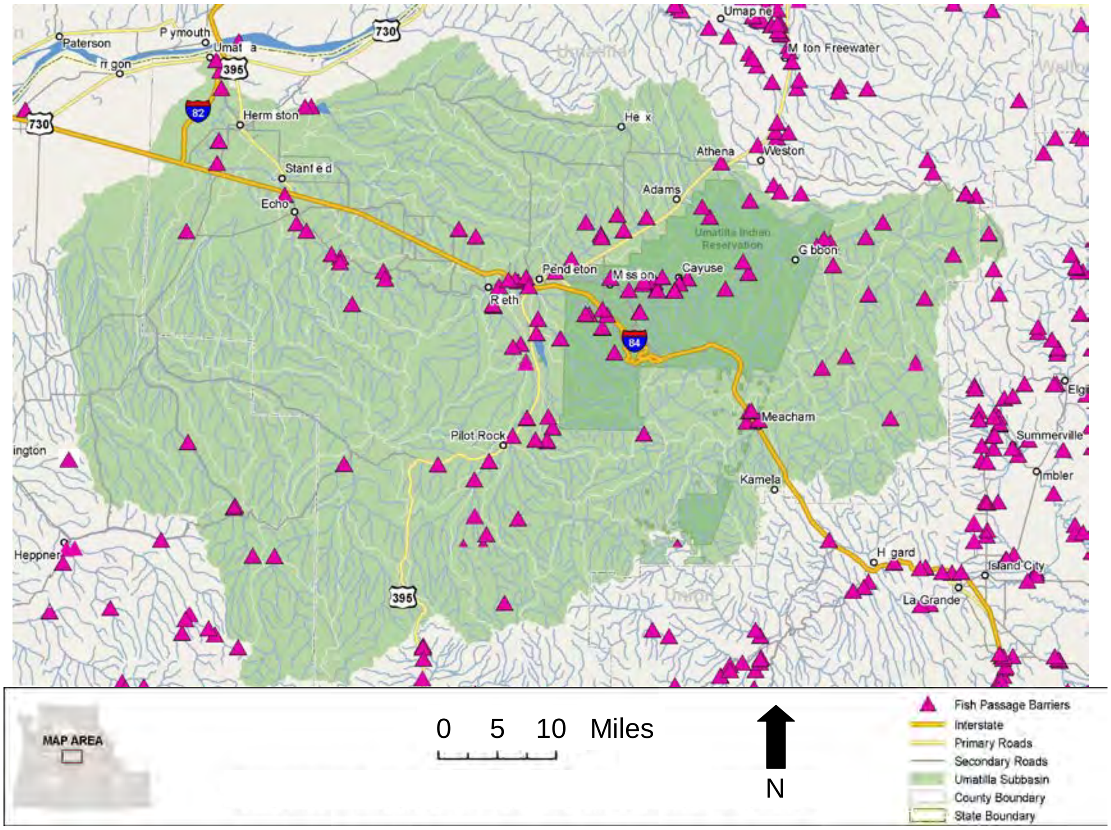

Figure 1. Potential lamprey passage barriers (pink triangles) in the Umatilla subbasin.

The Umatilla River is a typical tributary of the Columbia River in that it provides water for irrigation, having seven irrigation diversion dams in its lowest 55 km (Figure 2). Radiotelemetry has been used in other studies to determine passage efficiency, timing of movements, and the rates of passage of adult Pacific lamprey (Moser et al. 2002a, Moser et al. 2002b, Moser et al. 2005). From 2005 to 2008, we examined migration behavior of spawning-phase fish (those that had over-wintered in freshwater) or migratory-phase fish (those that were captured during the start of freshwater migration)(Figure 3). Passage efficiency varied by structure, but was often less than 50% (Figure 4).

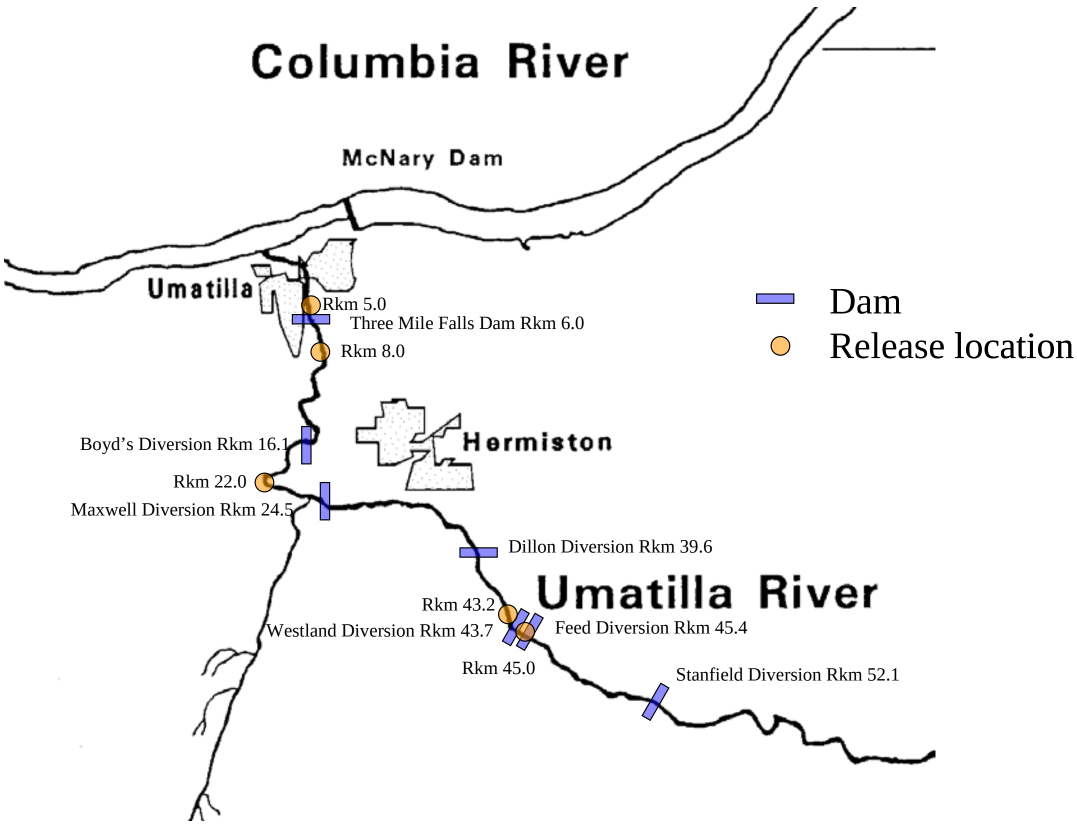

Figure 2. Study area in the lower Umatilla River. Potential obstacles to lamprey adult passage are indicated by the shaded rectangles, and lamprey release sites are indicated by black circles.

Efforts to improve lamprey passage in the Umatilla River were started in the fall of 2006 when Boyd’s Diversion Dam was breached. Radiotelemetry in 2007 and 2008 indicated that breaching this dam significantly improved lamprey passage from 32 to 81% (Jackson and Moser 2012, Figure 3). In 2007, an agreement was reached to allow greater summertime flows (water previously used for irrigation) for fish. Our data indicated that improved summer flows for fish in the lower Umatilla River significantly increased lamprey passage efficiency at Three Mile Falls dam. However, some structures still obstructed or delayed lamprey spawning migration. For restoration of Pacific lamprey to come full circle the next step was installation of lamprey-specific fishways (Moser et al. 2011) at the most problematic structures.

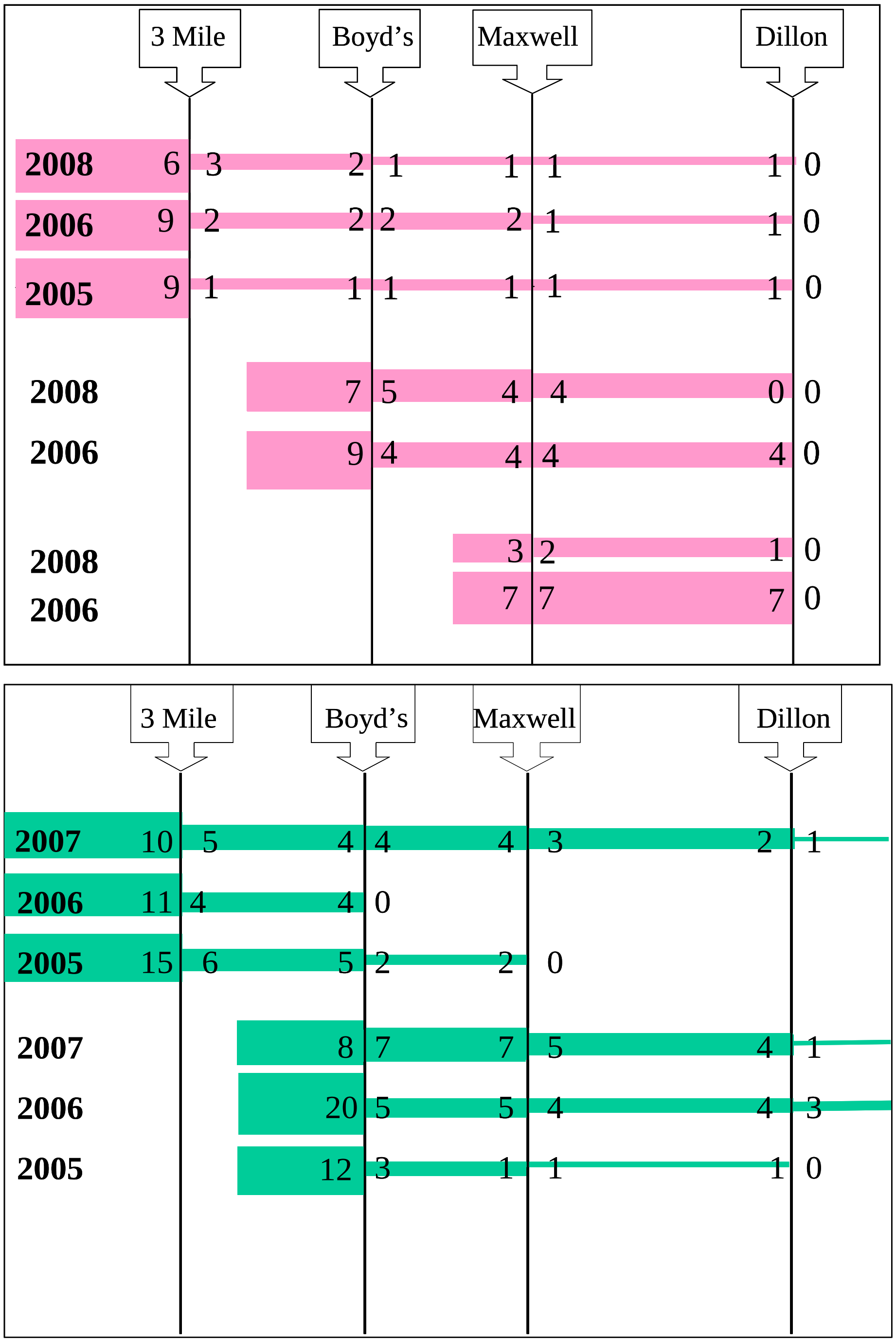

Figure 3. The number of radio-tagged spawning-phase lamprey that approached and passed Three Mile Falls Dam, Boyd's Diversion Dam, Maxwell Irrigation Diversion Dam, and Dillon Irrigation Diversion Dam in 2005-2007. The top three lines denote fish released below Three Mile Falls Dam (km 5) and the bottom three lines were fish released above that dam (km 8 or km 22). Green bars (upper panel) denote spawning-phase lamprey and pink bars (lower panel) are migratory-phase fish.

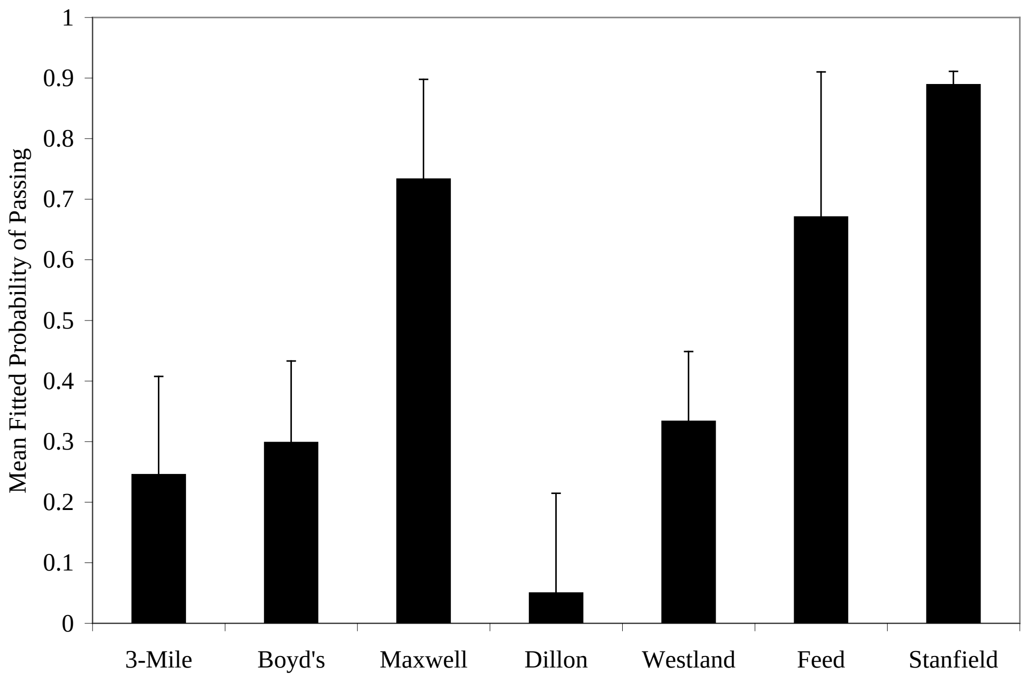

Figure 4. Maximum likelihood analysis was used to determine the most parsimonious logistic regression model for lamprey passage efficiency in 2005-2008. Probabilities of individual lamprey passage were fitted using the resulting model and mean values are given for each dam (bars indicate standard deviation of the mean).

In late summer 2009, a lamprey passage structure (LPS) was installed near the traditional fishway at Three Mile Falls Dam. In November 2010, Feed Diversion Dam was fitted with an LPS in an area where lamprey consistently have difficulty passing and make multiple approaches (Camp 2012). In the same year, improvements were also made at the Maxwell Diversion dam (installation of a flat plate ramp at the weir crest (Camp 2012). Finally, in fall 2010 a gravity-fed LPS was designed and constructed for deployment at Dillon Diversion dam in 2011. Our objective in 2011 was to use radiotelemetry and counts at each LPS to assess adult lamprey passage before and after the various structural improvements and to evaluate the efficacy of each modification.

Methods

LPS Fabrication, Installation, and Maintenance

In 2012, the event logger and time-stamp recorder at the terminus of the Three Mile Falls LPS were activated prior to tagging in April. In addition, the ramps of this LPS were cleared of algae and water flow was turned on. The gravity-fed LPS at Dillon was lowered and flow was checked prior to lamprey migration in April. At Feed (Camp 2012), improvements were made to pumps to reduce vibration and hopefully stimulate lamprey use of this structure. A security camera was installed just downstream from the PIT antennas integrated into Three Mile, Feed, and Dillon structures (Figure 5). At Three Mile the camera was used to validate event recorder detections and at Feed and Dillon, this was the only source of information on use of the structure by un-tagged lamprey. Pit tag readers at all three locations were activated and tested prior to release of tagged lamprey. High water resulted in inundation of the PIT system at Dillon in spring 2012; however, the antenna sustained no permanent damage and was operational throughout the year.

Figure 5 Security camera and housing installed at Feed LPS to monitor lamprey passage.

Figure 6. Float at the upstream end of the LPS (right side of photo) controls water flow into the infiltration gallery (left side of photo at dam crest) at high flows in 2012. Note inundation of PIT antenna (gray square in center of photo).

The camera system at Dillon was also undamaged and yielded imagery of a single lamprey using the passage structure on September 9, 2012 at 5:15 am (Figure 7). Imagery at Feed was plagued by low resolution due to cloudy conditions, or lens obstructions. Much greater success was obtained with the security camera at Three Mile, where lamprey images matched up nicely with recordings at the terminal counter and with PIT detections.

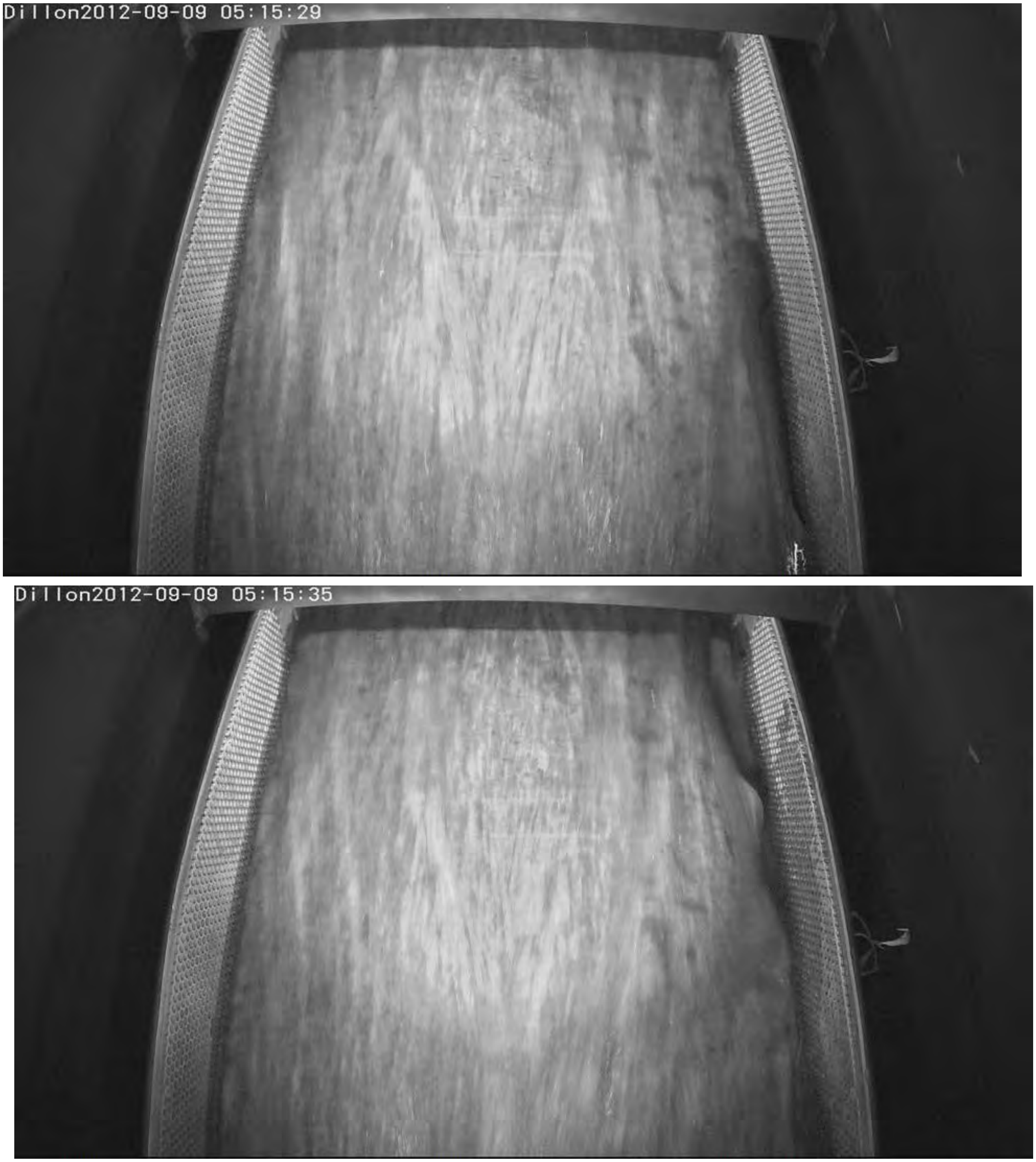

Figure 7. Lamprey detected using the Dillon LPS on September 9, 2012 at 0515 hr.

Tagging

We tagged only spawning-phase lamprey in 2012. Spawning-phase fish were collected from John Day, The Dalles, and Bonneville dams during summer migration in 2011 and were held over winter at the Minthorn Adult Lamprey Holding Facility on the Umatilla River (see Chapter 1 for details). These fish were tagged at the Minthorn Facility in late April just prior to release in the lower Umatilla River.

Each lamprey was equipped with a uniquely coded radio transmitter (16.5 x 8 mm, 2.0 g in air (Lotek Wireless NTC-4-2L) that was less than 0.6% of its body weight and less than 25% of its girth (to minimize tagging effects). The lamprey were anaesthetized using 60 ppm clove oil, measured (length and girth to the nearest mm), and weighed (nearest g). A transmitter was inserted into the body cavity, and the antenna threaded through the body wall approximately 3 cm posterior to the incision using a cannula (following the methods of Moser et al. 2002). The incision was closed with a 19-mm needle and three or four simple interrupted 3-0 absorbable sutures. Fish were allowed to recover for at least 2 hours prior to release in the lower Umatilla River.

Tracking

Movements of radio-tagged lamprey were tracked using a portable receiver from a vehicle. We also monitored lamprey passage using an array of fixed-site receiving stations positioned at the mouth of the Umatilla River (Rkm 1), at Three Mile Falls Dam fishway (Three Mile, Rkm 6), above the Boyd's Diversion (Boyds, Rkm 16.1), at the Maxwell Diversion (Maxwell, Rkm 24.5), at the Dillon Diversion (Dillon, Rkm 39.6), at the Westland Diversion (Westland, Rkm 44), at the Feed Diversion (Feed, Rkm 45.5) and at the Stanfield Diversion (Stanfield, Rkm 52.1, Figure 2). Fixed site receivers were also positioned at upstream locations:

confluence with Birch Creek (Rkm 77), confluence with McKay Creek (Rkm 81), and Mission Falls (Rkm 87.5).

The receiving stations were each equipped with digital spectrum processors (Lotek Wireless SRX-400 or DRX-600) and a Yagi aerial antenna to monitor lamprey approaching the dam. At Westland, Feed, and Stanfield, receivers scanned both the aerial antenna and underwater coaxial cable antennas to obtain higher resolution lamprey positions. At Westland the underwater antenna was located in the fish ladder. At Feed, the underwater antennas were located at the water control slot on the north side of the dam and in the fish ladder. Fish passing over Feed were detected by an aerial antenna oriented upstream. At Stanfield there was an underwater antenna in the fish ladder and an aerial antenna to monitor fish that passed over the dam. At upstream sites aerial antennas were used to determine whether lamprey entered either Birch or McKay creeks.

Data were downloaded from the fixed-site receivers approximately monthly and transmitted electronically to an existing database housed at the Northwest Fisheries Science Center in Seattle, WA. In addition, mobile tracking transects from a vehicle were conducted at approximately two week intervals during the summer and monthly thereafter. Lamprey that entered the Columbia River could also be detected by receiving equipment operated by the University of Idaho, Cooperative Fish and Wildlife Research Unit at McNary Dam (Columbia Rkm 470) and other mainstem Columbia River dams.

Data Analysis

The radiotelemetry data were summarized to determine general patterns of lamprey movement. Passage efficiency at each structure (number of lamprey that passed over of those that approach each structure) was determined where possible. In addition, the timing, route of passage, and the amount of time lamprey required to complete their migration was calculated when possible.

Results

Spawning-phase Fish

Forty spawning-phase lamprey were tagged and released on 24-26 April 2012. These fish ranged in length from 510 to 710 mm (mean = 587.6, standard deviation = 55.4) and weighed 267 - 590 g (mean = 376.1 g, standard deviation = 72.4 g). To avoid tag effects, we have only tagged fish with girth (measured at the insertion of the first dorsal fin) greater than 9 mm in previous years. In 2012, the over-wintered fish girths were lower than normal and it was necessary to relax this standard. The mean girth for fish tagged in 2012 was 8.4 cm with a range of 7 – 10 cm (standard deviation = 0.8 cm). There were more males (n = 23) than females (n = 15).

Tagged lamprey were released at three release sites (Figure 2): below Three Mile Falls Dam (n=15), Cottonwood Bend (Rkm 22.5, n=10), and below Feed (Rkm 45, n=15). All but one transmitter were detected after the release day. The one undetected tag was in a fish released downstream from Feed.

All of the fifteen spawning-phase fish detected downstream from Three Mile approached the dam. Seven fish did not pass over the dam and were detected at the base of the dam for a mean of 82.1 d. All of these unsuccessful fish made repeated approaches to the fish ladder area. The remaining 8 fish (53%) passed successfully upstream; two via the LPS and six via unknown routes. One fish that was known to have used the LPS was detected on the HD-PIT detector at 04:24 hr on 9 May 2012. It was subsequently detected downstream from the dam 4 h later and continued to attempt passage. This fish eventually passed over Three Mile via the fish ladder on 14 May and proceeded to pass all of the remaining diversion dams. It was last detected at Rkm

103 on 27 July 2012. The other fish that used the LPS was detected on the PIT antenna at 23:42 hr on 16 May, passed over Boyd's and was last detected at Maxwell on 19 July 2012.

Of the eight fish that passed over Three Mile, the mean time spent below the dam was 12.6 d. All of these individuals passed Boyd's Diversion and seven approached Maxwell. Of the seven that approached Maxwell, five were known to pass and mean time spent below this dam was 1.6 d. Only the fish that had used the LPS (channel 3, code 107) was detected as it approached and passed Dillon and all of the remaining dams, as described above.

In addition to the fish that we radio-tagged in 2012, one lamprey originally HD-PIT-tagged at Bonneville Dam (Columbia Rkm 235) for another study was detected in the Three Mile LPS. This fish was tagged on 4 August 2011 and was detected passing John Day Dam (Columbia Rkm 347) on 2 September 2011. It apparently over-wintered in the John Day Reservoir and was detected at the Three Mile Falls LPS site on 5/14/12. This fish was one of only 190 pit-tagged lamprey that were released downstream from Bonneville Dam and were either known or inferred to have passed John Day Dam (Keefer et al. 2012).

We released ten spawning-phase fish at Rkm 22 (Figure 2) and all of them approached Maxwell Diversion dam. Eight passed over Maxwell Diversion and were at the base of the dam on average 2.9 d before passing upstream. All but one approached and passed over Dillon and were only delayed at this structure for an average of 0.25 d. Six of these seven lamprey approached and passed Westland Diversion, with a mean time below the dam of 4.1 d. These six fish also approached and passed Feed (mean time below Feed = 4.0 d). None of these fish were detected on the PIT antenna at the Feed LPS and there were no camera images of fish at this site. Five of these six fish approached and passed at Stanfield (mean time below Stanfield = 1.0 d). These five fish were last detected at the following locations: three near Birch Creek (Rkm 77) on 18 June, 29 May and 5 June, one at Rkm 84.5 on 6 August and one at Rkm 109.4 on 8 August.

Of the 14 fish released downstream from Feed Diversion with working transmitters, two fell back downstream below Westland immediately after release. One of these fish re-ascended on 18 June and passed both Westland and Feed on that day. This fish was over Stanfield by 20 June and was last detected at Rkm 87.5 (near Mission) on 17 July. The other fish that fellback re-ascended at Westland on 9 May and required 3 d to pass Feed. This fish rapidly passed upstream from Stanfield (0.9 d) and was last detected at Rkm 81.1 on 31 May.

Of the remaining twelve fish that moved upstream to Feed after release, eight were not detected passing over the dam. On average these fish spent 19.1 d below the dam before moving downstream. Three of these fish were last detected downstream from Westland. These unsuccessful fish showed exploratory movements into both the fish ladder and slot at Feed, but there were no detections at the LPS PIT antenna and they do not appear to have attempted this route.

Of the four fish that moved upstream and passed over Feed immediately after release, the average time spent downstream from Feed was 11.6 h. These four fish all proceeded upstream to Stanfield and passed that dam on average in 1.2 d. While most of these fish were detected at the fish ladder for at least some time, one appeared to use the ladder for passage, while the others used other routes. One fish was last detected at on 11 September at 56.3, but spent significant time further upstream at Rkm 67.6. One fish was last detected on 6 August at Rkm 68.4. The third fish was last detected at Rkm 85.3, also on 6 August. And the remaining individual was last detected at Rkm 117.5 on 8 August.

Discussion

The LPS at Three Mile Falls Dam provided an important passage route for lamprey (Figure 8). Three HD-PIT tagged fish were detected and 48 untagged lamprey were counted as they exited the structure into the dam forebay. The PIT-tagged fish that were detected in the LPS represented 13% of the tagged lamprey released into the Umatilla River downstream from Three Mile. Similar LPS passage efficiencies were recorded in 2010 and 2011 (Figure 8).

Detections of PIT-tagged fish also provided information on over-wintering behavior of lamprey tagged in other studies. One fish that was originally tagged at Bonneville Dam on 8/4/2011 and passed John Day Dam on 9/2/11 was detected at Three Mile on 5/14/12. In contrast, a second fish tagged at Bonneville Dam on 7/13/11 and detected at John Day Dam on 8/8/11 was detected at Three Mile on 8/14/11. Hence, 1% of the lamprey that passed John Day Dam in 2011 was detected at the Three Mile LPS and there was evidence for tributary entry both in the year of tagging and after over-wintering in the John Day Reservoir (Figure 8).

2010	2 of 14 = 14%
2011	1 of 8 = 12%
2012	2 of 15 = 13%

Mainstem		3 Mile
8/12/10	MN (6%)	5/22/11
7/13/11	BO	
8/08/11	JD (0.5%)	8/14/11
8/4/2011	BO	
9/2/2011	JD (0.5%)	5/14/12

Figure 8. Summary of results from PIT-tagged fish detections at the Three Mile Falls LPS.

The earliest date of untagged lamprey passage at the LPS in 2012 was 9 May, further indicating that fish over-wintering in the Columbia River used the structure. In both 2011 and 2012, the peak of passage occurred in August (Figure 9). A second peak that occurred at both the fishway and LPS in September 2011, did not occur at the LPS in 2012. This was observed in spite of the fact that lamprey were counted passing via the fishway in September (Figure 9). The reason for this apparent loss in LPS function in September is unknown, but may account for the low LPS use in 2012 relative to 2011 (Moser and Jackson 2012).

As in 2011, up to seven lamprey each night were counted during periods of peak passage. Counts at LPS structures of similar design at Bonneville Dam regularly pass over 100 lamprey each night (Corbett et al. In Press). Thus, lamprey use of the LPS at Three Mile Falls Dam was limited only by collection efficiency and the numbers of lamprey entering the Umatilla River.

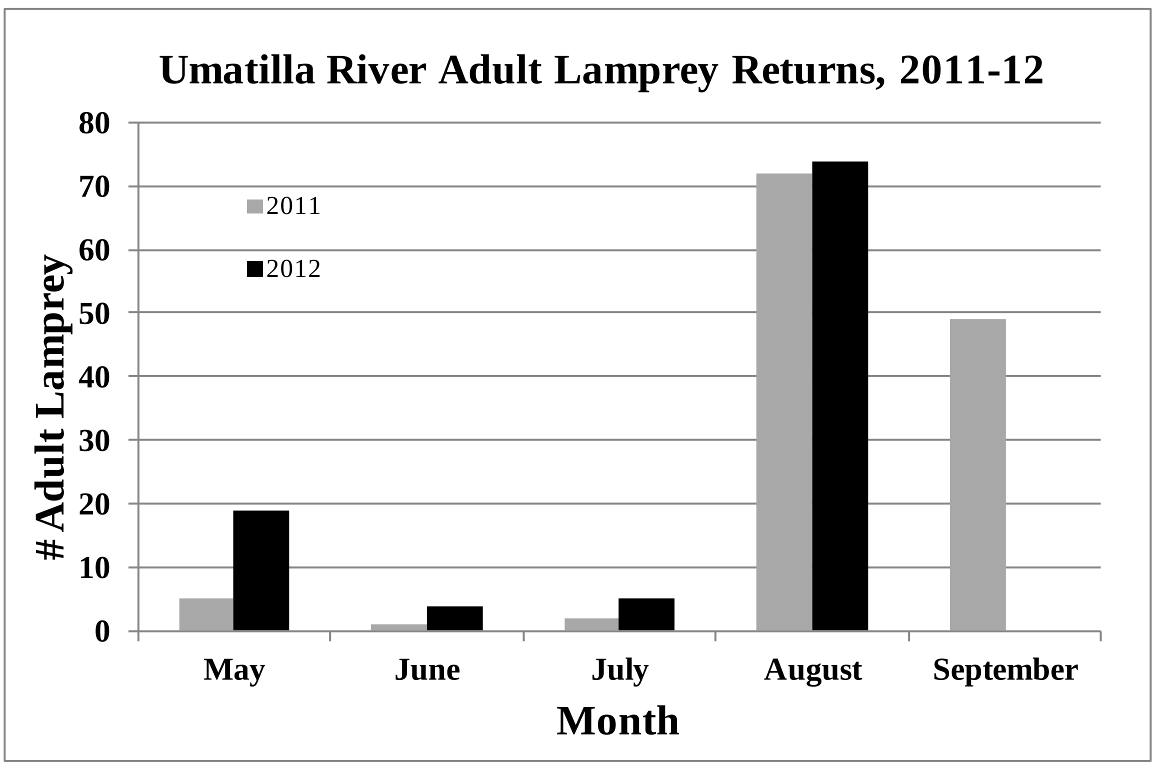

Figure 9. Counts of lamprey at the Three Mile LPS (black bars) and fishway (gray bars) in 2011 and 2012.

A total of eight radio-tagged lamprey successfully passed over Three Mile Falls dam in 2012, and two of these (25%) used the LPS. An even higher percentage of successful fish used the LPS in 2011 (50%, Moser and Jackson 2012). However, there was evidence in 2012 that one fish that used the LPS subsequently fell back downstream. This is the first observation of a fall back event among fish that used the Three Mile LPS, and it appears to have fallen back immediately after having exited the structure. This fish subsequently passed the dam a second time, was detected passing all the other irrigation diversions and was detected at the confluence with Birch Creek in late June.

The next structure upstream (Boyd's Hydroelectric Diversion) has not been a serious impediment to lamprey passage since it was breached in 2006 (Table 1). In both 2011 and 2012, all tagged fish that approached this structure were able to pass upstream. Any efforts to re-construct the dam could result in serious reductions in lamprey passage (Jackson and Moser 2012). If such an action is considered, installation of lamprey-specific aids to passage must be required.

Sample sizes at Maxwell Diversion Dam (the next upstream dam that migrants would encounter) were higher in 2012 than in any previous year (n=17) and continued to show relatively high lamprey passage success (Table 1). Following the installation of a flat plate to provide a lamprey passage route in 2010, mean passage efficiency showed a modest increase from 69% to 78%. Modifications to this structure could potentially improve lamprey passage even more. For example, the flat plate design is not integrated with the side of the bulkhead where it is attached (Figure 10). By flaring the ramp up onto the wall lamprey could maintain attachment under a variety of flow regimes that occur during the migration season (Figure 11).

Table 1. Passage efficiency (%) of spawning-phase radio-tagged lamprey that approached the four lower irrigation diversion dams in the Umatilla River study area. Values in red with yellow highlighting are passage efficiencies recorded after improvements (LPS installations at Three Mile and Dillon, plate installation at Maxwell, and dam breach at Boyds).

	Three Mile	Boyds	Maxwell	Dillon
2005	6/12 (50)	5/17 (29)	1/3 (33)	1/3 (33)
2006	4/11 (36)	5/24 (21)	4/5 (80)	3/4 (75)
2007	5/10 (50)	11/12 (92)	8/11 (73)	1/4 (25)
2009	0/10 (0)		3/3 (100)	4/6 (67)
2010	8/14 (57)	6/7 (86)	3/5 (60)	6/7 (86)
2011	2/8 (25)	2/2 (100)	5/7 (71)	3/5 (60)
2012	8/15 (53)	8/8 (100)	13/17 (76)	8/8 (100)

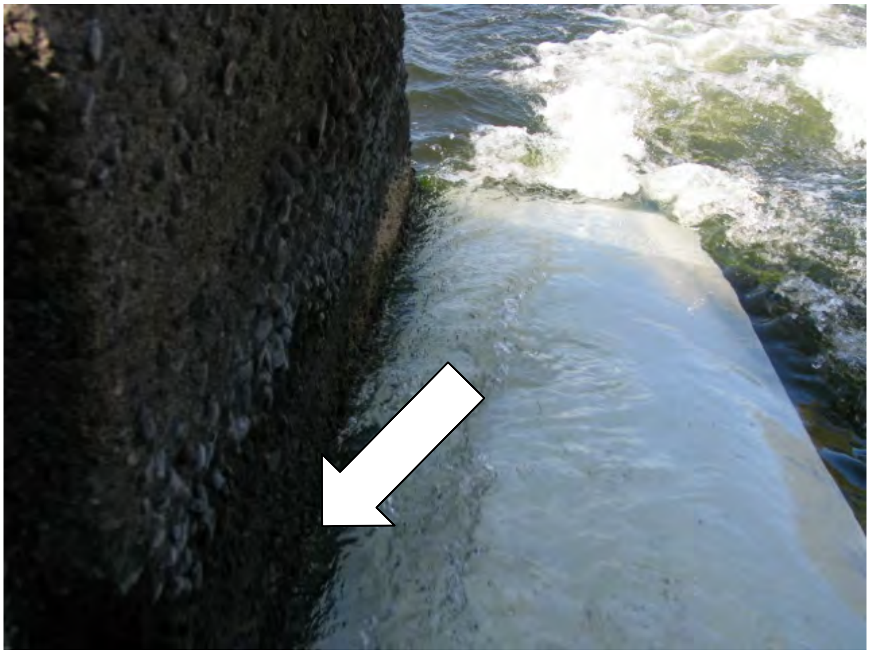

Figure 10. Flat plate installed at Maxwell Diversion Dam. Flaring the side of this plate (indicated by the white arrow) to make a smooth attachment surface with the adjacent wall could improve its performance.

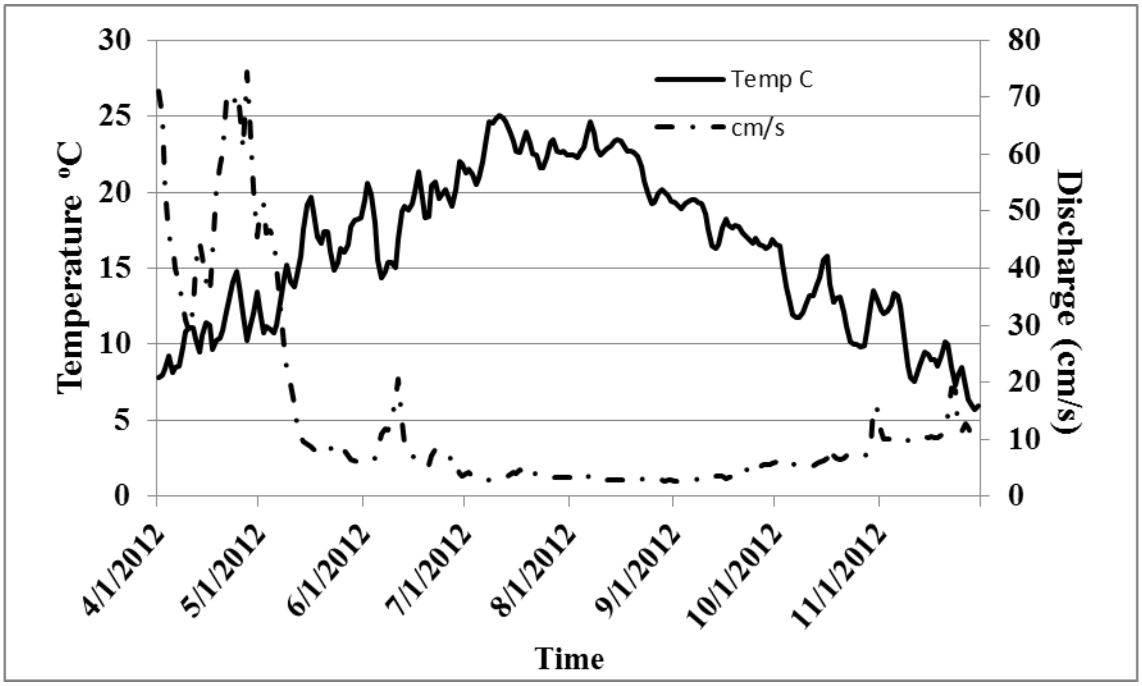

Figure 11. Umatilla River discharge (cubic meters/s, dashed line) and water temperature (ºC, solid line) recorded U.S. Geological Survey and U. S. Bureau of Reclamation gauging stations at Umatilla, Oregon during the 2012 lamprey passage period (May – October).

Dillon Diversion Dam (the next upstream structure, Figure 2) was identified as a critical impediment to passage of spawning-phase lamprey (Jackson and Moser 2012). The fitted probability of passage at this dam, based on 2005-2008 radiotelemetry results, was lower than any other structure in the drainage (Figure 4) and it was targeted for improvement. A gravity-fed structure that can function at this site during both high and low discharge periods with low maintenance and power requirements was installed in fall 2010.

No lamprey were observed using the structure in 2011 and only three of five fish that approached the dam were able to pass over. In 2012 the sample of radio-tagged lamprey was slightly higher (n = 8) and all of these fish were able to pass the dam. However, there was only one record of a lamprey using the structure (Figure 7). High spring flows in 2012 (Figure 11) resulted in inundation of the LPS infiltration gallery and PIT antenna (Figure 6). However, subsequent testing confirmed that the system was operational thereafter and that lamprey using the structure would have been detected by both the security camera system or the PIT detector. Hence, the inexplicably higher passage recorded in 2012 cannot be directly attributed to the LPS. Further assessment with larger sample sizes is needed to fully evaluate this structure.

The high passage success at Dillon and fallbacks from fish released at Rkm 45 resulted in a relatively high sample size of tagged lamprey at Westland (n = 9) and all of these fish were recorded upstream after having passed the structure. Unfortunately, it was difficult to determine the exact passage route taken by these fish, but they did not appear to use the fishway. For fish released at Rkm 22.5 that passed Dillon, the mean passage time at Westland was 4.1 d. Improvements to the Westland structure could potentially reduce the delay lamprey experience at this impediment to migration.

To assess passage at Feed, and Stanfield Diversion dams, we released spawning-phase fish immediately downstream from Feed (Figure 2). Several of these fish fell back downstream before re-ascending at Westland, Feed, and Stanfield. Of the 12 that swam upstream immediately after release and approached Feed, only 4 (33%) passed over, and none of them used the LPS. There were also no PIT or video detections at this LPS, further indicating that lamprey did not use it.

Most of the fish that approached Feed were detected in the vicinity of the LPS entrance. In 2011, we suspected that high levels of vibration on the LPS collector ramp may have discouraged lamprey from attaching to it. This problem was rectified in February 2012 by damping the connection between the pumps and their casings. However, this apparently did not solve the problem. Visual observations and higher sample size of PIT-tagged fish downstream from this structure are needed to determine why the LPS is not used by lamprey. The addition of a lamprey-activated counter (like the one at Three Mile) would also help to determine whether any lamprey are finding and passing via this LPS, as video assessment at this structure was difficult.

As in previous years, lamprey exhibited 100% passage success at Stanfield Diversion Dam in 2012 (n=12) and on average they required less than one day to pass. While most fish were detected at the fish ladder antennas, only one apparently used the fish ladder. Stanfield Diversion is upstream from dams where a greater proportion of the river is diverted for irrigation (Westland and Dillon diversions) and there is higher water volume at this site, providing lamprey with more passage opportunities. Therefore, as long as instream flows at this site remain high, Stanfield Diversion Dam should be a relatively low priority for lamprey passage improvements.

The design of irrigation diversions in the Umatilla drainage clearly impacts lamprey passage (Jackson and Moser 2012). At Maxwell and Stanfield diversions, more lamprey are able to pass because the structures do not have an over-hanging lip at the crest and feature a lamprey-friendly breach in the structure. In contrast, Dillon and Westland dams have over-hanging lips at the crest. In the Great Lakes region of the United States this type of structure is used specifically to halt spawning migrations of the nonnative sea lamprey (*Petromyzon marinus*) (GLFC 2006). In 2009, the Bureau of Reclamation re-structured the fishway approach at Feed to eliminate the "perched" fishway entrance for salmonids. This change seems to have improved the fishway for lamprey as well.

As in previous years, most lamprey that passed Stanfield Diversion dam proceeded upstream to putative spawning areas. However, they often did not reach these sites until early June, when water temperatures exceeded 20ºC (Figure 11). Optimum egg development occurs at 15ºC, so even if these fish spawned, their production may have been compromised by delayed passage and exposure to high temperature. Delays we documented at small structures are similar to those exhibited at main stem dams. In the Columbia River mainstem, mean lamprey passage rates were up to 30 km/d in stretches without obstacles (Noyes et al. 2012), but lamprey are regularly delayed for days to weeks when they encounter mainstem dams (Moser et al. 2002a; 2002b, Keefer et al. 2012). The cumulative effects of these delays may influence both the timing and success of spawning.

In summary, low-head dams impede Pacific lamprey migration in the Umatilla River, but efforts to improve passage have resulted in both higher passage and insights into lamprey life history. The removal of Boyd's Diversion dam in fall of 2006 restored lamprey passage at this important location. The addition of a functional LPS at Three Mile Falls Dam (downstream-most irrigation diversion) has resulted in an estimated 25-50% higher passage rate at this structure. Monitoring at this site has also shown that pulses of spawning-phase fish likely peak in May, with peaks of migratory-phase fish in late August and September. Armed with these data, managers can proceed with outright removal of barriers, retro-fitting structures to accommodate lamprey, and/or improving instream flows at critical passage periods. These actions are needed if restoration of Pacific lamprey in the Umatilla River is to come full circle.

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Attachment B

Presence of Early Life-Stages of Pacific Lamprey Above and Below Water Intake Screens in Bureau of Reclamation Canals in the Umatilla River Basin: Year 2

RECLAMATION

Managing Water in the West

Technical Memorandum No. 86-68290-13-2

Presence of Early Life-Stages of Pacific Lamprey Above and Below Water Intake Screens in Bureau of Reclamation Canals in the Umatilla River Basin: Year 2

Mission Statements

The mission of the Department of the Interior is to protect and provide access to our Nation's natural and cultural heritage and honor our trust responsibilities to Indian Tribes and our commitments to island communities.

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

This study was initiated under one of Reclamation's commitments in the 2008 Columbia River Fish Accords. The purpose of this study is to help Reclamation understand the potential effects of Reclamation projects on Pacific lamprey.

Cover Photograph: Pacific lamprey sampling in Feed Canal, Umatilla River Basin (Insert: Pacific lamprey)

Technical Memorandum No. 86-68290-13-2

Presence of Early Life-Stages of Pacific Lamprey Above and Below Water Intake Screens in Bureau of Reclamation Canals in the Umatilla River Basin: Year 2

Umatilla River Basin, Oregon

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Contents

Page

Figures

Appendix A

Executive Summary

Pacific lamprey (Lampetra tridentata) are a resource of great significance and importance to Tribes in the Pacific Northwest. In 2008, Reclamation entered into a Memorandum of Agreement with Columbia River Basin states and Tribes, known as the Fish Accords, which are tied to the Federal Columbia River Power System Biological Opinion. In the Fish Accords, Reclamation committed to assessing Reclamation project effects on Pacific lamprey and working with Tribes on Pacific lamprey issues. Under one of these commitments, Reclamation worked with the Confederated Tribes of the Umatilla Indian Reservation to systematically sample Reclamation canals in the Umatilla River Basin shortly after they were dewatered to estimate the extent of juvenile lamprey entrainment through the fish screens.

For the second consecutive year, Feed, Maxwell, and West Extension canals were sampled by backpack electrofisher and other methods to search for stranded lamprey both in front of and behind the screens, including down the length of the canals. Entire sampling effort (above/below screens in minutes) for Feed, Maxwell, and West Extension canals were 175.3/550 min, 384/275 min, and 160.2/354.6 min, respectively. In this second year of systematic sampling, a total of 33 Pacific lamprey were collected: 14 in Feed Canal, zero in Maxwell Canal, and 19 in West Extension Canal. No lamprey were sampled below the screens in Feed or Maxwell canals. However, two juvenile lamprey (macropthalmia life stage) were captured below the screen at West Extension Canal, and an additional four lamprey were sampled below the screen after the screen was raised for annual maintenance.

Introduction

Pacific lamprey show declining abundances throughout much of their native range, including the Umatilla River Drainage, OR. In recent years, the population of adult Pacific lamprey has declined sharply. Record low returns were seen in 2010; though numbers have rebounded somewhat in 2011 they are still much below historical returns. Screens developed at the head of instream water diversions (i.e., canals) in the Umatilla River Basin were not designed to exclude ammocoete (larval life-stage, pre eye development) or macropthalmia (juvenile eyed life-stage) Pacific lamprey, but generally to prevent entrainment of more efficient and powerful swimming salmonids (Mesa et al. 1999; CRITFC 2011; Sutphin and Hueth 2010). However, early life-stages of Pacific lamprey are likely to be exposed to screened (and unscreened) diversions because they generally migrate downstream either as ammocoetes dislodged from sediments by high-flow events, or as outmigrating macropthalmia.

Reclamation works with the Yakama Nation (YN) and the Confederated Tribes of the Umatilla Indian Reservation (CTUIR) to better understand effects of Reclamation projects to Pacific lamprey and investigate possible solutions. Reclamation entered into a memorandum of agreement known as the Columbia River Fish Accords (Accords), which are linked to the Federal Columbia River Power System (FCRPS) Biological Opinion, in May 2008 with three of the four Columbia River Treaty Tribes (YN, CTUIR, and Warm Springs). Under the Accords Reclamation conducted a study, in consultation with the Tribes, to identify all Reclamation projects in the Columbia Basin that may affect lamprey, investigate potential effects of Reclamation facilities on adult and juvenile lamprey, and where appropriate, make recommendations for either further study or for actions that may be taken to reduce effects on lamprey. One recommendation from this assessment was to further evaluate possible entrainment of juvenile lamprey into Reclamation canals. Reclamation worked with CTUIR to develop study plans to evaluate this issue.

The primary objective of this research was to complete short-term data collection efforts to estimate entrainment loss (i.e., loss into canals and through screens) of early life-stages (larval – juvenile) of Pacific lamprey from the mainstem Umatilla River into regional Reclamation canals: Feed Canal, Maxwell Irrigation District Canal (Maxwell), and West Extension Irrigation District (WEID) Canal, shortly after dewatering. This is a summarization of Year 2 data from a multi-year data collection effort. More detailed background and methods are available in Sutphin et al (2012), hereby incorporated by reference.

Methods

Data Collection

Backpack electrofishing methodology closely followed those used by the CTUIR and developed by Hintz (1993). A comprehensive summary of electrofishing and other data collection methods are described in Sutphin et al. 2012. Changes to methods employed during Year 1 sampling efforts included applying an amplified sampling effort (~15m2 over a single 11 min pass) throughout all sample sites, which was developed while sampling Maxwell canal in Year 1 to enable more extensive, yet still effective sampling. Similar to Year 1, sampling efforts were concentrated immediately above and below canal screening structures (Figure 1), while targeting lamprey preferred type-I habitat (soft small grain sediments). Specific sample locations details (maps and GPS coordinates) are available in Sutphin et al. 2012. When sample locations assessed or sampled in Year 1 were dewatered, an attempt was made to find additional locations with similar habitat conditions to supplement sampling effort.

Figure 1. Bureau of Reclamation Biologist Zak Sutphin using backpack electrofisher to sample for Pacific lamprey above drum screens at West Extension Canal.

Sample Locations and Dates

Generally speaking, Feed Canal is used to fill Cold Springs Reservoir and runs from late fall through about April. Maxwell and WEID canals are used to deliver water during growing season and operate early spring through late fall (late October/early November). Primary lamprey sampling at Feed Canal occurred on April 18 and 19, 2012, shortly after dewatering was initiated the morning (~8:30a) of April 18, 2012. In addition to primary sampling efforts, a secondary sampling effort occurred at Feed Canal on November 7, 2012 (Figure 2) in response to new information regarding a short stretch (~100 x 10m) of the canal upstream of S. Edwards Rd Bridge that seemingly remains watered year round as a result of spring fed seepage. This Feed Canal section was sampled coincidental with fall sampling of WEID and Maxwell canals. Sampling at WEID canal occurred on November 6 and 7, 2012, following dewatering on October 31, 2012. The primary sampling effort at WEID occurred on November 6, but a return effort was made on November 7 following the raising of the canal drum screens. Maxwell Canal lamprey sampling was completed on November 7 and 8, 2012 after dewatering occurred on October 26, 2012. Likely a result of the time lapse between Maxwell Canal dewatering and sampling, a significant number of Year 1 sample sites were dewatered at the time of sampling. Therefore, additional sites (detailed in Appendix A, Table 2a) were added to make up for sites that could not be sampled. For a more thorough description of the sampled canals and canal sample sites, see Sutphin et al. 2012.

Figure 2. Feed Canal sample location #13 that remains watered year round and was sampled on November 7, 2012 after initial canal sampling efforts (April 18-19, 2012).

Results and Discussion

Total sampling effort, reported as time, up- and downstream of fish screens in Feed, Maxwell, and WEID were 175.3 and 550 min, 384 and 275 min, and 160.2 and 354.6 minutes, respectively (Appendix A, Tables 1A, 2A, 3A). In this second year of sampling, a total of 33 Pacific lamprey (Figure 3) were collected: 14 in Feed Canal (Appendix A, Table 1A), zero in Maxwell Canal (Appendix A, Table 2A), and 19 in WEID (Appendix A, Table 3A). No lamprey were sampled below the screens in Feed or Maxwell canals. However, two juvenile lamprey (macropthalmia life stage) were sampled below the screen at WEID, and an additional four lamprey (macropthalmia) were sampled below the screen after the screen was pulled on November 8, 2012. Sampling dates, canal shutdown dates, and lamprey collected are summarized in Table 1.

Canal	Dewatered Date	Sampling Dates	Lamprey Collected			
			Above Screens	Below Screens	Unknown	Total
Feed Canal	Apr 18, 2012	Apr 18-19, 2012, + Nov. 7, 2012	14	0	0	14
WEID Canal	Oct. 31, 2012	Nov. 6-7, 2012	13	2	4	19
Maxwell Canal	Oct. 26, 2012	Nov. 7-8, 2012	0	0	0	0

Table 1. Dates dewatered and sampled, and number of juvenile lamprey collected at each canal.

All lamprey sampled from Feed Canal were ammocoetes (mean ± standard deviation total length (TL) = 127 ± 37 mm). Eight ammocoetes (mean ± standard deviation = 139 ± 36 mm) and five macropthalmia (mean ± standard deviation = 153 ± 9 mm) were sampled above drum screens at WEID, and two macropthalmia (mean ± standard deviation = 150 ± 13 mm) were sampled below. After the screens were removed from WEID, four additional macropthalmia (mean ± standard deviation = 152 ± 6 mm) were sampled. Of these four lamprey, three were sampled below the drum screen location, but above the initial WEID check structure gates. The additional lamprey was collected from dirt and debris removed from the canal (immediately above and below drum screens) following annual silt removal operations. It is important to note lamprey sampled after the screen removal could have originated from above or below the screen before removal. Therefore, the sample location for these lamprey, in relationship to the drum screen, was identified as "unknown".

Figure 3. Image of Pacific lamprey (macropthalmia life-stage) salvaged above drum screens at West Extension Canal (Umatilla, Oregon).

Aside from lamprey sampling below screens in Feed Canal, effort, both as a function of time and area covered, increased above and below screens in Year 2. This is a result of increasing sample site area covered from 7.5 to 15 m^2/11 min, and because we had two working backpack electrofishers in Year 2. Similarly, the number of lamprey sampled above screens increased in Feed (1 in Year 1, 14 in Year 2). The number of lamprey sampled above screens in WEID (13 in Year 1, 13 in Year 2, Figure 3) and Maxwell (0 both years) were the same. Whereas the number of lamprey sampled below the screens in WEID increased from zero in Year 1, to two in Year 2. Additionally, the four lamprey sampled after

WEID screen removal resulted in 19 total lamprey salvaged (13 above, 2 below, 4 unknown), six more than in Year 1. Range of water temperature and conductivity levels above and below the fish screens at Feed, Maxwell, and WEID Canals were 9.5 – 15.4°C and 44.3 – 82.5 µs/cm, 7.3 – 13.7°C and 140.2 – 713 µs/cm, and 12.4 – 14.5°C and 144.7 – 813 µs/cm, respectively.

Recommendations

Systematic sampling in 2011 of all three Reclamation canals on the Umatilla River yielded very few lamprey overall, and no lamprey were found beyond the screen structures at any of the facilities. Sampling in 2012 still found relatively few lamprey in canal structures, although two were sampled below screens in West Extension Irrigation District canal. While these results indicate relatively few lamprey are left stranded in canals after dewatering, further work may be warranted to better understand the interactions of lamprey larvae and juveniles with project structures.

The sampling for stranded lamprey in canals of the Umatilla projects was originally planned for three years. Reclamation plans to continue the sampling in 2013, then will evaluate the value of continued sampling. Additionally, other sampling methods and experiments are being explored to provide a more complete picture by allowing for the quantification of lamprey actively entrained into diversions and past screening structures. In 2012, Reclamation worked with CTUIR to develop a pilot study to test PIT tagged individual juveniles exposed to the headworks structures, and also developed study plans for a possible entrainment netting apparatus at West Extension Diversion. Reclamation will continue to provide funding as identified in cooperative agreement with CTUIR to perform PIT tag studies in relation to juvenile entrainment at Reclamation facilities.

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Appendix A

Sample locations, sites, total time and number of Pacific lamprey sampled in Feed, Maxwell, and West Extension Canals (near Hermiston, OR).

Table 1a. Sample locations on Feed Canal, total number of sample sites and sample time, and total number of Pacific lamprey (a = ammocoete, m = macropthalmia life stage) sampled within each sample location. Dotted vertical line (between locations one and two) isolates sample locations above and below the canal fish screening facilities. Sites described in grey text indicate locations where historic sampling occurred, but could not take place as a result of dewatered habitat.

Sample Location (ID)	Sample Sites (#)	Time Sampled (min)	Lamprey Sampled	Location/Comments
				16 sites constituting total sampling effort above screens
1	1 - 3	33	3 (a)	Immediately upstream of lower PIT tag array (above screens), primarily soft sediment
	4, 5, 14 - 16	55	3 (a)	Immediately above screens, turbid water, primarily soft sediment
	6 - 9	44	3 (a)	Left (2 sites) and right (2 sites) banks upstream of sites 1 - 3
	10 - 13	43.3	5 (a)	Intermittent available habitat covered (not plots) below upper PIT tag array
				14 sites constituting total sampling effort immediately below screens
2	1 - 7	77	0	7 sites covered entire concrete lined area below screens, turbid, intermittent soft sediment
	8 - 11	44	0	Below screens/upstream of first check structure, banks sampled due to deep (> 1 m) water throughout middle section of the canal
	12 - 14	33	0	Immediately downstream of concrete lining (below screens)
3	4	44	0	0.37 km downstream of screens
4	0	0	0	Substrate severely armored. Not suitable habitat for lamprey. Did not sample
5	4	44	0	100 m upstream of E. Gerone St Bridge in Echo, OR
6	0	0	0	Substrate severely armored. Not suitable habitat for lamprey. Did not sample
7	4	44	0	Armored substrate
8	4	44	0	2 sites upstream and downstream of S .Edwards Rd Bridge
9	0	0	0	Substrate severely armored. Not suitable habitat for lamprey. Did not sample
10	0	44	0	Upstream of Bartley Rd Bridge, primarily soft sediment
11	4	44	0	Upstream of Interstate Highway 84, primarily soft sediment (some armored)
12	4	44	0	Downstream of Highway 395, primarily soft sediment
13	8	88	0	~ 300m upstream of site #8. Sampled on 11/7/12. Site watered year round

Table 2a. Sample locations on Reclamation's Maxwell Canal, total number of sample sites and sample time, and total number of Pacific lamprey sampled within each sample location. Dotted vertical line (between locations 12 and 13) isolates sample locations above and below the canal fish screening facilities. Sites described in grey text indicate locations where historic sampling occurred, but could not take place as a result of dewatered habitat.

Sample Location (ID)	Sample Sites (#)	Time Sampled (min)	Lamprey Sampled	Sample Site ID/Comments
2	4	44	0	Sites MC1-MC3 (MC3b added), upstream of screens, turbid, soft sediment + vegetation
1	2	120	0	Sites MCTA-B, two $55m^2$ plots sampled immediately upstream of screens
3	2	22	0	Sites MC4-MC5, primarily soft sediment + vegetation
4	2	22	0	Sites MC6-MC7, primarily soft sediment + vegetation
5	2	22	0	Sites MC8-MC9, primarily soft sediment + vegetation
6	2	22	0	Sites MC10-MC11, intermittent sampling of pools, primarily armored substrate
7	2	22	0	Sites MC12-MC13, primarily soft sediment + vegetation
8	2	22	0	Sites MC14-MC15, intermittent sampling of pools
9	2	22	0	Sites MC 16-MC17, primarily packed substrate
10	2	22	0	Sites MC18-MC19, primarily armored (< 1/2 - 1" cobble) substrate
11	2	22	0	Sites MC20-MC21, primarily armored (< 1/2 - 1" cobble) substrate
12	2	22	0[B]	Sites MC22-MC23, primarily soft silt sediment, 1 lamprey observed but not captured
13	2	22	0	Sites MC24-MC25, dense aquatic vegetation, primarily soft sediment
14	0	0	0	Sites MC26-MC27, no available habitat to sample (dewatered)
15	2	22	0	Sites MC28-MC29, dense aquatic vegetation, primarily soft sediment
16	0	0	0	Sites MC30-MC31, no available habitat to sample (dewatered)
17	2	0	0	Sites MC32-MC33, no available habitat to sample (dewatered)
18	2	0	0	Sites MC34-MC35, no available habitat to sample (dewatered)
19	2	0	0	Sites MC36-MC37, upstream of Minnehah Rd, no available habitat to sample (dewatered)
20	2	0	0	Sites MC38-MC39, Upstream of Lloyd Ln, no available habitat to sample (dewatered)
21	2	0	0	Sites MC40-MC41, Hwy 107 crossing, no available habitat to sample (dewatered)
22	2	22	0	Sites MC42-MC43, soft sediment, Townsend Rd crossing
23a	0	0	0	Sites MC44, end of canal (Ott Rd), no available habitat to sample (dewatered)
23	3	33	0	Sites MC45-47, soft sediment, deep pools, end of canal (Ott Rd)
24	4	44	0	Sites MC48-52 added to supplement for dewatering at sites MC26-17 and MC30-31
25	2	22	0	Sites MC53-54 added to supplement for dewatering at sites MC32-MC33
26	10	110	0	Sites MC55-65 added to supplement for dewatering at sites MC34-41, downstream of MC45-47

Table 3a. Sample locations on Reclamation's West Extension Canal, total number of sample sites and sample time, and total number of Pacific lamprey (a = ammocoete, m = macropthalmia life stage) sampled within each sample location. Dotted vertical line (between locations 1 and 2) isolates sample locations above and below the canal fish screening facilities. The grey shaded region represents fish sampled following the removal of canal drum screens, and as a result they could not be classified as being either above or below the screen

Sample Location (ID)	Sample Sites (#)	Time Sampled (min)	Lamprey Sampled	Location/Comments
1	1	160.2	13 (8 a, 5 m)	Inundated areas (~99% of total) directly upstream of drum screens
2	1	134.6	2(m)	Inundated areas (~99% of total) directly downstream of drum screens
3	8	88	0	2.4 km downstream of West Extension Canal headworks
4	6	66	0	~2.4km/1.5mi downstream of Location # 3
5	6	66	0	Near canal's termination
NA	NA	NA	4 (m)	Area immediately up- and downstream of screens sampled AFTER screens lifted

Attachment C

Passage of Radio-tagged Adult Pacific Lamprey at Yakima River Diversions - 2012 Annual Report

Passage of Radio-tagged Adult Pacific Lamprey at Yakima River Diversion Dams

2012 Annual Report

Andy Johnsen, Mark C. Nelson, Daniel J. Sulak, Cal Yonce, and R.D. Nelle

U.S. Fish and Wildlife Service
Mid-Columbia River Fishery Resource Office
Leavenworth, WA

On the cover: Pacific lamprey code 69 attempting to climb the closed headgate in the right fishway at Prosser Dam, April 30, 2012. Photograph by Cal Yonce, USFWS.

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2012 Annual Report

Passage of Radio-tagged Adult Pacific Lamprey at Yakima River Diversion Dams

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January 9, 2013

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PASSAGE OF RADIO-TAGGED ADULT PACIFIC LAMPREY
AT YAKIMA RIVER DIVERSION DAMS
2012 ANNUAL REPORT

Andy Johnsen, Mark C. Nelson, Daniel J. Sulak, Cal Yonce, and R.D. Nelle

Final Report

U.S. Fish and Wildlife Service
Mid-Columbia River Fishery Resource Office
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Abstract- The Pacific lamprey *Entosphenus tridentatus* is an anadromous fish native to the Pacific Northwest. Information about Pacific lampreys in the Yakima River is very limited. Several irrigation diversion dams exist on the Yakima River that may prevent or delay the upstream migration of adult Pacific lampreys; however, the total impact of these dams on adult Pacific lamprey migration and spawning is not known. We used radio telemetry to determine approach timing, residence time, fishway routes, other passage routes, and migration rates at the diversion dams on the lower Yakima River. Wanawish, Prosser, Sunnyside, and Wapato dams were equipped with multiple antenna telemetry stations. Seven additional stations were established to monitor tributaries and the boundaries of the study area. Seventy-six Pacific lampreys, collected from lower Columbia River dams in summer 2011, were radio-tagged and released near Wanawish and Prosser Dams on October 4, 2011 and March 28, 2012. Seventy-four lampreys made upstream movements with sixty-eight approaching at least one dam. Overall passage success at the dams varied from a low of 39% at Sunnyside Dam to a high of 62% at Wanawish Dam. Only two lampreys passed all four dams. All passage events occurred in October and April-June. At all four dams combined, the average residence time for lampreys that passed in the fall was 5.45 d with a fishway passage time of 2.2 h. Lampreys that passed in the spring had an average residence time of 23.7 d and a fishway passage time of 3.4 h. Fall passage occurred during discharges between 500 and 2,500 ft^3/s. Average discharge during spring passage events was highest at Wanawish with 8,300 ft^3/s and lowest at Prosser Dam with 5,200 ft^3/s. The majority (78%) of passage occurred when water temperatures were between 12 and 15 °C. The average migration rate between dams was 10.1 km/day with most movements past stations occurring at night. Fishway entrance velocities at all four dams ranged between -4.61 and 10.09 ft/s. To date, our results indicate the diversion dams on the Yakima River are impeding the upstream migration of Pacific lampreys. We suggest several different modifications that may increase lamprey passage including a lamprey passage system (LPS), reduced fishway velocities, and modifications to fishway entrances.

Table of Contents

List of Tables

List of Figures

Introduction

The Pacific lamprey *Entosphenus tridentatus* is an anadromous fish native to the Columbia River Basin and many of its tributaries, including the Yakima River (Patten et al. 1970). Over the last decade the number of adult Pacific lampreys returning to the Yakima River has been minimal, with counts at Prosser Dam (river kilometer 75) ranging from 0 to 87 individuals per year (DART 2011). These low counts are consistent with the declines observed at Columbia River dams (Kostow 2002, DART 2011). Several factors including construction and operation of hydroelectric and diversion dams, river impoundment, water withdrawals, stream alteration, habitat degradation, elevated water temperatures, pollution, and ocean conditions have likely contributed to this decline (Luzier et al. 2011).

Telemetry studies of Pacific lamprey movements within the Columbia River have documented that hydroelectric dams cause major delays and difficulties for the upstream migration of Pacific lampreys, resulting in less than half of tagged fish successfully passing upstream through the fishways (Moser et al. 2002, Johnson et al. 2009, Keefer 2009). Several diversion dams exist in the Yakima River Basin and may be impediments for adults migrating to suitable spawning areas, however, details on upstream migration, timing, spawning, and distribution of Pacific lamprey in the Yakima River are not well understood. Results from the pilot year of this study indicate dam passage success rates as low as 25%, however, the sample size was small and more detailed information about passage and residence time at the dams is needed (Johnsen et al. 2011).

The objective of this multi-year radio telemetry study is to determine adult Pacific lamprey passage at the Yakima River diversion dams, including approach timing, residence time downstream of dams, passage routes, time in the fishways, total time spent at the dams, and migration rates between dams. In addition, areas where Pacific lamprey over-winter and spawn in the Yakima River will be located if possible. Information from this study will help guide management recommendations for improving passage at the dams in the Yakima River.

This annual report presents the results of our study for the 2011 migratory year, from September 13, 2011 through August 31, 2012. Because of the increased interest and urgency for actions to conserve Pacific lamprey we also make some preliminary recommendations in this report.

Background

Similar to summer steelhead *Oncorhynchus mykiss,* Pacific lamprey enter freshwater a year prior to spawning, migrate upstream to overwinter, and then access spawning tributaries or areas the following spring. It is thought Pacific lampreys do not home to their natal streams, unlike many anadromous fishes, but instead may utilize the “suitable river strategy” in which returning adults are attracted to streams inhabited by larval lamprey or ammocoetes (Waldman et al. 2008). Recent genetic studies indicate Pacific lampreys are panmictic (Goodman et al. 2008 and Docker 2010) and support the hypothesis of no natal homing in Pacific lamprey. Adults typically return to the Columbia

River from February to June (Kostow 2002) and begin to arrive at McNary Dam (67 kilometers downstream of the Yakima River confluence) in early June with the peak of migration in late July or early August (DART 2011). During a migratory year, lampreys are not observed at Prosser Dam until mid to late August and only a few are counted through the fall. Most of the returning adults are observed the following spring with the majority counted during April and May (DART 2011). However, radio telemetry studies conducted in tributaries such as the John Day River (Bayer et al. 2000), the Willamette River (Clemens et al. 2011), and the Methow River (Nelson et al. 2009) found that Pacific lamprey entered these spawning tributaries in late summer and completed about 85% of their migration to spawning areas before overwintering. Thus it appears there has been a shift in migration timing in the Yakima River that differs from other tributaries and may be related to temperature differences between the Yakima and Columbia rivers. During July and August, temperatures in the lower Yakima River are on average almost 4 °C higher than in the Columbia River (mean 23.8 °C vs. 20.0 °C, 2002 to 2009 data-USBOR 2011; DART 2011). This appears to create a thermal barrier that either encourages lampreys to migrate past the Yakima River and continue upstream in the Columbia River or discourages lampreys from entering the Yakima River until later in the fall after temperatures equilibrate. Lampreys may also be overwintering in the Columbia River and entering the Yakima River the following spring. Radio-tagged Pacific lampreys translocated to the Yakima River exhibited the same migratory behavior as those that entered the river naturally (Johnsen et al 2011), supporting both the hypothesis of no natal homing and shifted migration timing within the Yakima River.

Investigation of the potential thermal barrier and its effect on lamprey migration in the Yakima River is beyond the scope of our current study. However, because it appears to shift the majority of the migration to the spring, we designed our study to test passage at the dams during both the fall and spring of the lamprey migration year. Accordingly, we tagged and released a portion of our study fish in the fall and held the others over winter before tagging and releasing them in the spring in order to mimic both the timing of the "natural" run and the condition of the lampreys during their migration in the Yakima River.

Methods

Study Area

The Yakima River flows for 344 km, from the headwaters at Keechelus Lake in the Cascade Mountains to the confluence with the Columbia River at river kilometer (rkm) 539, and drains an area of approximately 15,941 km^2 (Figure 1). Annual mean discharge at the Kiona Gage Station (rkm 48.1) is 3,479 cubic feet per second (ft^3/s) (range 1,293 – 7,055 ft^3/s), with the highest daily mean discharge of 59,400 ft^3/s recorded on December 24, 1933 and the lowest daily mean discharge of 225 ft^3/s recorded on April 4, 1977 (USGS 2011). The main tributaries include Satus Creek, Toppenish Creek, Naches River, Taneum Creek, Teanaway River, and Cle Elum River.

A complex irrigation network, managed in large part by the U.S. Bureau of Reclamation, makes the Yakima River Basin one of the most intensely irrigated areas in the United States, and has served to make it a leading producer of tree and vine fruit as well as other diverse agricultural products. Six lakes and reservoirs, with a total active storage capacity of 1.07 million acre-feet, hold the spring and summer snowmelt in the mountains for delivery to irrigation districts between April and October (Fuhrer et al. 2004). Irrigation water is distributed throughout the network via rivers, creeks, and man-made canals. Irrigation diversion dams include Wanawish, Prosser, Sunnyside, Wapato, Roza, and Easton on the Yakima River and Cowiche and Wapatox on the Naches River (Figure 1).

Surface water diversions are equivalent to about 60% of the mean annual stream flow from the basin (Fuhrer et al. 2004). In spring, the stream flow reflects the quantity of water stored in the mountain snowpack, while during the dry summer months it reflects the quantity of water released from the basin’s storage reservoirs. During summer, return flows from irrigated land account for 50 to 70% of the flow in the lower Yakima River (Fuhrer et al. 2004).

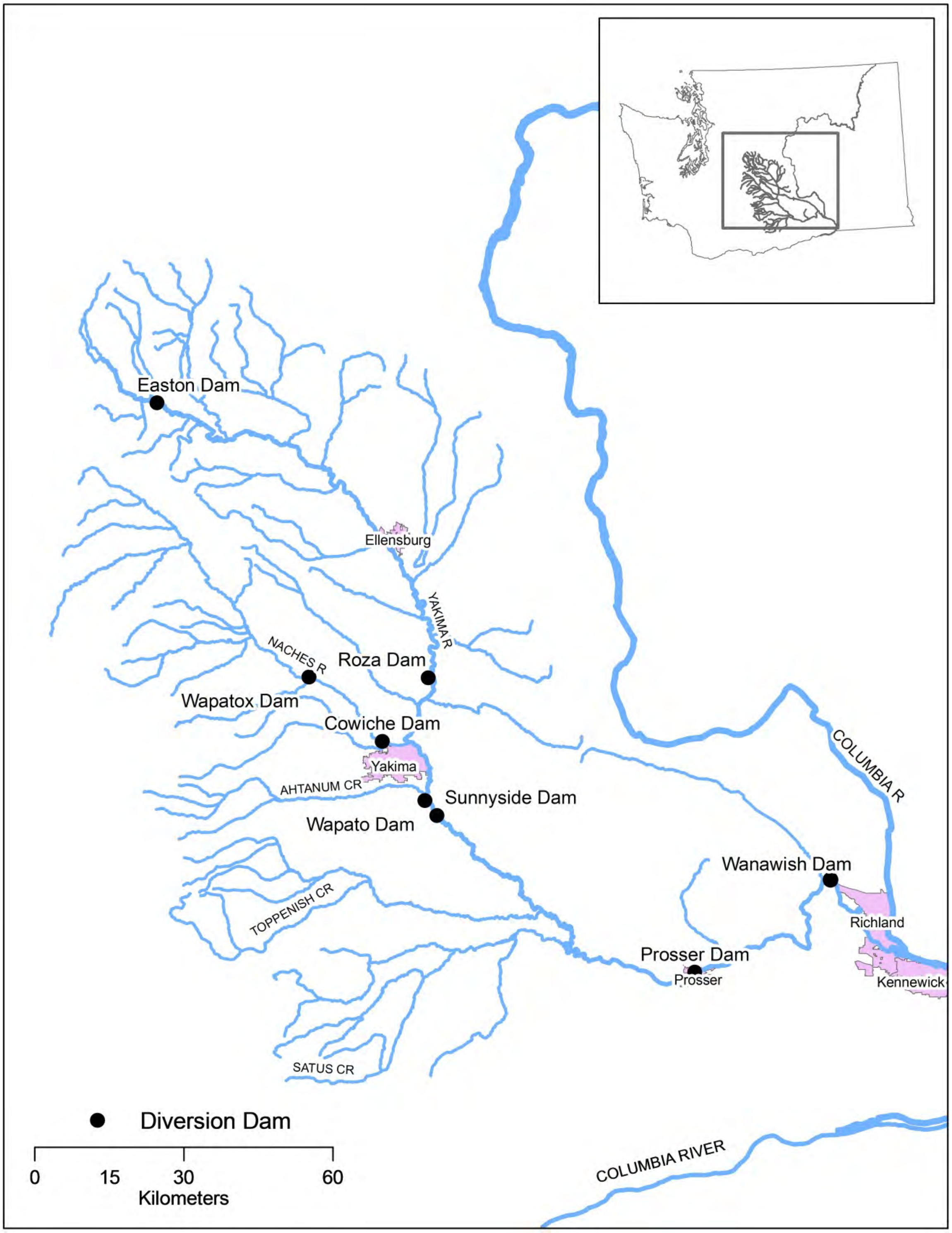

Figure 1. Map of the Yakima River watershed, showing the locations of the major diversion dams.

Fixed Stations

Fixed telemetry stations were set up at six diversion dams, in three tributaries, at the outfall of an irrigation diversion, and near the mouth of the Yakima River (Figure 2). The basic layout at a diversion dam consisted of aerial antennas that monitored downstream of the dam, the face of the dam, and upstream of the dam. Underwater antennas monitored pools at the entrance, middle, and exit of each fishway. Aerial antennas were four element Yagi-type and underwater antennas were constructed of coaxial cable with 100 mm of the inner wire bared at the end. Hanging antennas were added to the arrays during the spring of 2012 and were the same design as the underwater antennas except they were suspended above the waterline. Aerial antennas were mounted on masts, underwater antennas were suspended on chains, and hanging antennas were zip-tied to rails and posts. Data recording telemetry receivers (Lotek SRX-400A), equipped with an antenna switching unit (Grant Engineering Hydra) programmed on a "master-slave" cycle, were housed in a metal box at each station. AC power, when available, was used to charge the external 12v battery that powered the receiver at each diversion station. Solar panels were used as a back-up power system in case AC power was lost and as the primary power source at stations with no available AC power.

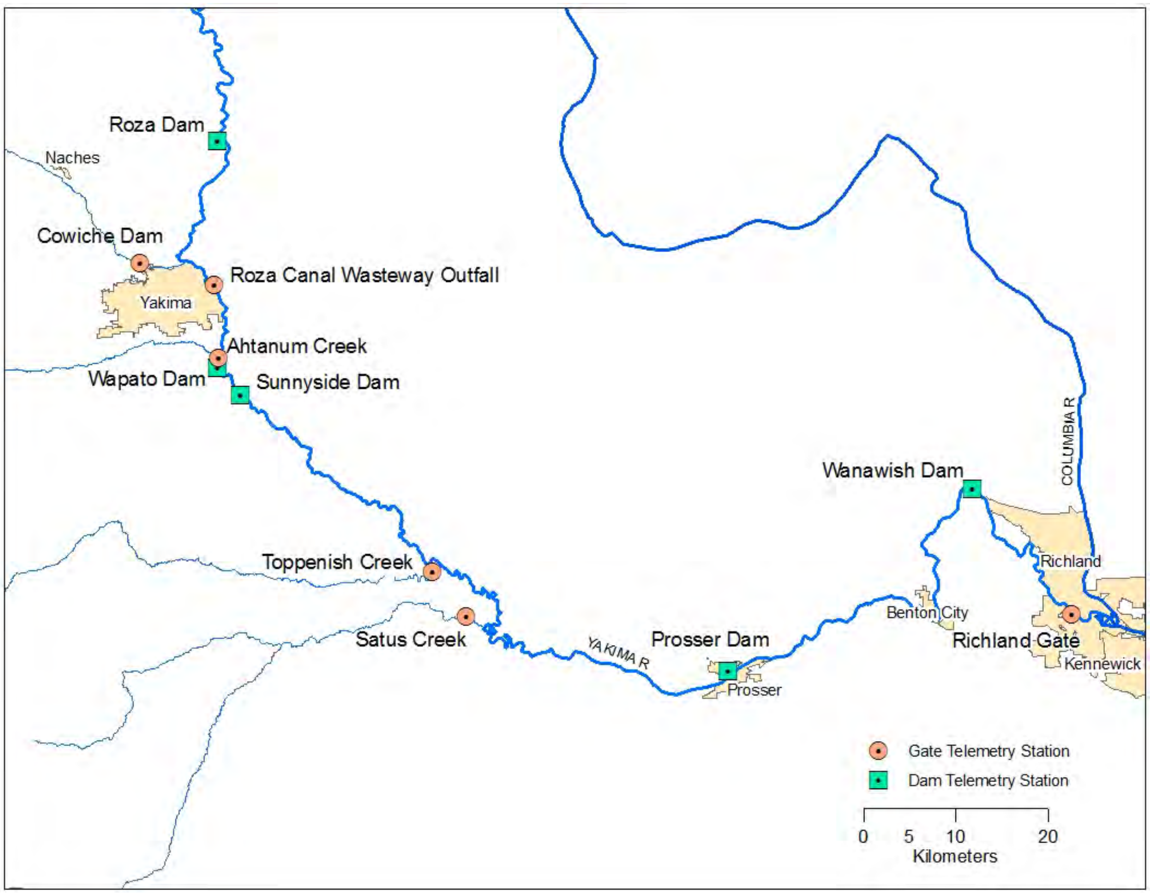

Figure 2. Map of the lower Yakima River basin showing the locations of fixed telemetry stations in 2012.

Wanawish Dam

Wanawish Dam, constructed in 1892 at rkm 29 near Horn Rapids, is a rock filled timber crib dam with a concrete face. It is 160 m long and approximately 2 m high and diverts water into canals on both banks of the river. Fishways, consisting of an entrance pool and 4 vertical slot pools, are located on each bank at the dam, with the fishway exit near the mouth of each canal (Figure 3). Each entrance pool has a high flow and low flow gate that were operated in relation to river flow. Both fishways at the dam had one aerial antenna facing downstream, one upstream, and one across the face of the dam. Underwater antennas were located at the entrance, middle, and exit pool of each fish ladder, as well as the entrance to the irrigation canal on river left. Hanging antennas were placed in the entrance of the right bank irrigation canal and in each corner where the face of the dam meets the bank (Figure 3).

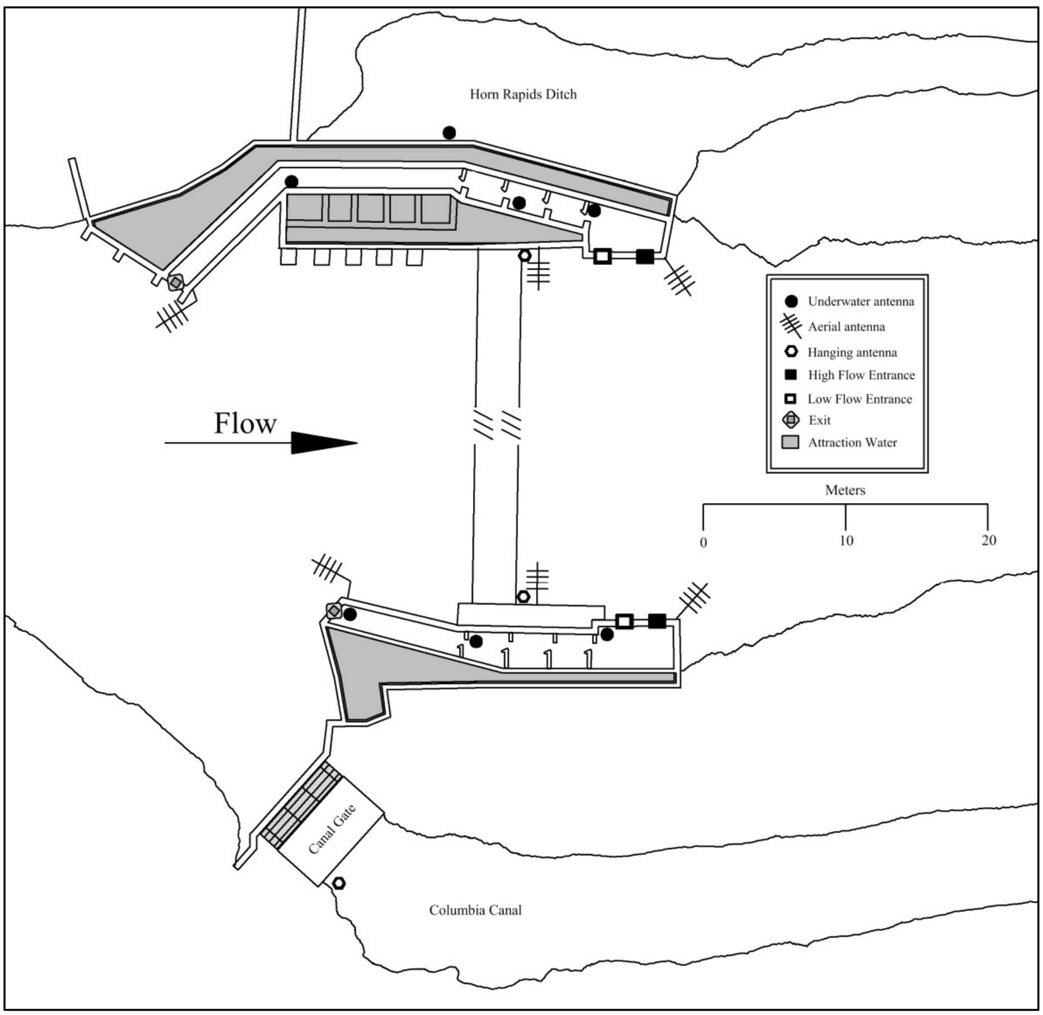

Figure 3. Locations of telemetry antennas on right and left bank fishways at Wanawish Dam, 2011 to 2012.

Prosser Dam

Prosser Diversion Dam, constructed in 1904 by private interests and now operated by the U.S. Bureau of Reclamation, is located at rkm 75. The facility consists of a concrete weir structure (2.7 m tall, 201 m long), an irrigation canal (1,500 ft^3/s capacity) on the left bank, an adult sampling facility (in the right bank fishway), three vertical slot type fishways (one on the right bank and two mid-river “islands” on the dam), and a juvenile bypass and sampling facility (downstream at the canal screen structure). The left island entrance pool has four gates: two high flow and two low flow. The center island fishway entrance pool has high flow and low flow gates on each side. The right bank fishway has an upper entrance with high and low flow gates and a lower entrance with one high/low flow gate (USBOR 2011). The right bank fishway had one aerial antenna monitoring downstream and one upstream; underwater antennas were located at the high water entrance, low water entrance, middle, and exit pools of the fish ladder. A hanging antenna was placed near an outflow pipe located at the most downstream end of the dam (Figure 4). The center island fishway had one downstream aerial antenna and two upstream aerial antennas (combined as one unit); underwater antennas were at both entrance pools and the exit pool of the fish ladder. Hanging antennas monitored where the face of the dam met the left and right sides of the island (Figure 4). The left island fishway was equipped with aerial antennas monitoring upstream, downstream, and across the face of the dam to the left and right of the island; underwater antennas were located within the entrance, middle, and exit pool of the fish ladder. Hanging antennas were placed on the outside of each fish ladder entrance gate and where the face and the left side of the island meet (Figure 4).

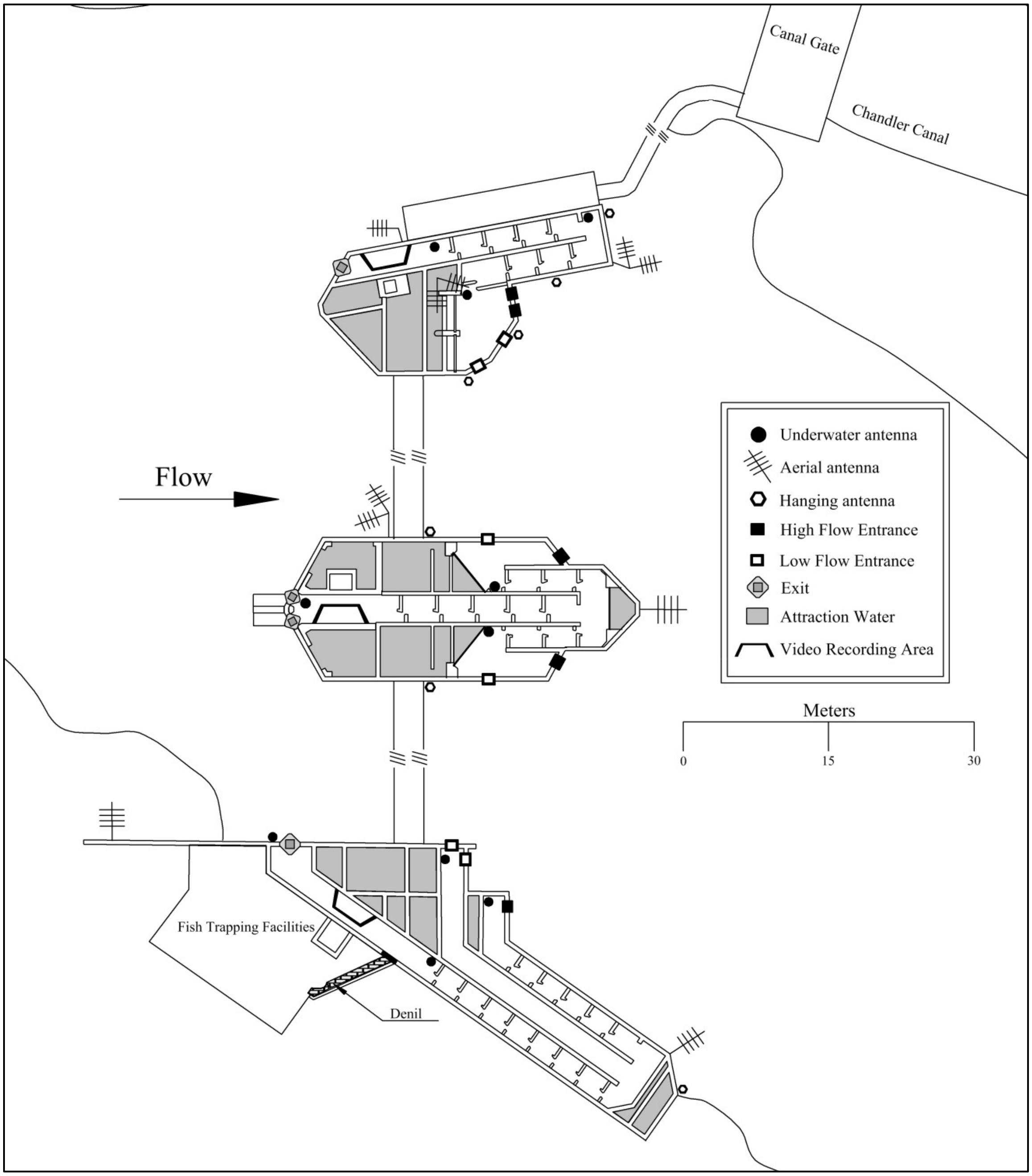

Figure 4. Locations of telemetry antennas on right, center, and left fishways at Prosser Dam, 2011 to 2012.

Sunnyside Dam

Sunnyside Diversion Dam, located at rkm 167, was completed in 1907. It is a concrete ogee weir with embankment wing and a canal (1,320 ft^3/s capacity) on the left bank. The structural height is 2.4 m and the weir crest length is 152 m (USBOR 2011). Fish passage facilities consist of three stair step ladders, one on each bank and one near the center of the dam. The left and right bank fishways have one high flow and one low flow gate. The center island has two high flow and two low flow gates; one located on each side. The left bank fishway had one upstream aerial antenna and two downstream aerial antennas (combined as one unit); underwater antennas were located in the entrance, center, and exit pool of the fish ladder. Hanging antennas monitored the sluiceway and the corner where the structure met the face of the dam (Figure 5). The center island fishway was equipped with a total of four aerial antennas: two (combined as one unit) monitored downstream and two monitored upstream on either side; underwater antennas were located in both entrance pools and a middle pool of the fish ladder. Hanging antennas were placed in the corners of the island and the face of the dam (Figure 5). The right bank fishway was equipped with three aerial antennas: one downstream, one across the face of the dam, and one upstream; underwater antennas were located in the entrance, middle, and exit pools of the fish ladder. One hanging antenna monitored where the right bank structure and the face of the dam met (Figure 5).

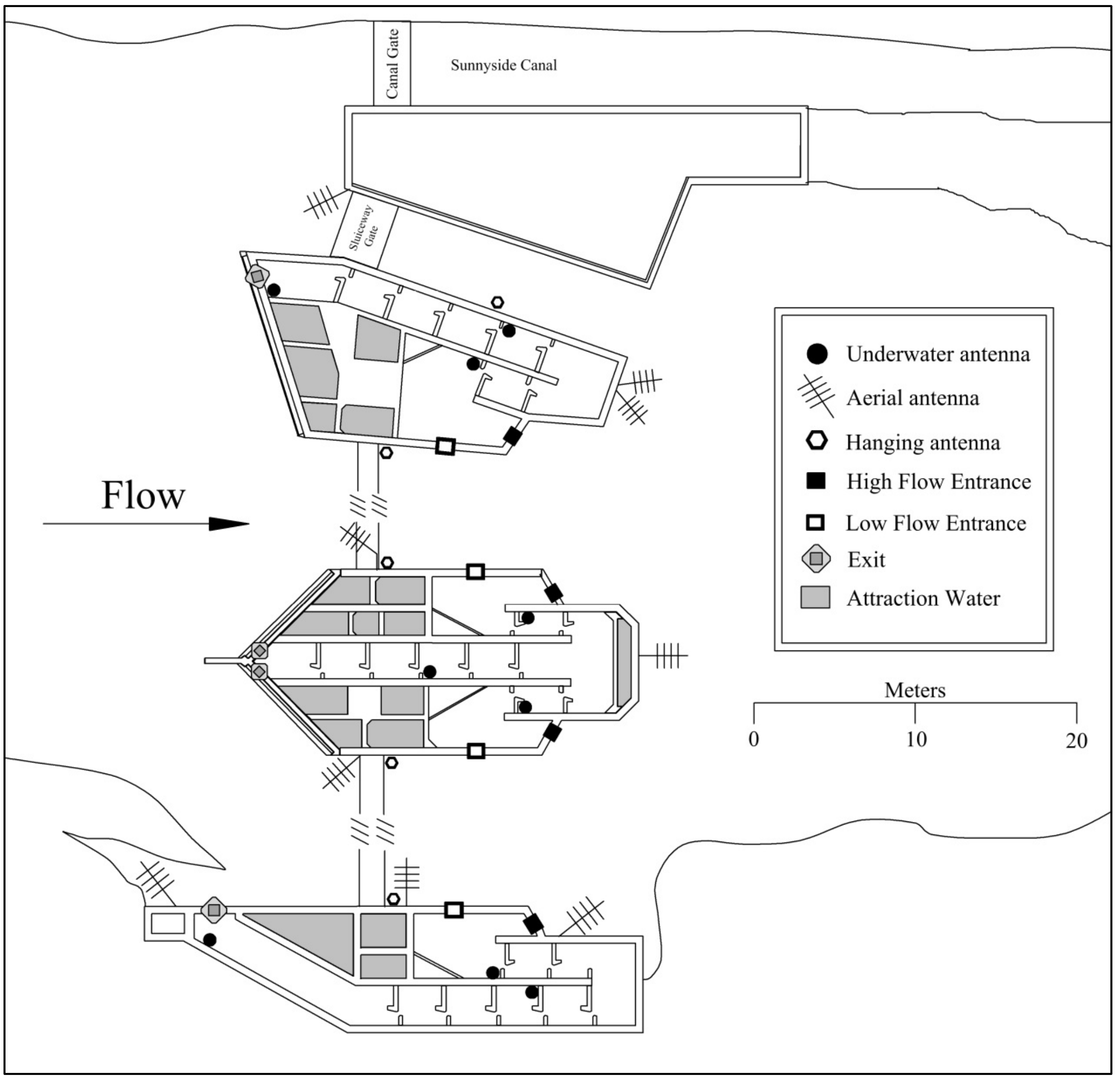

Figure 5. Locations of telemetry antennas on the right, center and left bank fishways at Sunnyside Dam, 2011 to 2012.

Wapato Dam

Wapato Dam (rkm 171.5) consists of two separate structures in two channels connected by a natural island. The west channel structure has one fishway located on a center island with a diversion canal on the right bank. The east channel structure has fishways on both the center island and on the right bank. All the fishways consist of serpentine vertical slot pools with high and low flow gates in the entrance pool. The east channel structure center island was equipped with three aerial antennas: one downstream, one upstream, and one monitoring the face on the river left side of the island. Underwater antennas were located in the entrance, middle, and exit pools of the fish ladder. A hanging antenna was located on the right side of the island near the face of the dam (Figure 6). The right bank of the east channel structure utilized three aerial antennas: one downstream, one upstream, and one across the face of the dam. Underwater antennas were positioned in the entrance, middle, and exit pools of the fish ladder. One hanging antenna was placed in the corner where the face and left bank structure met (Figure 6). The west channel structure was equipped with four aerial antennas: one downstream, one upstream, and one across the face of the dam on either side of the center island. Underwater antennas were located in the entrance, middle, and exits pools of the fish ladder (Figure 7).

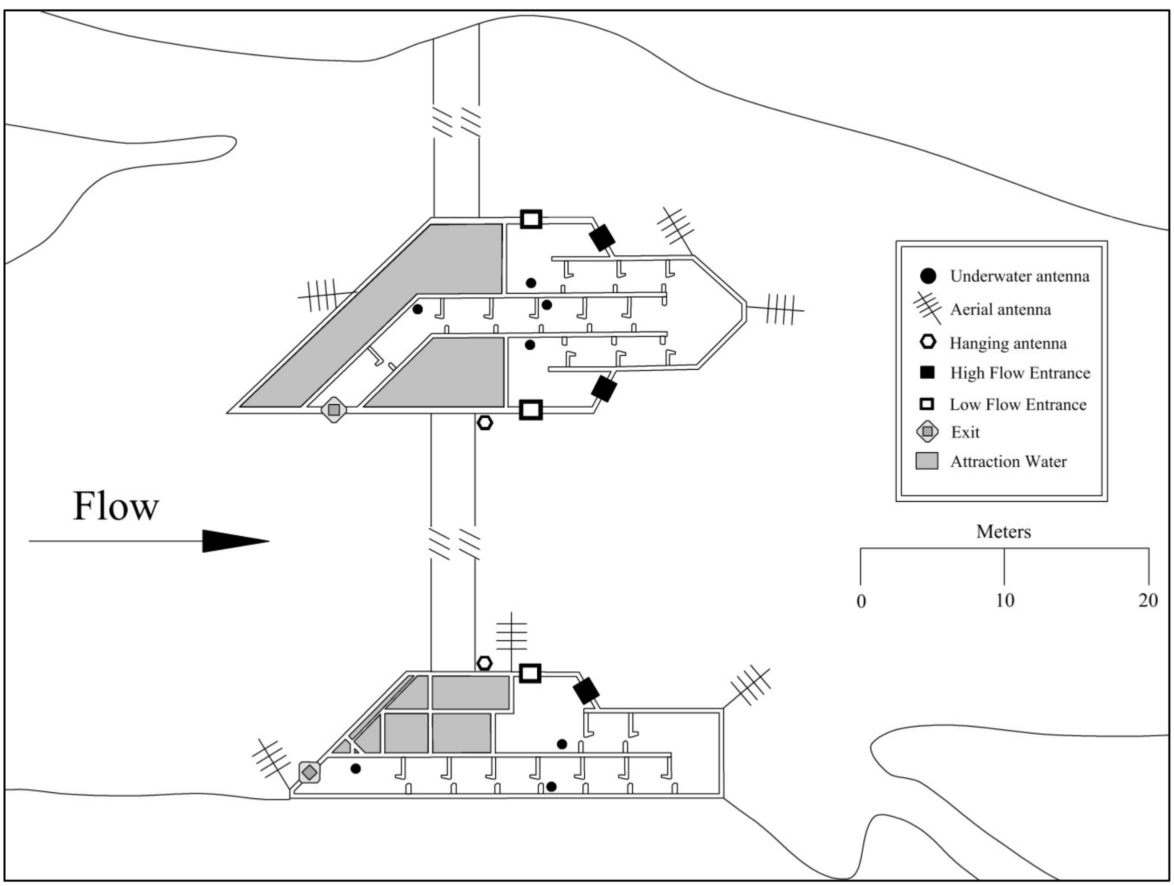

Figure 6. Locations of telemetry antennas on the left island and right bank of the east structure of Wapato Dam, 2011 to 2012

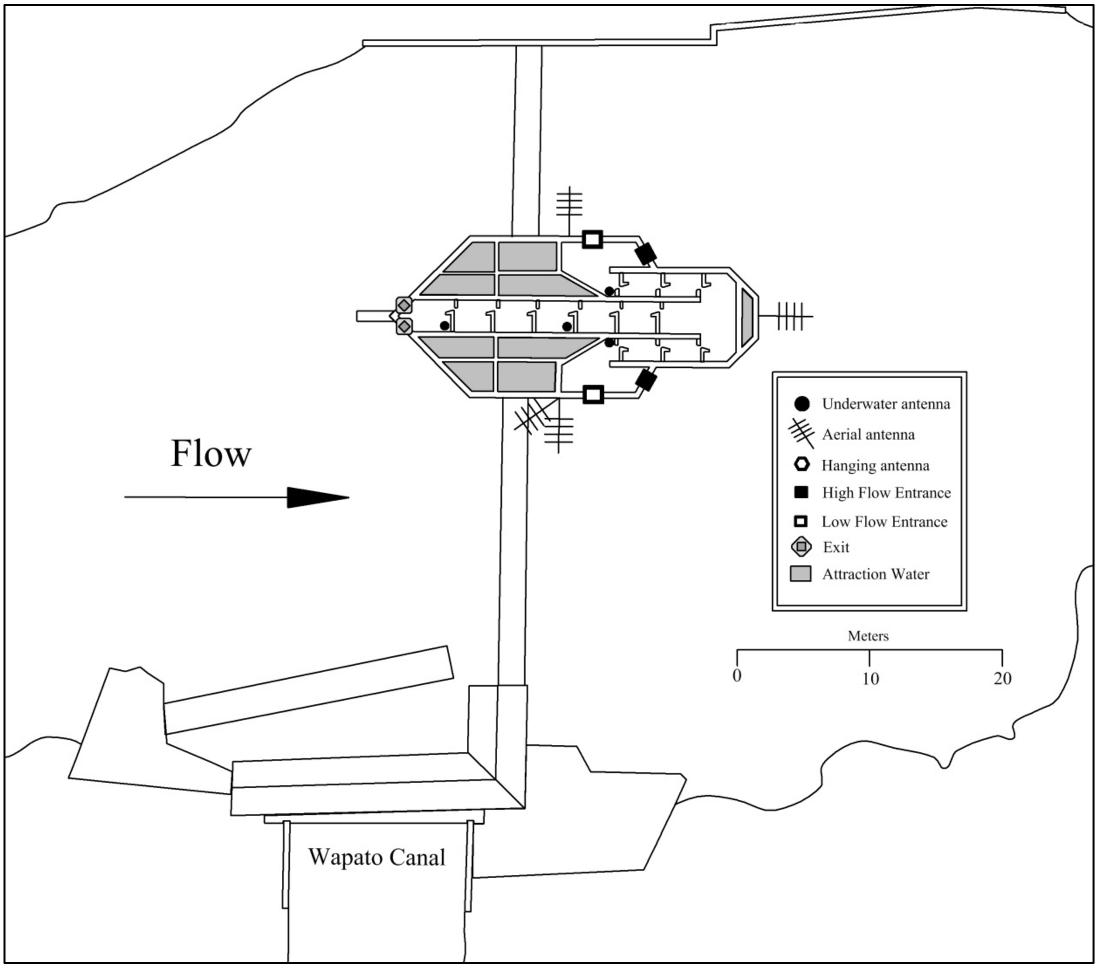

Figure 7. Locations of telemetry antennas on the center island of the west structure of Wapato Dam, 2011 to 2012.

Cowiche Dam

Cowiche Dam (rkm 6) on the Naches River is a concrete ogee spillway structure. It is approximately 65 m in length, with a 1.5 m crest, a 6.4 m ogee spillway, and a 6.4 m apron (George and Prieto 1993). A fish ladder consisting of vertical slot pools is located on the river left of the dam. A diversion canal and fish screen is located on the river right portion of the dam. The dam was equipped with three aerial antennas: one downstream, one across the face of the dam, and one upstream (Figure 8).

Roza Dam

Roza Dam (rkm 205) was originally built in 1939 and is operated by the U.S. Bureau of Reclamation. It is a concrete weir with a movable crest structure. The dam stands 20.4 m tall and is 148 m in length (USBOR 2011). Water is diverted into an irrigation canal on the river right of the dam. The fishway utilizes a vertical slot pool design with entrances on both banks. These entrances merge into a single ladder on the left bank. A simple telemetry station consisting of one downstream antenna was installed at Roza Dam to detect if any tagged Pacific lampreys migrated that far upriver (Figure 2). No solar power backup was utilized at Roza Dam.

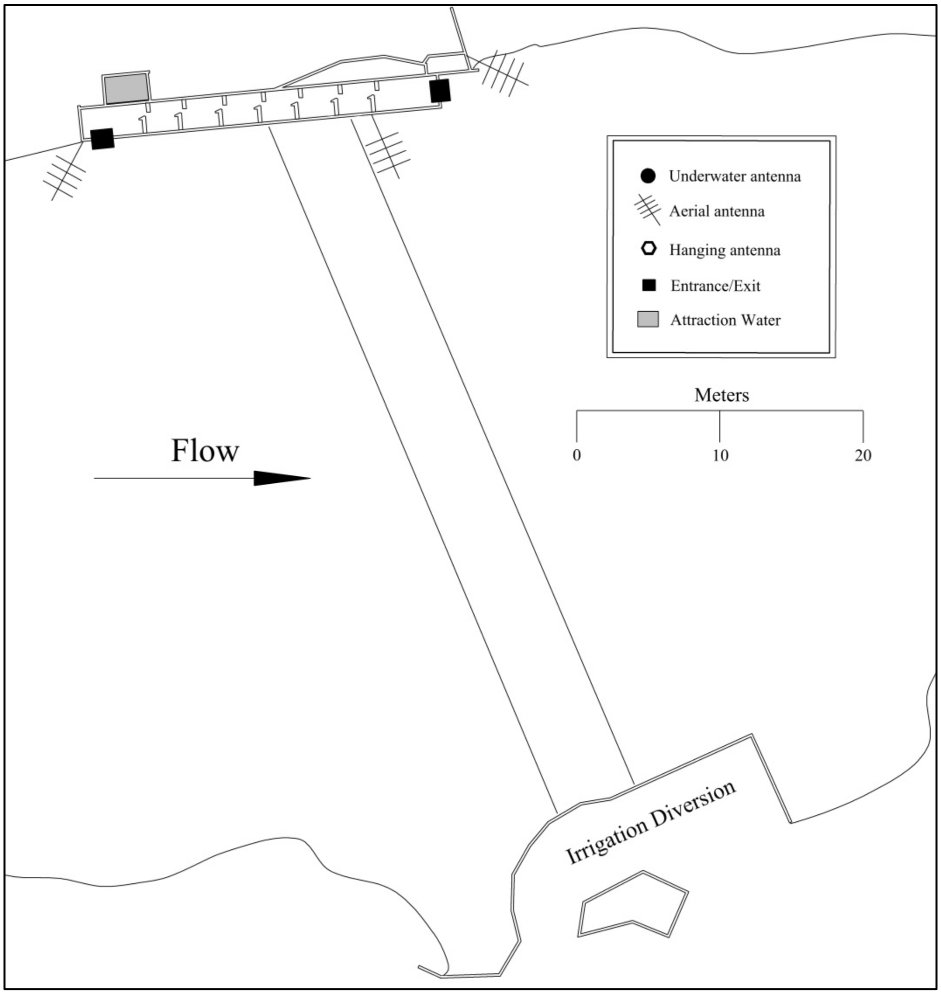

Figure 8. Locations of telemetry antennas on Cowiche Dam, 2011 to 2012.

Gate Stations

"Gate" stations were set up to determine if any tagged lampreys left the study area or entered tributaries (Figure 2). A station near the mouth of the Yakima River (rkm 6.9) was set up to determine if Pacific lamprey moved downstream to the Columbia River. This fixed station consisted of one aerial antenna aimed across the river, a SRX400A receiver, and a car battery charged by AC power provided by the landowner. Gate stations were also set up on Satus and Toppenish creeks to determine movement into these tributaries. These stations each had one antenna facing upstream and one facing downstream combined together as one unit. The receivers at these stations were powered by solar panels. A station using solar power and a single downstream facing antenna monitored movement into Ahtanum Creek (Figure 2). A station at the Roza irrigation canal wasteway outfall near the city of Yakima (rkm 182) was also set up to aid in upstream migration detections. This station was equipped with a single upstream facing antenna and was AC powered.

Telemetry Data Analysis

For descriptive purposes, the definitions of *left* and *right* were referenced to the downstream or river flow direction, and applied to the river banks as well as the island fishways at the dams. *First approach* was defined as the first detection recorded on an aerial antenna at a fixed telemetry station. *Below dam residence* was calculated as the difference between the first downstream detection at the dam and the first detection of entry into the fishway during a passage event. *Below dam residence* was further separated into three segments based on activity: *fall residence*, *over-winter*, and *spring residence*. *Fall residence* was defined as the time a lamprey spent actively moving at a dam in an attempt to pass. *Over-winter* was calculated as the time of inactivity during the winter months in which a lamprey did not move or attempt to pass a dam. *Spring residence* was calculated as the difference between when movement commenced after the over-winter period and when a lamprey either entered a fishway on a passage event or moved downstream from the dam. *Fishway passage* was calculated as the elapsed time between the first fishway entrance detection and the last fishway exit detection during a passage event. *Above dam residence* was defined as the difference between the last fishway exit detection and the last upstream aerial antenna detection at the dam. Diurnal movements were described as occurring either during day or night hours. Civil twilight, as noted at the town nearest to each dam (www.sunrisesunset.com), was used to differentiate between day and night hours. *Migration time* was calculated as the difference between the last detection as the lamprey moved from one station to the first detection at the next station. *Migration rate* was as defined the distance between stations divided by migration time.

Collection

Adult Pacific lampreys were supplied by the Yakama Nation Fisheries Program from lampreys collected at Bonneville Dam, The Dalles Dam, and John Day Dam on the lower Columbia River between June 24 and August 18, 2011. Fish were captured in funnel traps at the picketed leads of the fish counting stations on both sides of the dams and transported to the Yakama Nation Prosser Hatchery facility and held until tagged. All were injected with 0.15 cc of Oxytetracycline to prevent the spread of disease (Patrick Luke, Yakama Nation Fisheries Program, pers. comm.). Holding facilities consisted of flow-through metal stock tanks supplied with river and/or well water.

Radio Transmitter Implantation

Implantation surgeries took place in the spawning shed at the Yakama Nation Prosser Hatchery facility. The surgical procedure was modified from methods described in Moser et al. (2002) and Nelson et al. (2007). Tools and transmitters were chemically disinfected with Benz-All®. Fish were anesthetized in a bath of 80 ppm tricaine methanesulfonate (MS-222) buffered with sodium bicarbonate to match the pH of the river water. After 8 to 10 minutes the fish was removed from the bath and total length (mm), interdorsal base length (mm), girth (mm), and weight (g) were measured and recorded. The lamprey was then placed on a cradle made from PVC pipe and the head and gills were immersed in a 15 L bath of 40 ppm of buffered MS-222. Wet sponges were placed in the cradle to prevent the lamprey from sliding and to assist in incision placement. Using a number 12 curved blade scalpel, a 25 mm incision was made 1 cm off the ventral midline with the posterior end of the incision stopping in line with the anterior end of the first dorsal fin. A catheter was inserted through the incision and out the body wall approximately 4 cm posterior to the incision. The antenna was threaded through the catheter and the individually coded radio transmitter (Lotek NTC-6-2, 9 x 30 mm, 4.3 g, 441 d battery life or Lotek NTC-4-2L, 8 x 18 mm, 2.1 g, 162 d battery life) was inserted into the incision. Using a 19 mm needle the incision was then closed with 3-4 braided absorbable sutures. The lamprey was then transferred to a holding tank until release.

Release

Release dates were chosen in an attempt to mimic the movements of the natural run in the river. Release sites were located upstream and downstream of both Wanawish Dam and Prosser Dam. Release sites were chosen by accessibility and relative close proximity to each dam. Individuals were chosen for each release site by removing them from the holding tank at random. The code of each fish was then recorded prior to release.

Tracking

Fixed telemetry stations were downloaded on a weekly schedule. Test beacons were activated during downloads at each station to ensure the antennas and receivers were operating and recording properly. In addition to the data recorded at fixed stations, mobile tracking was opportunistically conducted to determine exact locations at the dams as well as approximate locations between the dams. Mobile tracking was conducted by foot, truck, boat, and airplane.

Temperature

Stream temperatures were monitored at Wanawish, Prosser, Sunnyside, and Wapato dams. Electronic data loggers (HOBO® U22 Water Temp Pro v2, Onset Computer Corp.) were calibration checked for accuracy with an NIST-tested thermometer and only units that agreed to within 0.2 °C were deployed. The data loggers were housed in perforated PVC pipe (40 mm dia.) and tethered to wire cable suspended into the river from one fishway at each dam. Data loggers were programmed to record once every hour. Data were downloaded into a shuttle, offloaded, and saved to a desktop computer. Mean, minimum, and maximum daily water temperatures were calculated with the Hoboware® Pro software package.

Discharge

Stream discharge was obtained from the USBOR Pacific Northwest Region Hydromet website (http://www.usbr.gov/pn/hydromet/yakima/yakwebarcread.html). Average daily flow (QD) was queried for the Yakima River stations at Kiona (KIOW), Prosser (YRPW), and Parker (PARW). Discharge is reported in ft^3/s.

Velocity

Velocities at the entrances to the fishways were measured during weekly downloading of the telemetry stations. Measurements were taken when the velocity meter was available for use and when time allowed. Velocities were measured using a Marsh McBirney Flo-Mate™ 2000 portable flow meter. The sensor and mount were attached to an extension pole so measurements could be taken from the deck of the dam. Measurements occurred on the downstream side of all open entrances to the fishways. The meter was placed approximately 0.5 m into the water column, though this varied between fishways and levels of discharge. Three measurements were taken and the median velocity was recorded in feet per second (ft/s). For analysis purposes, each island fishway had velocities of all its open gates averaged and reported as one. Statistical analyses of entrance velocities were performed using a single factor analysis of variance. The field measurements of entrance velocity are recorded in Appendix B.

Results

Tagging

Tagging and release occurred during two time periods; one in the fall 2011 and the other in the spring 2012. For the fall releases, a total of 42 adult Pacific lampreys were radio tagged September 13-15, 2011 (Table 1). Weights ranged from 356 to 825 g (mean 509.5 g), lengths from 624 to 780 mm (mean 685 mm) and girths from 100 to 135 mm (mean 116.5 mm). For the spring release, 35 lampreys were tagged on March 21-22, 2012 (Table 2). Weights ranged from 276 to 499 g (mean 361.8 g), lengths from 532 to 687 mm (mean 595.7 mm), and girth ranged between 95 and 123 mm (mean 106.2 mm) (Figures 9 and 10).

Holding

Lampreys tagged in the fall were held for 3 weeks before release. Lampreys tagged in the spring were held for one week. One lamprey shed its tag during the fall holding period. No mortalities occurred during holding.

Releases

Fall release- A total of 41 tagged lampreys were released on October 4, 2011. Five were released from the left bank 1.2 km upstream of Wanawish Dam; sixteen were released 0.45 km downstream of the dam, eight on each bank (Figure 11). The upstream release location was in a slow water area consisting of submerged grasses and an undercut bank. The downstream release locations were in areas consisting of various sized cobbles. Sixteen lampreys were released on the left bank 0.30 km downstream of Prosser Dam amongst large boulders in a slow, deep pool. Four lampreys were released 1.1 km upstream of the dam on the right bank in a slow water area with boulders and floating debris (Figure 12).

Spring release- A total of 35 Pacific lampreys were released on March 28, 2012 at the same locations used in the fall. Seven lampreys were released on each side of the river downstream of Wanawish Dam and four were released upstream of the dam. Thirteen tagged fish were released downstream of Prosser Dam and 4 upstream of the dam.

Table 1. Weight, total length, girth, dorsal base length, and release location of radio-tagged adult Pacific lampreys released in the Yakima River on October 4, 2011.

Code	Total Length (mm)	Weight (g)	Girth (mm)	Dorsal Base Length (mm)	Release Location
4	710	587	135	34	Wanawish Left d/s
11	669	570	122	35	Wanawish Left d/s
21	644	377	103	26	Wanawish Left d/s
27	780	665	128	44	Wanawish Left d/s
18	642	420	108	30	Wanawish Left d/s
22	654	466	115	45	Wanawish Left d/s
35	662	425	110	35	Wanawish Left d/s
43	657	450	115	38	Wanawish Left d/s
6	715	571	128	47	Wanawish Right d/s
7	726	644	125	40	Wanawish Right d/s
10	724	525	113	43	Wanawish Right d/s
14	716	581	123	36	Wanawish Right d/s
19	675	444	105	45	Wanawish Right d/s
23	661	473	119	38	Wanawish Right d/s
28	719	598	124	44	Wanawish Right d/s
12	664	475	118	55	Wanawish Right d/s
13	720	825	127	38	Wanawish u/s
20	700	479	114	39	Wanawish u/s
32	669	464	119	32	Wanawish u/s
45	669	445	112	31	Wanawish u/s
40	660	461	111	40	Wanawish u/s
5	732	596	115	44	Prosser d/s
9	739	647	125	41	Prosser d/s
15	678	476	113	39	Prosser d/s
17	653	392	105	50	Prosser d/s
26	690	514	116	34	Prosser d/s
29	703	530	122	44	Prosser d/s
31	649	420	109	38	Prosser d/s
34	754	676	127	55	Prosser d/s
37	640	437	111	29	Prosser d/s
39	719	558	119	41	Prosser d/s
41	687	470	113	39	Prosser d/s
42	684	470	116	36	Prosser d/s
8	680	544	119	41	Prosser d/s
16	732	600	124	47	Prosser d/s
33	666	468	118	31	Prosser d/s
46	683	540	120	35	Prosser d/s
30	675	475	114	34	Prosser u/s
38	624	367	104	29	Prosser u/s
36	632	356	100	31	Prosser u/s
44	684	462	109	38	Prosser u/s
24	668	456	121	34	shed during holding

Table 2. Weight, total length, girth, dorsal base length, and release location of radio-tagged adult Pacific lampreys released in the Yakima River on March 28, 2012.

Code	Total Length (mm)	Weight (g)	Girth (mm)	Dorsal Base Length (mm)	Release Location
56	571	327	98	20	Wanawish Left d/s
67	572	315	102	18	Wanawish Left d/s
69	625	408	109	30	Wanawish Left d/s
71	620	348	97	40	Wanawish Left d/s
78	595	391	112	30	Wanawish Left d/s
85	622	387	106	30	Wanawish Left d/s
88	605	354	106	27	Wanawish Left d/s
55	542	297	105	12	Wanawish Right d/s
59	589	352	104	22	Wanawish Right d/s
60	625	445	113	18	Wanawish Right d/s
61	562	395	123	18	Wanawish Right d/s
65	638	377	103	30	Wanawish Right d/s
68	600	349	116	34	Wanawish Right d/s
77	602	371	103	25	Wanawish Right d/s
57	561	352	115	30	Wanawish u/s
72	532	276	95	17	Wanawish u/s
89	555	320	102	15	Wanawish u/s
82	553	293	98	15	Wanawish u/s
62	610	405	112	27	Prosser d/s
63	687	499	117	40	Prosser d/s
64	598	354	107	30	Prosser d/s
66	592	362	102	32	Prosser d/s
75	612	427	112	25	Prosser d/s
76	646	444	110	34	Prosser d/s
79	582	323	105	27	Prosser d/s
81	635	401	110	23	Prosser d/s
83	655	434	110	32	Prosser d/s
84	585	337	101	21	Prosser d/s
86	580	322	101	24	Prosser d/s
87	593	329	100	22	Prosser d/s
58	575	305	95	25	Prosser d/s
70	592	332	97	27	Prosser u/s
73	555	290	100	23	Prosser u/s
74	600	340	115	26	Prosser u/s
80	582	403	115	32	Prosser u/s

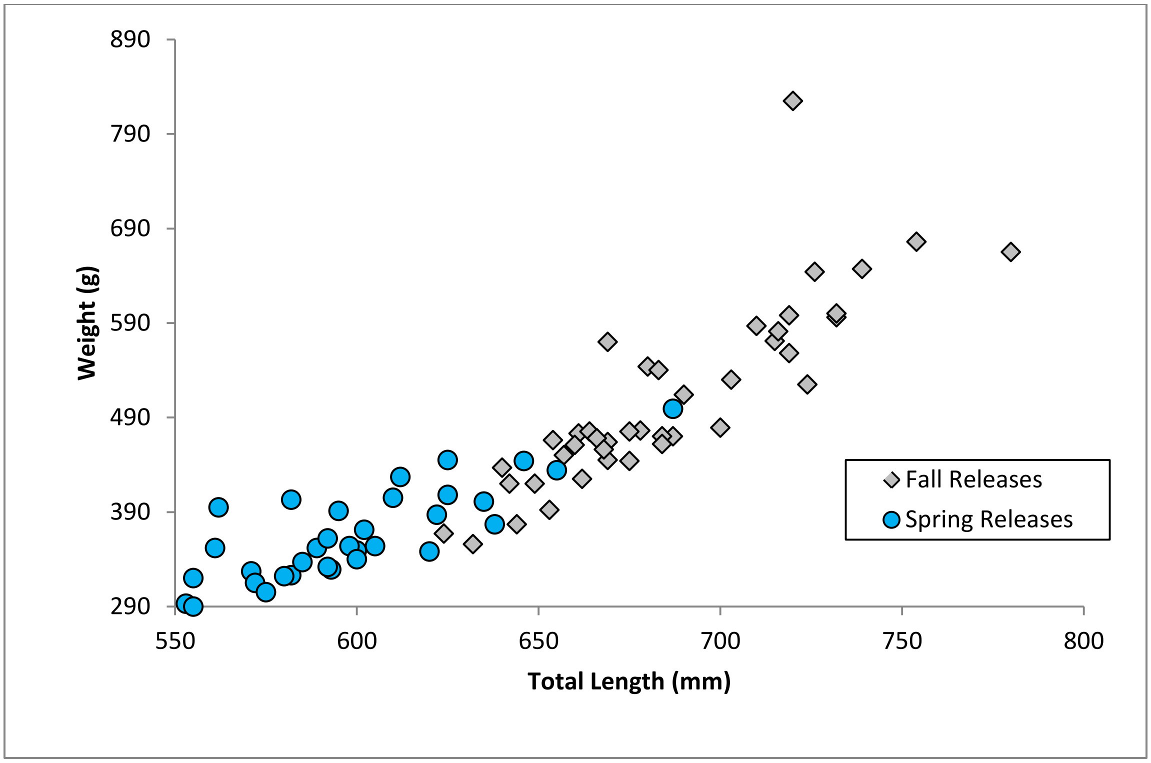

Figure 9. The lengths and weights of radio-tagged Pacific lampreys released into the Yakima River on October 4, 2011 and March 28, 2012.

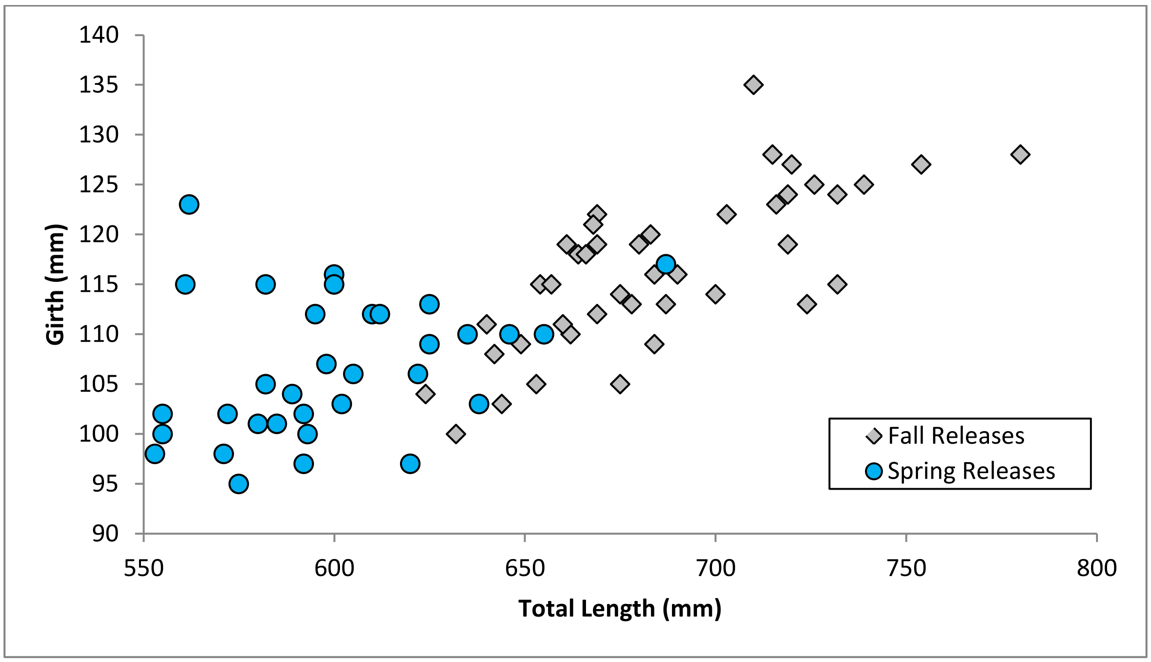

Figure 10. The girths of radio-tagged Pacific lampreys released into the Yakima River on October 4, 2011 and March 28, 2012.

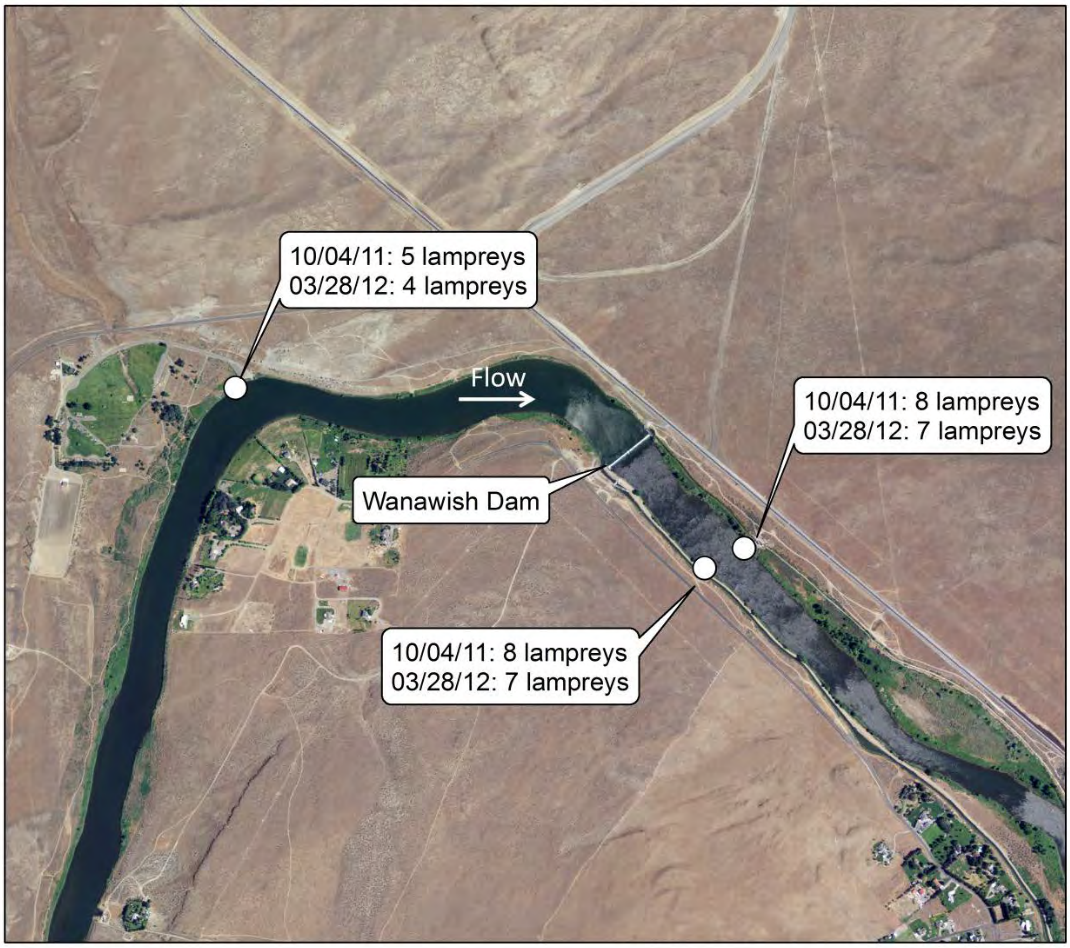

Figure 11. Aerial photograph showing the release locations of radio-tagged adult Pacific lampreys in the vicinity of Wanawish Dam on October 4, 2011 and March 28, 2012.

Figure 12. Aerial photograph showing the release locations of radio-tagged adult Pacific lampreys in the vicinity of Prosser Dam on October 4, 2011 and March 28, 2012.

Movements

A total of 73 (96%) Pacific lampreys moved upstream from their release sites. Two moved downstream from their release sites and one never moved. The tag of this latter individual was later determined to be on the bank, indicating either predation or scavenging had occurred. First approaches of a dam were made between October 4, 2011 and July 7, 2012. A total of thirteen lampreys resided at the dams through the winter. The movements of radio-tagged lampreys at each dam are described in the following sections.

Wanawish Dam

First approach of fall release- Sixteen tagged lampreys were released downstream of the dam on October 4 and first approach detections of individuals ranged from October 4 to December 20, with a second pulse from January to April 2012 (Table 3). Nine lampreys (56%) approached in October, one individual approached in December, five (31%) approached in the following spring, and one moved downstream from its release location. Detections of first approaches were on the downstream aerial antennas, with 62% near the left bank while the rest were near the right bank.

First approach of spring release- Fourteen tagged lampreys were released on March 28 and detections of first approach of individuals at the dam ranged from March 28 to April 24, 2012. One hundred percent of the spring released lampreys were detected approaching the dam.

Below Dam Residence- Total residence time below Wanawish Dam ranged from two hours and forty-five minutes to nearly 219 days (Table 3). Ten lampreys approached the dam before overwintering. Three passed the dam in October and had an average fall residence of 8 days (range 0.11-13.1 d). The remaining seven had an average fall residence of 12 days (range 1.7-19.7 d) before they stopped actively moving. These lampreys remained at the dam throughout the winter before continuing their upstream migration. Overwinter residence averaged 132 days, though one lamprey only overwintered for 55.5 days. Spring residence time of fall released lampreys averaged 33.9 days (range 21.3-50.9 d) for those who passed the dam and 58.1 days (range 29-82 d) for those that were unsuccessful in migrating past the dam. Successful spring released lampreys had an average residency time of 30.8 days (range 23-50 d) (Figure 13). All twenty-nine lampreys that approached Wanawish Dam were detected on each side of the dam at least once (Figure 14). Holding areas for lampreys were not localized to a pool or corner of the dam and instead were distributed across the width of the river, most commonly in middle of the river close to the face of the dam and along the banks just downstream of the dam. The mortality of one lamprey was indicated at Wanawish Dam on May 4 when code 19 stopped moving. On May 10 it was detected out of the river on the right bank 250 m downstream of the dam, but recovery of the transmitter was not possible and it is unknown if the lamprey was depredated or scavenged.

Table 3. Wanawish Dam approach and residence data: first and last detection dates and total number of days that adult radio-tagged Pacific lampreys resided below the dam before entering a fishway or moving downstream, October 2011 through August 2012.

Code	1st Station Detected	1st Detection Date	Last Detection Date	Days	Enter Fishway?
11	Left Bank	10/04/11 19:34	05/07/12 16:18	215.9	No
35	Left Bank	10/04/11 19:51	10/04/11 22:36	0.1	Yes
22	Left Bank	10/04/11 19:57	10/15/11 21:25	11.1	Yes
6	Left Bank	10/04/11 22:26	04/21/12 22:01	200	Yes
12	Right Bank	10/10/11 19:35	10/23/11 21:04	13.1	Yes
27	Left Bank	10/10/11 21:29	05/16/12 20:24	219	Yes
19	Left Bank	10/15/11 19:34	05/04/12 00:51[A]	201	No
4	Left Bank	10/18/11 19:46	04/22/12 20:58	187.1	Yes
18	Right Bank	10/22/11 19:21	04/15/12 21:33	176.1	No
14	Right Bank	12/20/11 22:45	04/23/12 00:15	124.1	Yes
21	Left Bank	02/24/12 03:34	05/06/12 09:01	72.2	No
7	Left Bank	02/26/12 02:05	05/18/12 02:23	82	No
43	Left Bank	03/17/12 13:53	04/27/12 15:50	41.1	No
23	Left Bank	03/17/12 14:32	05/18/12 05:06	61.6	No
60	Right Bank	03/28/12 16:01	04/23/12 00:09	25.3	Yes
65	Right Bank	03/28/12 20:03	04/24/12 01:26	26.2	Yes
71	Left Bank	03/28/12 20:18	05/08/12 22:53	41.1	Yes
88	Left Bank	03/28/12 20:41	05/17/12 18:50	49.9	Yes
69	Left Bank	03/28/12 21:00	04/21/12 21:18	24	Yes
78	Left Bank	03/28/12 23:51	04/22/12 20:38	24.9	Yes
28	Left Bank	03/31/12 14:15	04/21/12 22:06	21.3	Yes
77	Right Bank	04/01/12 18:45	04/24/12 21:30	23.1	Yes
68	Right Bank	04/10/12 20:40	04/22/120 8:28	11.5	No
59	Right Bank	04/12/12 19:39	05/14/12 19:04	31.9	Yes
55	Right Bank	04/21/12 21:31	08/21/12 00:37[B]	121.1	No
67	Left Bank	04/22/12 21:21	05/19/12 18:19	26.9	No
61	Right Bank	04/23/12 03:41	04/25/12 22:46	2.8	No
85	Left Bank	04/24/12 02:58	unknown	unk	Yes
56	unknown	unknown	05/28/2012 22:39	unk	Yes

[A] last date of movement

[B] date radio tag battery died

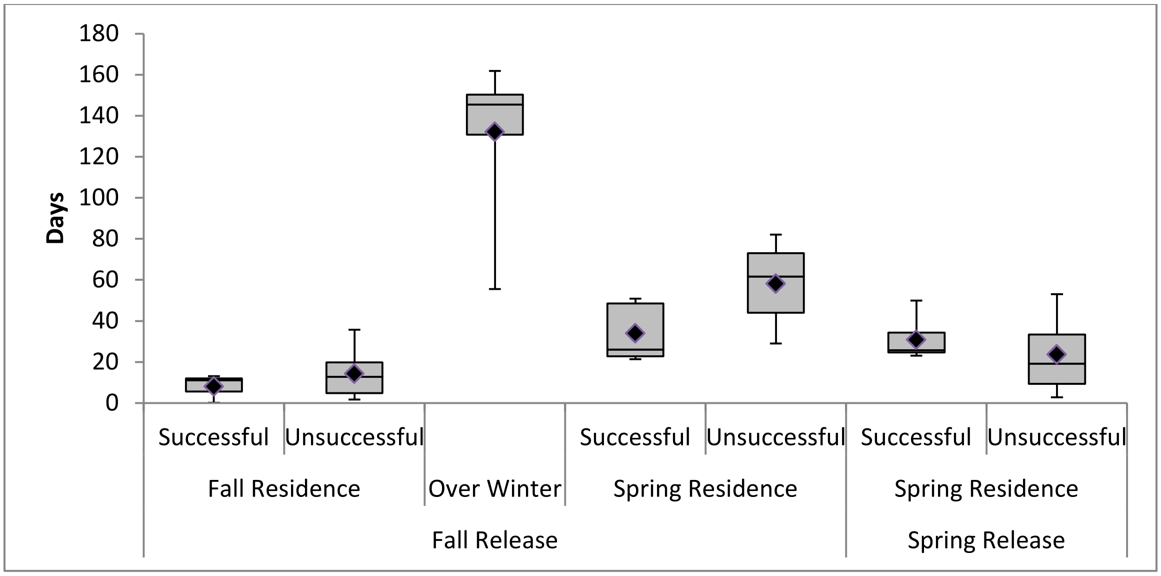

Figure 13. Periods of below dam residency for radio-tagged Pacific lampreys at Prosser Dam that were successful and unsuccessful in passing upstream of the dam, October 2011 through July 2012. Box plots show median and quartiles. The diamonds indicate the means.

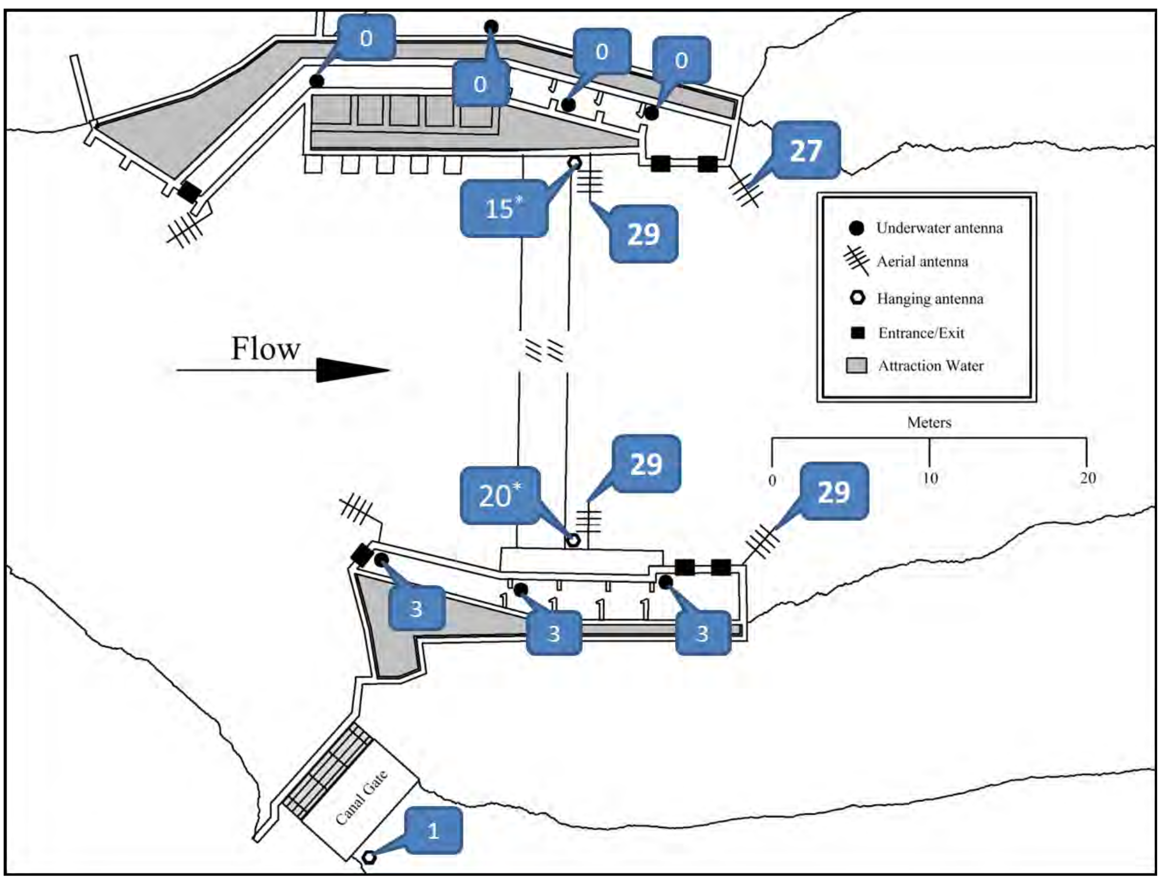

Figure 14. Number of radio-tagged Pacific lampreys detected on downstream and in-ladder antennas at Wanawish Dam, October 2011-July 2012. Antennas with a (*) were installed on March 27, 2012.

Fishway Passage- Of the 29 Pacific lampreys that approached the dam, 18 (62%) were ultimately successful in passing upstream (Table 4). Three fall released lampreys passed Wanawish Dam in October and five were successful in the spring months for a total fall release success rate of 53%. Ten of the fourteen spring released lampreys passed, for a success rate of 71%. All passage events took place in October, April, and May; half of which occurred between April 21 and 24. The right bank fishway was definitively used by three lampreys. Two lampreys were last detected passing the dam on the left bank antennas but there were no detections on the antennas within the fishway. The remaining 13 were detected passing the dam on the river right station. Data suggest that these individuals did not use the fishway but instead climbed over the dam using a ledge in between the fishway and the face of the dam (Figure 15). Passage time within the fishway ranged from 0.03 to 0.27 hours. The time it took to pass the dam using the ledge ranged from 0.18 to 2.98 hours (average 1.08 hours). Nine lampreys never passed the dam and instead moved back downstream. One individual remained at the dam until the transmitter battery died near the end of the study period. The status of that lamprey is not known.

Table 4. Wanawish Dam fishway data: dates of entry, exit and total time in fish ladder or passage area, and water temperature at passage for radio-tagged adult Pacific lampreys from October 2011 to July 2012.

Code	Release Site/Period	Fishway or Area	Entered Ladder or Area	Exited Ladder or Area	Time in Ladder or Area (hr)	Temp °C
35	WAN Fall Dn	L. Bank	10/04/11 22:36	10/05/11 02:45	4.15	15.4
22	WAN Fall Dn	Ledge	10/15/11 21:25	10/15/11 22:39	1.23	14.0
12	WAN Fall Dn	Ledge	10/23/11 21:04	10/23/11 22:08	1.07	14.0
69	WAN Spr Dn	Ledge	04/21/12 21:18	04/21/12 21:36	0.3	11.9
6	WAN Fall Dn	Ledge	04/21/12 22:01	04/21/12 22:27	0.43	11.9
28	WAN Fall Dn	R. Ladder	04/21/12 22:06	04/21/12 22:20	0.23	11.9
78	WAN Spr Dn	Ledge	04/22/12 20:38	04/22/12 21:36	0.97	13.3
4	WAN Fall Dn	Ledge	04/22/12 20:58	04/22/12 21:26	0.47	13.3
60	WAN Spr Dn	Ledge	04/23/12 00:09	04/23/12 00:28	0.32	14.3
14	WAN Fall Dn	R. Ladder	04/23/12 00:15	04/23/12 00:17	0.03	14.3
65	WAN Spr Dn	Ledge	04/24/12 01:26	04/24/12 01:53	0.45	14.7
77	WAN Spr Dn	Ledge	04/24/12 21:30	04/24/12 21:41	0.18	14.7
71	WAN Spr Dn	Ledge	05/08/12 22:53	05/08/12 23:09	0.27	13.3
59	WAN Spr Dn	L. Bank	05/14/12 19:04	05/14/12 19:32	0.47	15.1
27	WAN Fall Dn	Ledge	05/16/12 20:24	05/16/12 23:23	2.98	16.4
88	WAN Spr Dn	R. Ladder	05/17/12 18:50	05/17/12 19:06	0.27	15.3
56	WAN Spr Dn	Ledge	05/28/12 22:39	05/28/12 23:03	0.4	14.5
85	WAN Spr Dn	Ledge	unknown	05/13/12 15:06	unk	13.9

Figure 15. The ledge on the right bank of Wanawish Dam that it appears most Pacific lampreys used to pass upstream. The flow is approximately 5,500 ft^3/s in the left picture and 10,500 ft^3/s on the right. The entrance to the fishway is just out of the picture on the left hand side.

Discharge-
Pacific lampreys passed Wanawish during two distinct discharge levels. The three that passed in October 2011 did so at flows below 2,600 ft^3/s. Lampreys passing during the spring months did so at flows between 6,610 and 10,400 ft^3/s. The majority of passage events occurred during periods of increasing discharge (Figure 16).

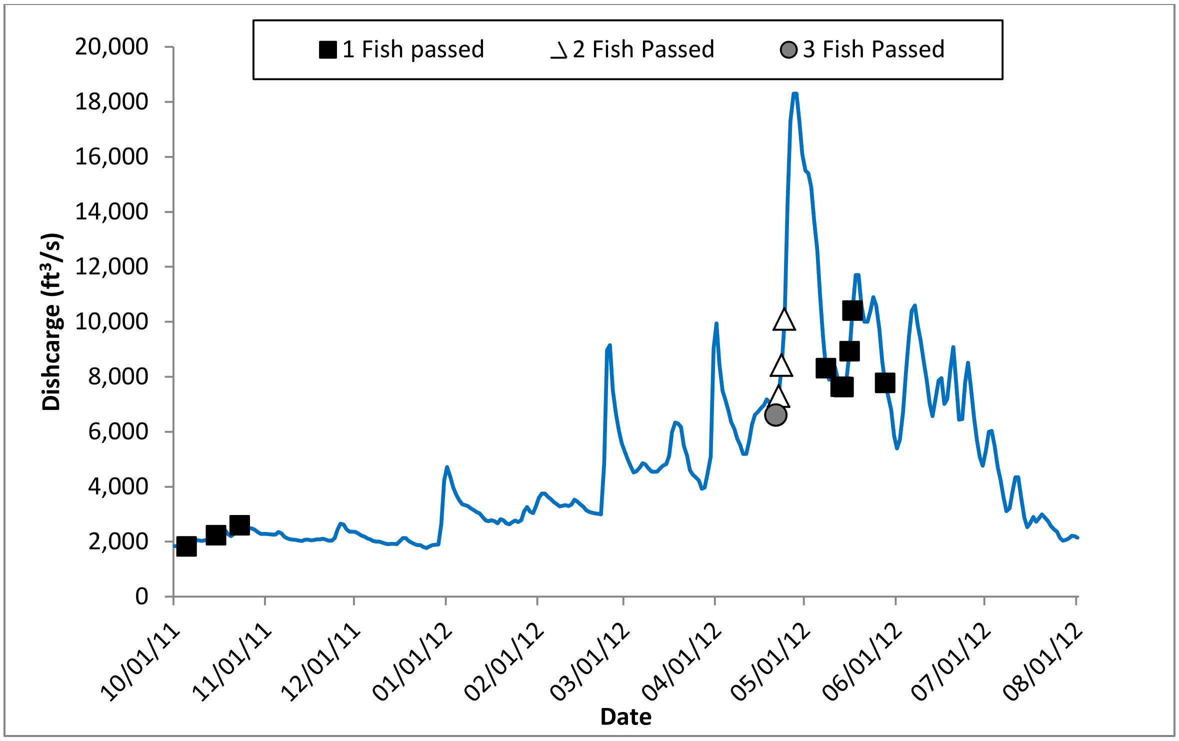

Figure 16. Graph showing the discharge and passage timing of radio-tagged Pacific lampreys at Wanawish Dam on the Yakima River, October 2011 through July 2012.

Velocity at Fishways- Fishway entrance velocities were recorded between April 5 and August 7, 2012 (Figure 17 and Appendix B). Velocities for the right bank fishway ranged between -0.81 and 6.92 ft/s. Several negative velocities were recorded for both fishways. The left bank fishway was inoperable during most of the study period. Its velocities are therefore representative of the velocity of the river as it passes the fishway entrance and not those of the fishway itself.

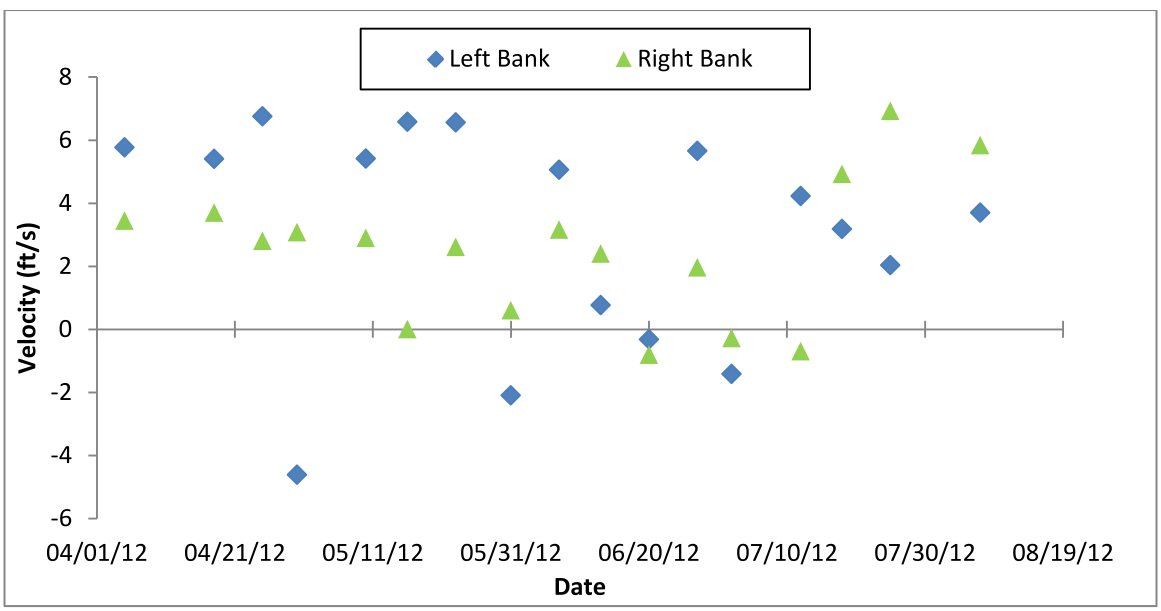

Figure 17. The entrance velocities at Wanawish Dam fishways between April and August, 2012.

Temperature- Water temperatures of the Yakima River were recorded at Wanawish Dam between October 1, 2011 and September 1, 2012 (Figure 18). Daily averages varied from 0 to 25 °C. Lamprey passage occurred during daily mean temperatures of 11.9 to 16.4 °C with the majority (78%) passing between 13.4 and 14.7 °C (Figure 18, Table 4). In the fall, water temperatures rapidly declined to less than 10 °C after the last lamprey passed the dam and movements below the dam generally ceased for the remainder of the fall.

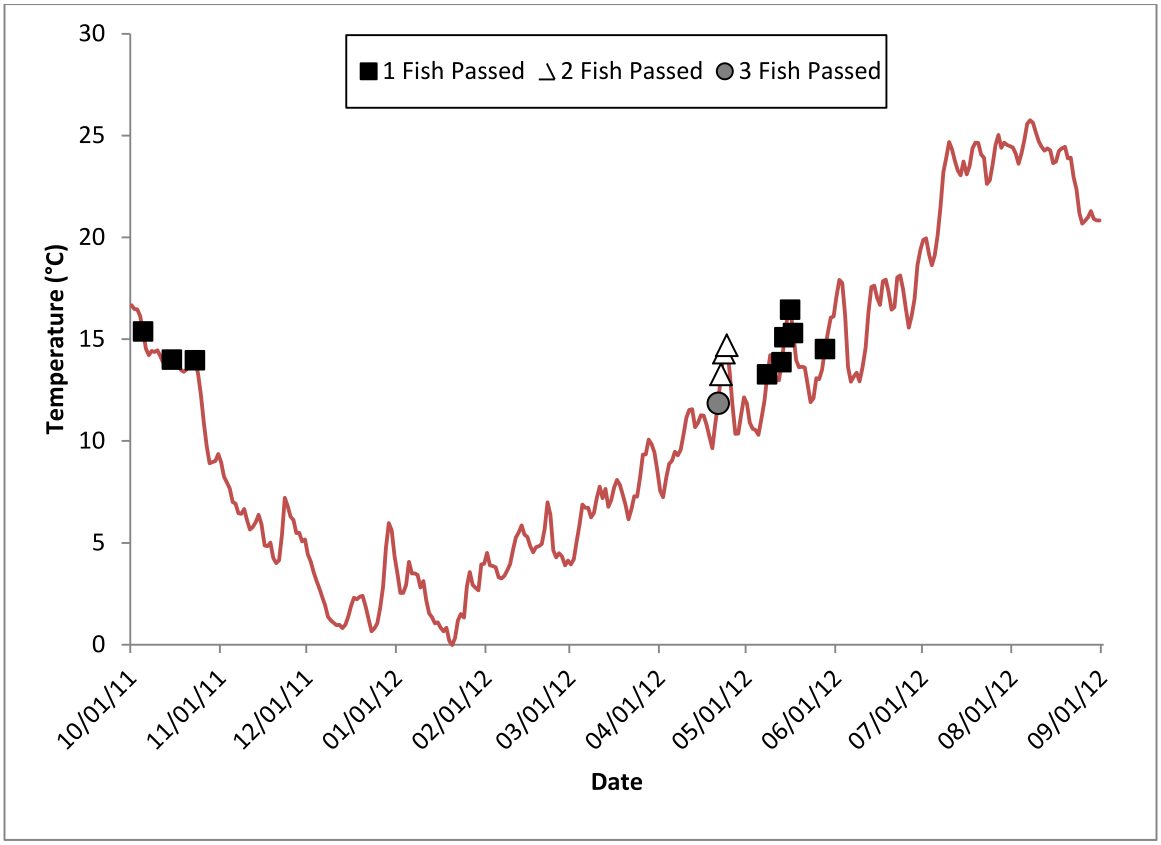

Figure 18. Average daily water temperatures of the Yakima River and dates of lamprey passage at Wanawish Dam between October 1, 2011 and September 1, 2012.

Above Dam Residence- On May 10, one lamprey (code 71) was detected in the right bank Columbia Irrigation District Canal after it had passed the dam. It stayed approximately 20 m downstream of the canal entrance for 58.1 days. It then exited through the upstream end of the canal and continued its upstream movement. No other lamprey resided more than a few minutes at the dam once it had successfully passed upstream of it.

Prosser Dam

First Approach- Pacific lampreys from both releases downstream of Prosser Dam began to approach on the evening of their release (Table 5). Twenty-eight of the 29 lampreys released downstream of the dam were detected approaching it. Twelve fall released lampreys first approached between October 4 and November 24, 2011 before overwintering. The remaining four approached between February 22 and May 28, 2012. Spring released lampreys approached the dam between March 28 and May 20, 2012. One spring released lamprey never approached the dam and instead moved downstream from the release site. Of the five lamprey released upstream of Wanawish Dam in the fall, one approached Prosser Dam in October. Three others overwintered before approaching between March 17 and April 11. Only one of the four lampreys released upstream of Wanawish in the spring approached Prosser Dam. It did so on April 7. Fifteen (83%) of those lampreys that successfully passed Wanawish Dam migrated upstream to Prosser Dam and approached it. One fall released lamprey approached on October 15, while the rest of the approaches from both release groups occurred between March 17 and May 28. Prosser Dam therefore had an overall approach rate of 84%. First approaches were made near the left bank 62% of time and the right bank 34% of the time. Only two lampreys were first detected on the downstream antenna on the center island.

Below Dam Residence- Average fall residence for lampreys that were successful in passing Prosser Dam was 0.5 days (Figure 19). Three lampreys approached the dam in the fall and moved downstream before over-wintering. These lampreys all spent less than two hours at the dam before moving downstream. Lampreys that remained at the dam and were unsuccessful in passing during the fall had an average fall residence of 23.5 days (range 24-77 d). These individuals stopped moving and over-wintered at the dam for an average of 120 days (range 87-152 d). Fall released lampreys that began moving again in the spring and ultimately passed Prosser Dam resided at the dam for an average of 45.8 days while those that were unsuccessful resided for an average of 59.4 days. Spring released lampreys had the most variable residence times at Prosser Dam: Lampreys that passed in the spring had an average residency of 27.4 days (range 0.04-93 d) while those that did not pass averaged 81.6 days (range 12-130.3 d) of residency at the dam.

Table 5. Prosser Dam approach and residence data: first and last detection dates and total number of days that adult radio-tagged Pacific lampreys resided below the dam before entering a fishway or moving downstream, October 2011 through August 2012.

Code	1st Station Detected	1st Detection Date	Last Detection Date	Days	Entered Fishway?
16	Left Island	10/04/11 19:46	10/04/12 20:16[C]	0.02	Yes
29	Right Bank	10/04/11 20:02	10/04/11 20:20	0.01	No
39	Right Bank	10/04/11 20:25	10/4/11 21:51[C]	0.06	Yes
8	Right Bank	10/04/11 20:26	10/05/11 22:46	1.1	Yes
42	Right Bank	10/04/11 20:33	10/04/11 22:06	0.06	No
17	Center Island	10/04/11 20:40	04/23/12 22:34	202.1	No
46	Right Bank	10/04/11 20:40	10/12/11[B]	7	No
26	Right Bank	10/04/11 21:14	5/29/12 23:39	238.1	Yes
9	Right Bank	10/04/11 21:22	10/04/11 21:23	0.00	No
31	Right Bank	10/04/11 22:41	10/17/11[B]	12	No
41	Right Bank	10/05/11 04:45	04/15/12 12:03	193.3	No
34	Right Bank	10/15/11 20:28	10/15/11 21:57	0.06	Yes
35	Right Bank	10/15/11 20:57	03/22/12[A]	158	No
13	Right Bank	10/21/11 21:32	10/22/11 06:04	0.4	Yes
37	Left Island	02/22/12 06:18	05/16/12 08:00	84.1	No
15	Left Island	03/17/12 00:23	06/03/12[A]	78	No
12	Left Island	03/17/12 20:26	06/03/12 23:00	78.1	No

Table 5 Continued

Code	1st Station Detected	1st Detection Date	Last Detection Date	Days	Entered Fishway?
40	Left Island	03/17/12 20:56	05/08/12 21:01	52.0	Yes
20	Left Island	03/25/12 23:55	06/05/12 11:29	71.5	Yes
66	Left Island	03/28/12 20:50	05/29/12 22:15	62.1	Yes
76	Left Island	03/28/12 22:10	06/29/12 22:41	93	Yes
63	Right Bank	03/29/12 01:10	08/06/12 07:45	130.3	No
75	Left Island	03/29/12 21:46	07/25/12[B]	117	No
33	Left Island	03/30/12 21:10	05/09/12 22:24	40.1	Yes
22	Right Bank	03/31/12 03:57	06/30/12 04:34	91	No
84	Left Island	03/31/12 05:18	04/12/12 20:30	12.6	Yes
58	Left Island	04/02/12 21:12	07/25/12 20:21	114	No
86	Left Island	04/03/12 02:35	07/12/12 04:59	100.1	No
83	Left Island	04/03/12 18:27	04/10/12 22:56	7.2	Yes
79	Left Island	04/05/12 02:15	04/22/12 22:33	17.9	Yes
89	Left Island	04/07/12 22:12	04/10/12 18:58	2.9	Yes
81	Left Island	04/09/12 22:37	06/09/12[A]	60	No
32	Left Island	04/11/12 02:32	05/15/12 23:38	34.9	Yes
5	Left Island	04/22/12 04:29	05/13/12 21:19	21.7	Yes
87	Left Island	04/23/12 12:43	08/25/12 18:04	124.2	No
28	Left Island	04/23/12 23:37	04/24/12 00:29	0.04	Yes[D]
69	Left Island	04/24/12 01:58	04/24/12 02:51	0.04	Yes
4	Left Island	04/25/12 00:05	07/14/12 22:11	80.9	Yes
78	Left Island	04/25/12 00:43	06/02/12 01:22	38	Yes
6	Center Island	04/28/12 00:18	05/08/12 21:25	10.9	Yes
14	Right Bank	05/01/12 02:25	06/01/12 22:08	31.8	Yes
77	Left Island	05/01/12 02:50	05/28/12 23:59	27.9	Yes
65	Left Island	05/08/12 21:19	08/03/12 14:27	86.7	No
59	Right Bank	05/19/12 00:22	05/31/12 00:05	12	No
85	Left Island	05/20/12 05:35	06/02/12 01:07	12.8	Yes
27	Left Island	05/28/12 12:09	06/29/12 22:28	32.4	Yes
62	Left Island	06/02/12 23:53	07/25/12[B]	52	No
60	Left Island	04/30/120 4:32	05/25/12 11:10	25.3	No

[A] last date of movement
[B] date tag was recovered
[C] last detection before power failure
[D] entered and went up left fishway on 4/24 when headgate was closed and backed down 1 hour later

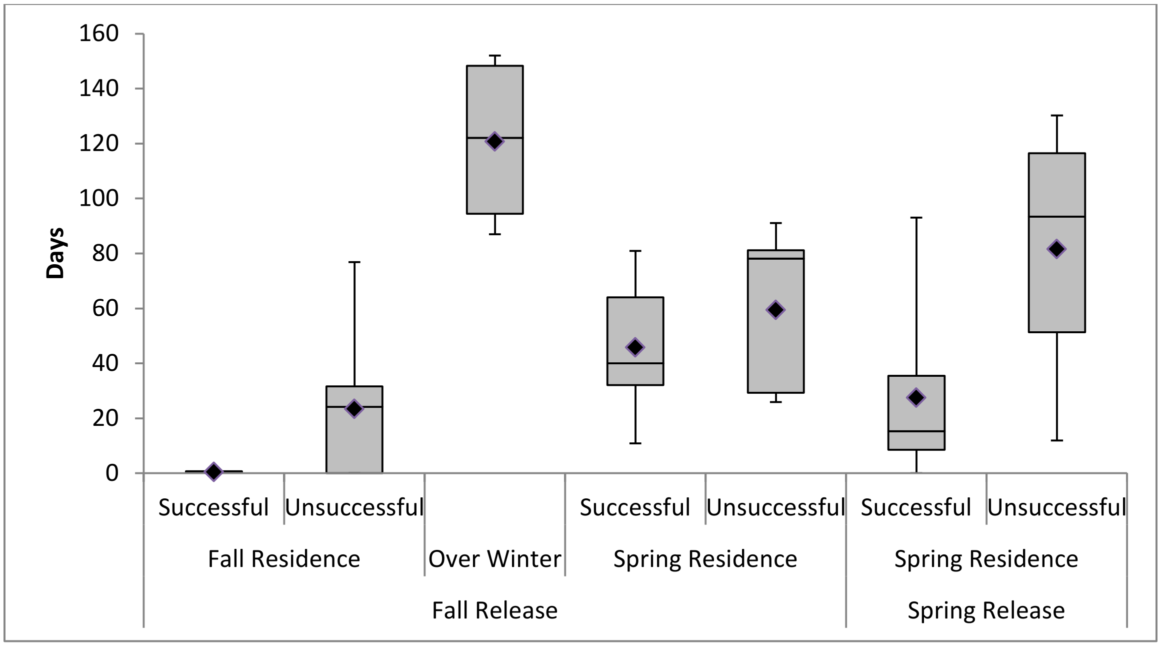

Figure 19. Periods of below dam residency for radio-tagged Pacific lampreys at Prosser Dam that were successful and unsuccessful in passing upstream of the dam, October 2011 through July 2012. Box plots show median and quartiles. The diamonds indicate the means.

Lampreys were detected on all three stations at Prosser Dam while they searched for upstream passage with the greatest number occurring on the left island antennas (Figure 20). Unlike at Wanawish Dam, lampreys spent little time near the face of Prosser Dam during holding periods or daylight hours, residing instead just downstream of the bedrock ledge the dam was built upon. The greatest concentration occurred in a pool along the left bank (Figure 21). This area included a boulder filled pool and areas of whitewater coming off the face of the dam. Pacific lampreys were consistently detected in this area during both day and night hours. Night observations during July showed tagged lampreys attempting to climb over the dam using the bedrock at face of the dam along the left bank (Figure 22). High velocities over the dam and the overhanging crest prevented these lampreys from being successful in their attempts.

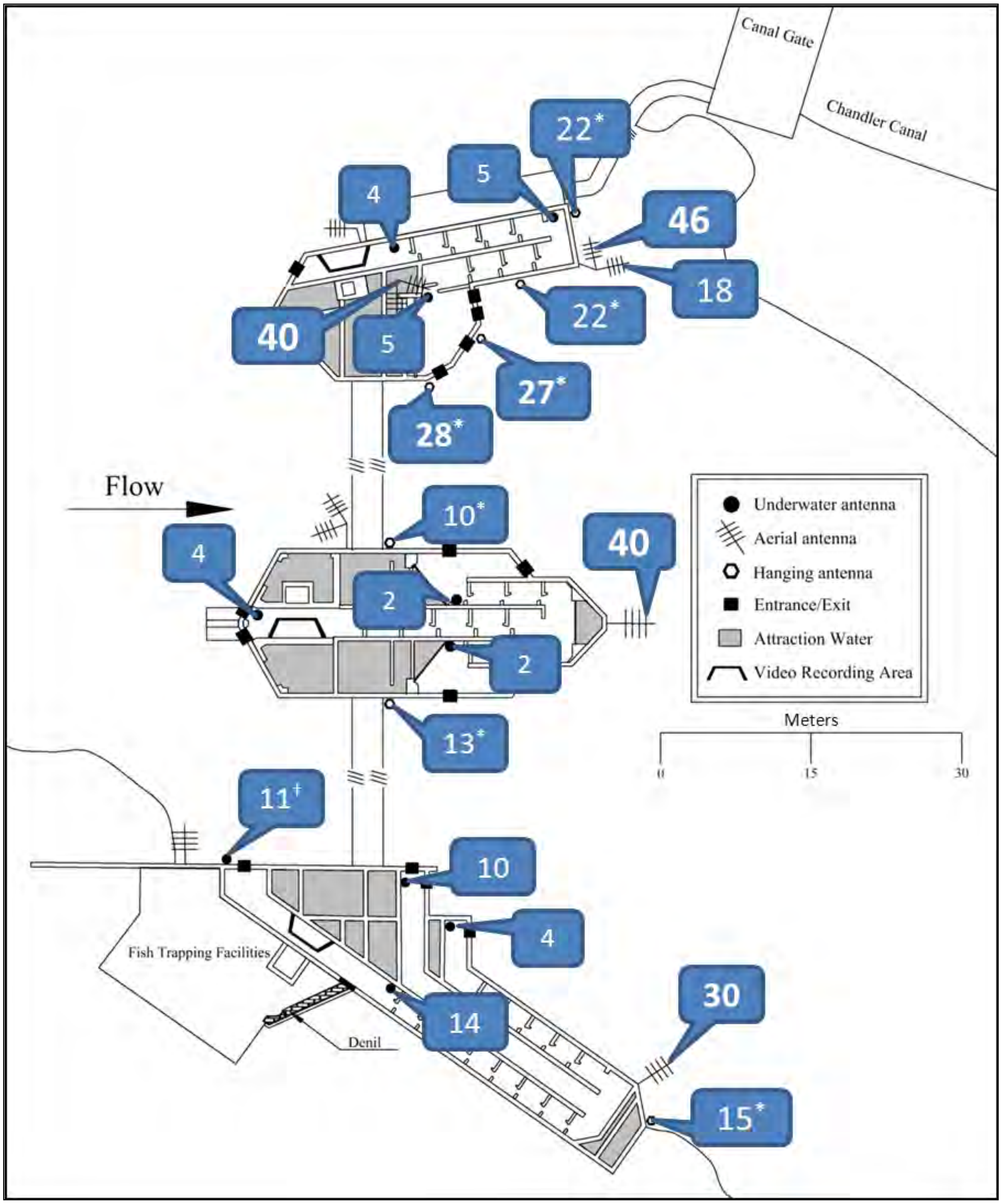

Figure 20. Number of radio-tagged Pacific lampreys detected on downstream and in-ladder antennas at Prosser Dam, October 2011-July 2012. † indicates two additional lampreys were not detected but were detected upstream by mobile tracking. Antennas with a (*) were installed on March 27, 2012.

Four tags were recovered at Prosser Dam. On October 12, 2011 a tag was recovered left of river center downstream of the dam. The tag was in a grassy area with approximately 5 cm of water covering it. The antenna appeared to have bite marks in it, but it is not known if predation or scavenging occurred. On October 17, 2011 a deceased radio-tagged lamprey was found in the drain pipe of the trap tank in the adult salmonid trapping facility on the right bank. This drain empties into the river along the bank downstream of the fishway. It is assumed that the lamprey swam up the 4 inch PVC drain pipe as it was not detected moving up the fishway. On July 25, 2012, two tags were recovered from the left bank downstream of the dam. Both were on the bank above the waterline in areas of grass and mud. Neither showed teeth marks, however, their presence on dry land indicate some type of predation or scavenging had occurred. Three lampreys ceased moving and were still at the dam at the end of the study period. It was determined from several foot tracking occasions that these individuals were in the river but visual observations of the lamprey or tag were not possible and their fates are not known.

Figure 21. Pool and whitewater along the left bank of Prosser Dam where the majority of Pacific lampreys held during the day and night hours.

Figure 22. Radio-tagged Pacific lampreys (circled in red) attempting to climb over Prosser Dam by way of the dam face and exposed bedrock, July 3, 2012.

Fishway Passage- A total of 23 tagged lampreys passed Prosser Dam, for an overall passage success rate of 48%. Five lampreys (22%) passed in October, two of which used the right bank fishway during adult salmonid trapping operations. Both lampreys successfully moved up the ladder and around or through the picket gate used to direct salmon into the denil and trapping facility. The remaining eighteen (78%) passed the dam between April 10 and July 14. Thirteen of the 23 (57%) passage events occurred in the right bank fishway (Table 6). Four lampreys used the center island fishway and four were known to have used the left island fishway. An additional two lampreys passed the dam during a power outage and we deduced they used the left fishway: Prior to losing power both were detected on the left island antennas; video recorded two lampreys in the fishway that night; both tagged lampreys were detected upstream of the dam the next day during mobile tracking. Passage time for Prosser Dam fishways ranged between 0.55 and 29.48 hours with an average of 5.05 hours (Table 6). One lamprey (code 69) entered the right bank fishway on April 24 at which time the fishway headgate was closed due to high flows. It remained near the headgate for several days attempting to pass (Figure 23). On May 2 it moved downstream within the ladder and was detected on the underwater center antenna near the gate blocking the entrance to the denil. The gate was lifted between May 6 and May 8 while the denil was in operation. On May 10, code 69 was foot tracked and located in the body of water beneath the denil. This area collects spillage from the denil but has no entry or exit for fish when the denil is not operating. Code 69 remained in this location for the remainder of the study as it had no way to exit. A lamprey also entered the left island fishway on April 24. The headgate in this fishway was also closed. Code 28 remained in the fishway for approximately an hour before returning downstream. It entered the fishway a second time on June 19 for approximately an hour and a half before once again returning downstream. On July 1 it moved downstream from the dam.

Table 6. Prosser Dam fishway data: dates of entry and exit, total time in the fish ladder, and water temperature at passage for radio-tagged adult Pacific lampreys, October 2011 through July 2012.

Code	Release Site/Period	Fishway	Entered Ladder	Exited Ladder	Time in Ladder (hr)	T °C	Video?
16	PRO Fall Dn	Left	10/04/11[A]	10/05/11[A]	unk	15.6	yes
39	PRO Fall Dn	Left	10/04/11[A]	10/05/11[A]	unk	15.6	yes
8	PRO Fall Dn	Right	10/05/11 22:46	10/05/11 23:28	0.71	15.1	no
34	PRO Fall Dn	Right	10/15/11 21:57	10/15/11 23:18	1.34	13.6	no
13	WAN Fall Up	Center	10/22/11 06:04	10/22/11 15:25	9.36	13.3	yes
89	WAN Spr Up	Right	04/10/12 18:58	04/10/12 23:15	4.29	10.6	no
83	PRO Spr Dn	Right	04/10/12 22:56	04/11/12 02:45	3.82	10.6	no
84	PRO Spr Dn	Right	04/12/12 20:30	04/13/12 07:06	10.6	10.7	no
79	PRO Spr Dn	Right	04/22/12 22:33	04/23/12 00:47	2.23	12.5	no
40	WAN Fall Up	Right	05/08/12 21:01	05/09/12 00:10	3.15	12.9	no
6	WAN Fall Dn	Right	05/08/12 21:25	05/09/12 03:20	5.92	12.9	no
33	PRO Fall Dn	Right	05/09/12 22:24	05/10/12 00:49	2.42	13.7	no
5	PRO Fall Dn	Right	05/13/12 21:19	05/14/12 01:48	4.48	13.2	yes
32	WAN Fall Up	Left	05/15/12 23:38	05/16/12 00:55	1.28	15.4	no
77	WAN Spr Dn	Center	05/28/12 23:59	05/29/12 02:56	2.95	14.0	no
66	PRO Spr Dn	Center	05/29/12 22:15	05/30/12 04:50	6.58	14.8	no
26	PRO Fall Dn	Center	05/29/12 23:39	05/31/12 05:08	29.48	14.8	yes
14	WAN Fall Dn	Right	06/01/12 22:08	06/02/12 03:06	4.97	15.8	yes
85	WAN Spr Dn	Right	06/02/12 01:07	unknown	unk	17.0	yes
78	WAN Sp rDn	Right	06/02/12 01:22	unknown	unk	17.0	no
27	WAN Fall Dn	Left	06/29/12 22:28	06/29/12 23:24	0.93	17.8	yes
76	PRO Spr Dn	Left	06/29/12 22:41	06/29/12 23:14	0.55	17.8	yes
4	WAN Fall Dn	Left	07/14/12 22:11	07/14/12 23:09	0.97	22.3	yes

[A] exact time of day unknown due to power outage

Figure 23. Radio-tagged Pacific lamprey code 69 attempting to exit the right bank fishway at Prosser Dam by climbing the closed headgate, April 30, 2012.

Discharge-
River discharge at Prosser Dam varied between 588 and 18,705 ft^3/s. In October 2011, three tagged lampreys passed the dam at flows of 1,460 ft^3/s or less. The other successful lampreys passed between April and July when flows ranged from 1,080 to 11,750 ft^3/s (Figure 24). Passage occurred primarily on increasing flows or during transitions between decreasing and increasing flows.

Velocity at Fishways- Velocities at the Prosser Dam fishway entrances were recorded between April 5 and August 7, 2012 (Figure 25 and Appendix B). Velocities varied between -0.9 and 9.5 ft/s. All three fishways had average velocities between 4 and 6 ft/s and did not differ significantly ($p=0.21$). Due to river conditions on several occasions, measurements were not taken at the Prosser Dam right bank upper fishway entrance. Large differences between the upper and lower fishways during the peak period of passage led us to analyze these two entrances separately.

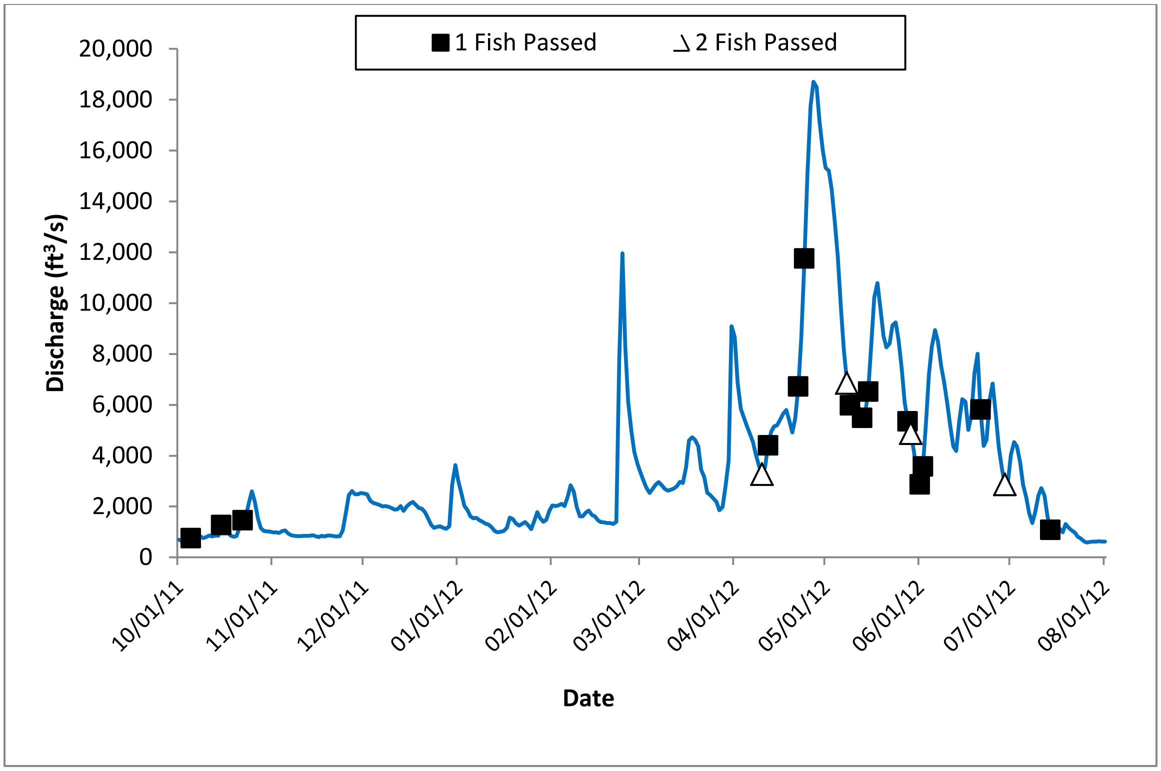

Figure 24. Graph showing the discharge and passage timing of radio-tagged Pacific lampreys at Prosser Dam on the Yakima River, October 2011 through July 2012.

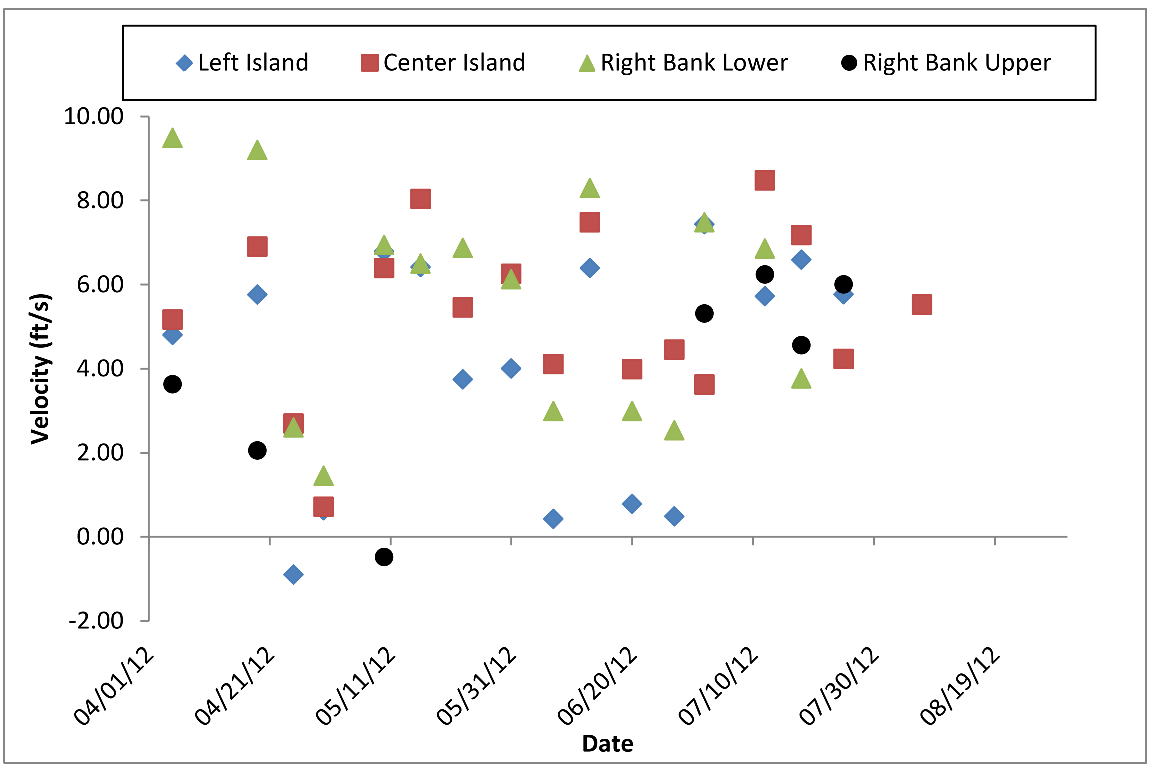

Figure 25. The entrance velocities at the Prosser Dam fishways between April and August, 2012.

Temperature- River water temperature was recorded at Prosser Dam from October 1, 2011 to September 1, 2012 (Figure 26). Daily averages ranged from 0.3 °C to 24 °C. The majority of tagged lampreys passed the dam at mean daily water temperatures between 12 °C and 15 °C, however, the last lamprey passed at 22.3 °C. In the fall after the 3 lampreys passed the dam water temperatures decreased rapidly and passage ceased for the winter.

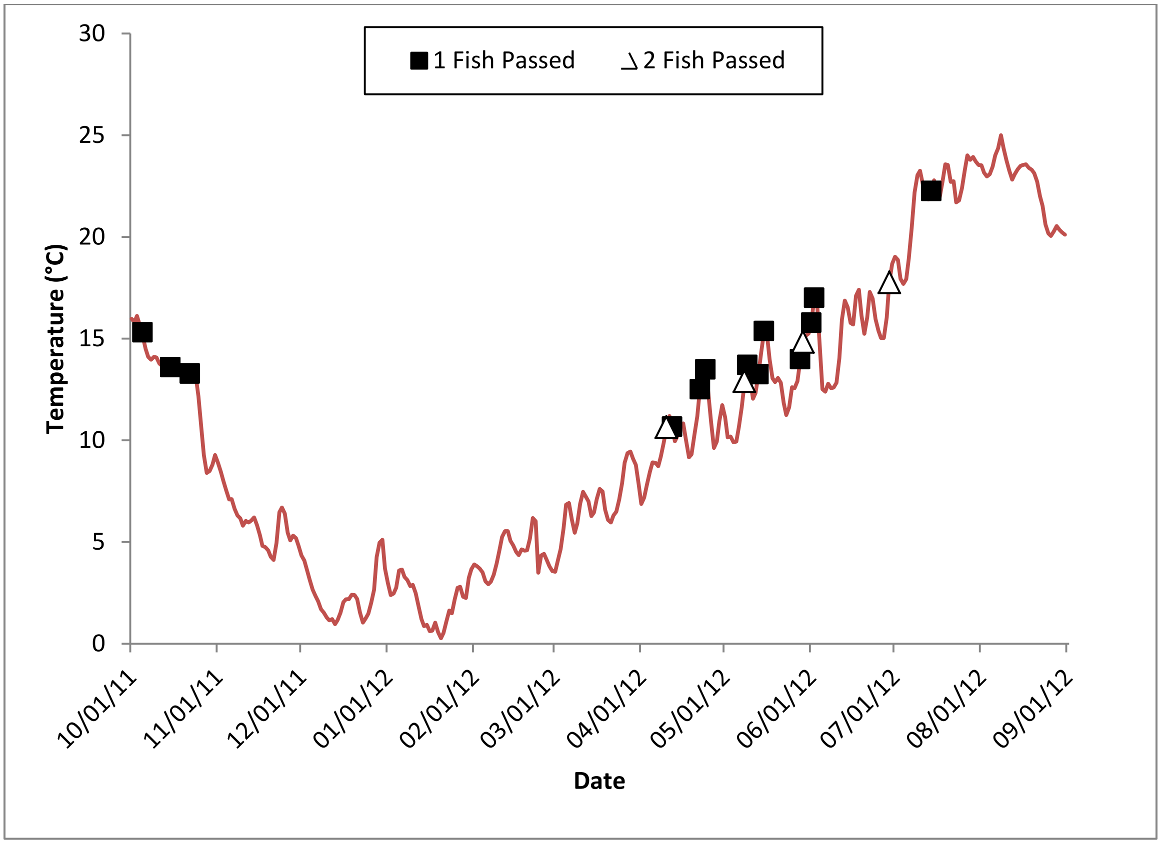

Figure 26. Average daily water temperatures of the Yakima River and dates of radio-tagged lamprey passage at Prosser Dam, October 2011 through August 2012.

Above Dam Residence- The lampreys that successfully passed Prosser Dam spent little time in the vicinity before continuing their migration. Two individuals spent 3.33 and 16.83 hours respectively while the rest spent less than 10 minutes before moving upstream.

Video counts of lampreys at Prosser Dam- Between August 22, 2011 and July 1, 2012 a total of 41 lampreys were observed on the video recorders within the fishways at Prosser Dam, 10 of which were radio-tagged. Thirteen tagged lampreys passed that were not detected on the video counts (Table 6 and Figure 27). Video recording was not operational for the time periods of March 31-April 2 and also April 23-May 7 and only one tagged lamprey passed Prosser Dam during these time periods. Thus during the times that the videos were recording, 12 of the 22 tagged lampreys (55%) were not observed or counted while passing in the fish ladders at Prosser Dam.

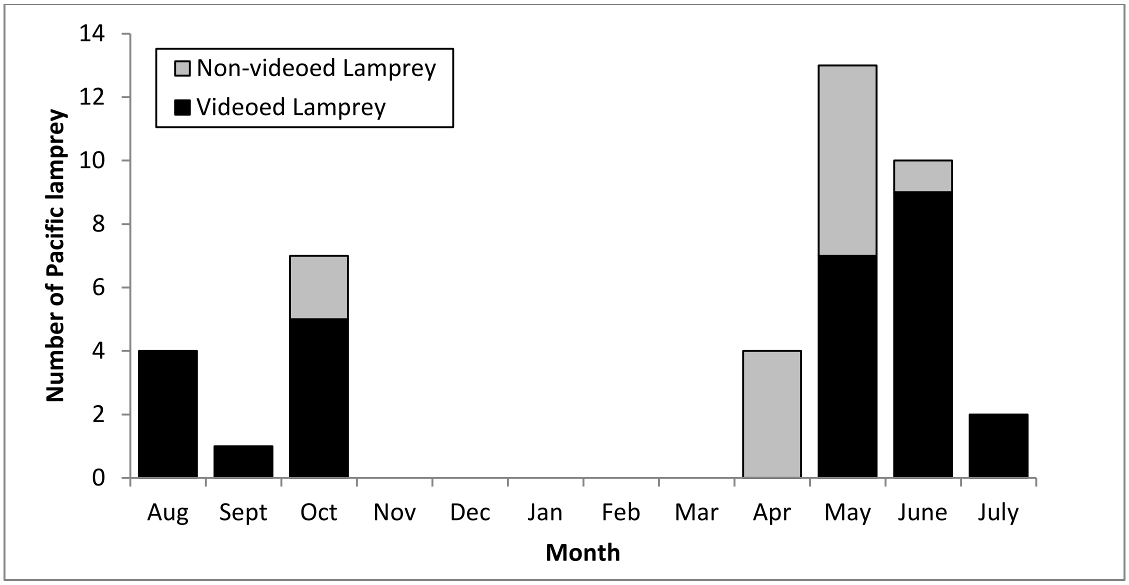

Figure 27. Video counts of upstream migrating adult Pacific lampreys at Prosser Dam, August 2011 to July 2012.

Sunnyside Dam

First Approach- The first detections at Sunnyside Dam were all on the aerial antennas of the center island station (Table 7). Thirty-one lampreys had either been released above Prosser Dam or had successfully passed above Prosser Dam and 18 (58%) migrated upstream to Sunnyside Dam. Three lampreys first approached the dam in October 2011. Approaches made during the spring months occurred from March 28 to July 3, 2012 with the majority in April (Table 7).

Below Dam Residence- Pacific lampreys that were successful in passing Sunnyside Dam had an average residency of 9.3 days before entering a fishway. The shortest residency occurred on June 16, 2012 and lasted just over 2.5 hours while the longest was 20.7 days (Table 7). The average residency time for those individuals who were not successful and ultimately moved downstream was 40 days (range 0.1 to 112.7 d). Only one lamprey (code 34) over-wintered at Sunnyside Dam. It attempted to find passage from its arrival on October 24 until December 29. It then over-wintered for 90 days until it began moving again on March 28. Its spring residence at the dam lasted for 81 days until June 17 when it stopped moving. It is not known if the tag was shed, the lamprey died, or it was still holding. Lampreys utilized holding areas across the width of the river downstream of the dam; however, the majority of lampreys used the area between the center island and the right bank for holding during daylight hours (Figure 28). A large log stuck on the face of the dam provided a break in the flow over the dam and lampreys were routinely detected beneath it.

Table 7. Sunnyside Dam approach and residence data: first and last dates of detection and number of days that radio-tagged adult Pacific lampreys resided below the dam before entering a fishway or moving downstream, October 2011 to August 2012.

Code	1st Station Detected	1st Detection Date	Last Detection Date	Days	Entered Fishway?
44	Center Island	10/16/11 01:32	10/23/11 20:04	7.8	Yes
38	Center Island	10/17/11 03:32	10/17/11 6:20	0.1	No
34	Center Island	10/24/11 04:10	06/17/12[A]	237	No
13	Center Island	03/28/12 01:16	05/24/12 04:00	57.1	No
30	Center Island	04/11/12 23:32	04/29/12 16:22	17.7	No
70	Center Island	04/14/12 06:04	06/15/12 02:17	61.8	No
73	Center Island	04/15/12 21:14	04/23/12 02:47	7.2	No
84	Center Island	04/22/12 17:31	06/06/12 02:14	44.4	No
83	Center Island	04/23/12 04:04	08/13/12 21:08	112.7	No
39	Center Island	04/24/12 03:18	06/21/12 16:23	58.6	No
8	Center Island	04/24/12 06:11	05/14/12 22:19	20. 7	Yes
79	Center Island	05/10/12 01:12	05/15/12 22:59	5.9	Yes
6	Center Island	05/17/12 02:24	05/28/12 00:53	10.9	Yes
36	Center Island	05/17/12 21:35	05/17/12 23:17	0.07	No
32	Center Island	06/03/12 22:50	06/17/12 22:28	14	Yes
14	Center Island	06/15/12 22:10	7/17/12[A]	30.1	No
77	Center Island	06/16/12 22:28	06/17/12 01:05	0.1	Yes
5	Center Island	07/03/12 07:05	07/09/12 00:43	5.7	Yes

[A] last date of movement

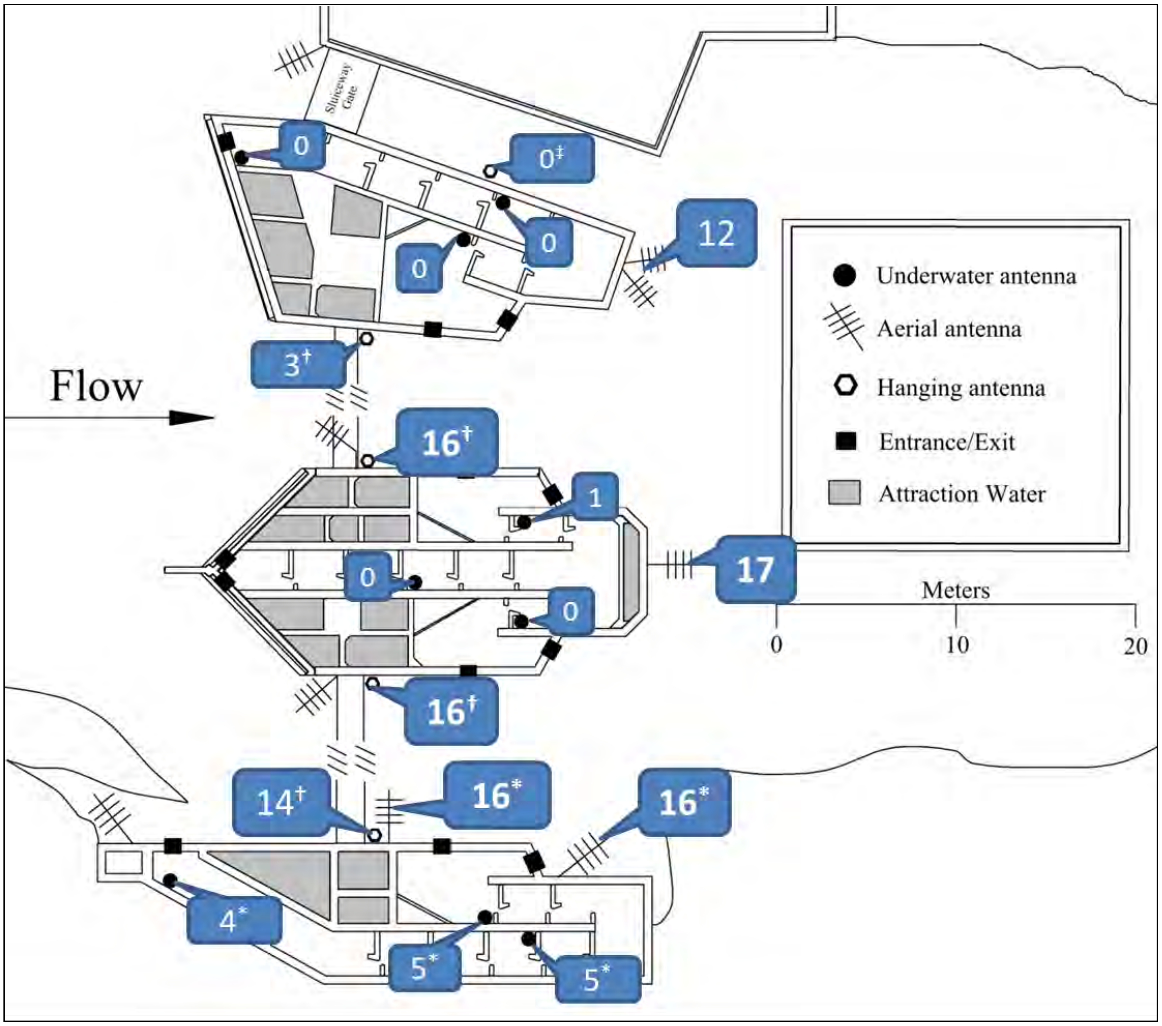

Figure 28. Number of radio-tagged Pacific lampreys detected on downstream and in-ladder antennas at Sunnyside Dam, October 2011-July 2012. Antennas with a (*) were installed on December 2, 2011. The † indicates antennas installed on April 5, 2012 and a ‡ indicates an installation date of April 30, 2012.

Fishway Passage- Seven of the eighteen (39%) lampreys that approached Sunnyside Dam successfully passed upstream using one of the fishways (Table 8). Of the fish released in the fall, 5 (42%) passed the dam while two (33%) from the spring release were successful. The first lamprey passed Sunnyside Dam on October 23, 2011, before the right bank fishway antennas were installed. Because it was not detected on any underwater antennas within the left and center island fishways, based on the data from aerial antennas we concluded it passed in the right bank fishway. Six lampreys passed upstream between May 14 and July 9, 2012; five using the right bank fishway and one using the center island fishway. Two lampreys were detected in the right bank fishway but did not successfully negotiate the ladder or pass the dam. Passage through the fishways ranged between 0.27 to 3.85 hours with an average of 1.09 hours.

Table 8. Sunnyside Dam fishway data: dates of entry and exit and total time in the fish ladder for radio-tagged adult Pacific lampreys from October 2011 to August 2012.

Code	Release Site/Period	Fishway	Entered Ladder	Exited Ladder	Time in Ladder (hr)	Temp °C
44	PRO Fall Up	Right	10/23/11 20:04[A]	10/23/11 21:14[A]	1.17	12.5
8	PRO Fall Dn	Right	05/14/12 22:19	05/14/12 22:35	0.27	11.9
79	PRO Spr Dn	Right	05/15/12 22:59	05/15/12 23:23	0.40	12.2
6	WAN Fall Dn	Right	05/28/12 00:53	05/28/12 01:39	0.77	12.3
77	WAN Spr Up	Right	06/17/12 01:05	06/17/12 01:50	0.75	14.6
32	WAN Fall Up	Right	06/17/12 22:28	06/17/12 22:58	0.50	14.6
5	PRO Fall Dn	Center	07/09/12 00:43	07/09/12 04:34	3.85	17.8

[A] based on center island aerial antennas

Discharge- Discharge at Sunnyside Dam ranged from a low of 586 ft^3/s on July 26, 2012 to a high of 18,924 ft^3/s on April 25, 2012. The one lamprey that passed in October did so at a discharge of 1,807 ft^3/s. The lampreys that passed in the spring did so at flows between 2,839 and 8,410 ft^3/s. The majority of passage events occurred during increases in the hydrograph (Figure 29).

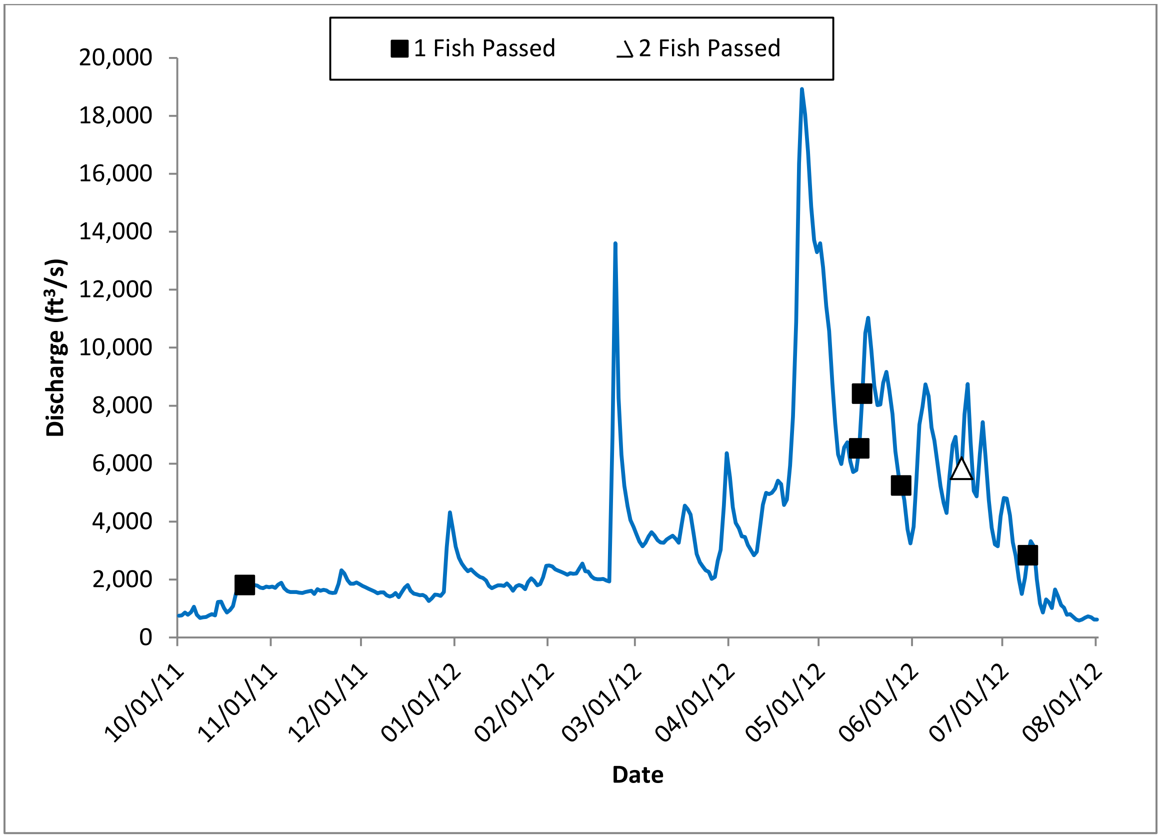

Figure 29. Graph showing the discharge and passage timing of radio-tagged Pacific lampreys at Sunnyside Dam on the Yakima River from October 2011 to August 2012.

Velocity at Fishways- Fishway entrance velocities were recorded at Sunnyside Dam between April 5 and August 7, 2012 (Figure 30 and Appendix B). Velocities at the dam ranged from -0.53 to 10.09 ft/s. The right bank fishway was the slowest with an average velocity of 4.7 ft/s. The center island fishway averaged 7.3 ft/s and the left island fishway had a slightly higher average of 7.5 ft/s. There were no significant differences between the left and center islands (p=0.5), however, the right bank velocities were significantly different than both the left and center island fishways (p=0.0005, p=0.01).

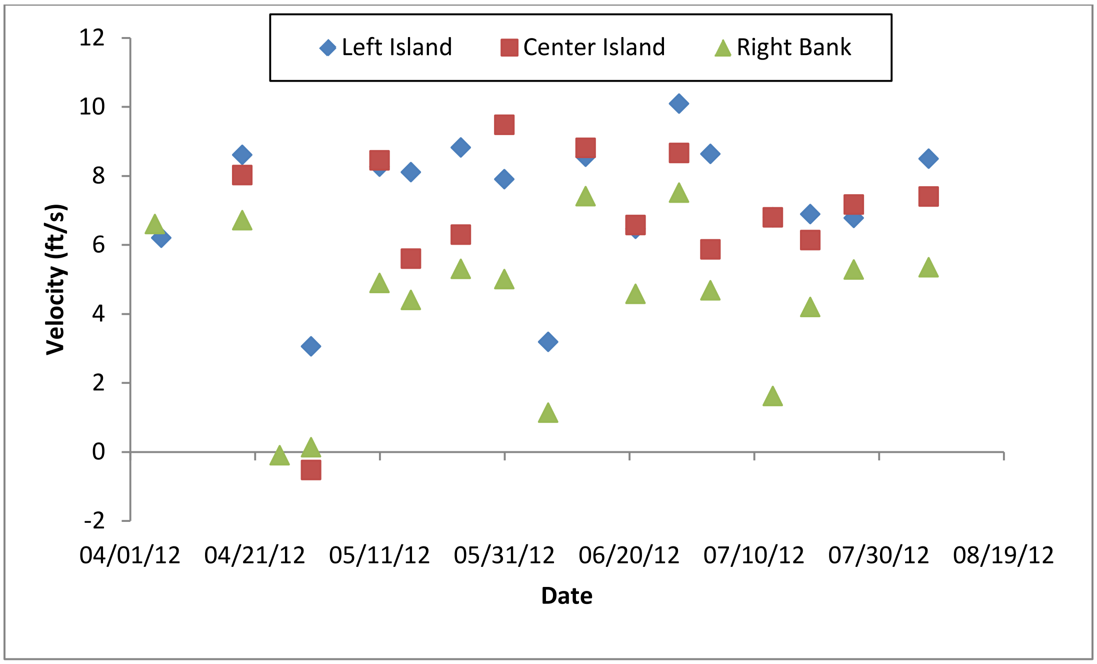

Figure 30. Entrance velocities at Sunnyside Dam fishways between April and August, 2012.

Temperature- Water temperature was recorded at Sunnyside Dam from October 1, 2011 through Sept 1, 2012 and mean daily temperature ranged from 0 to 18.3 °C (Figure 31). Six out of seven lampreys passed when temperatures were between 12 and 15 °C, including both fall and spring passage events. One lamprey passed the dam when the water temperature was 17.8 °C.

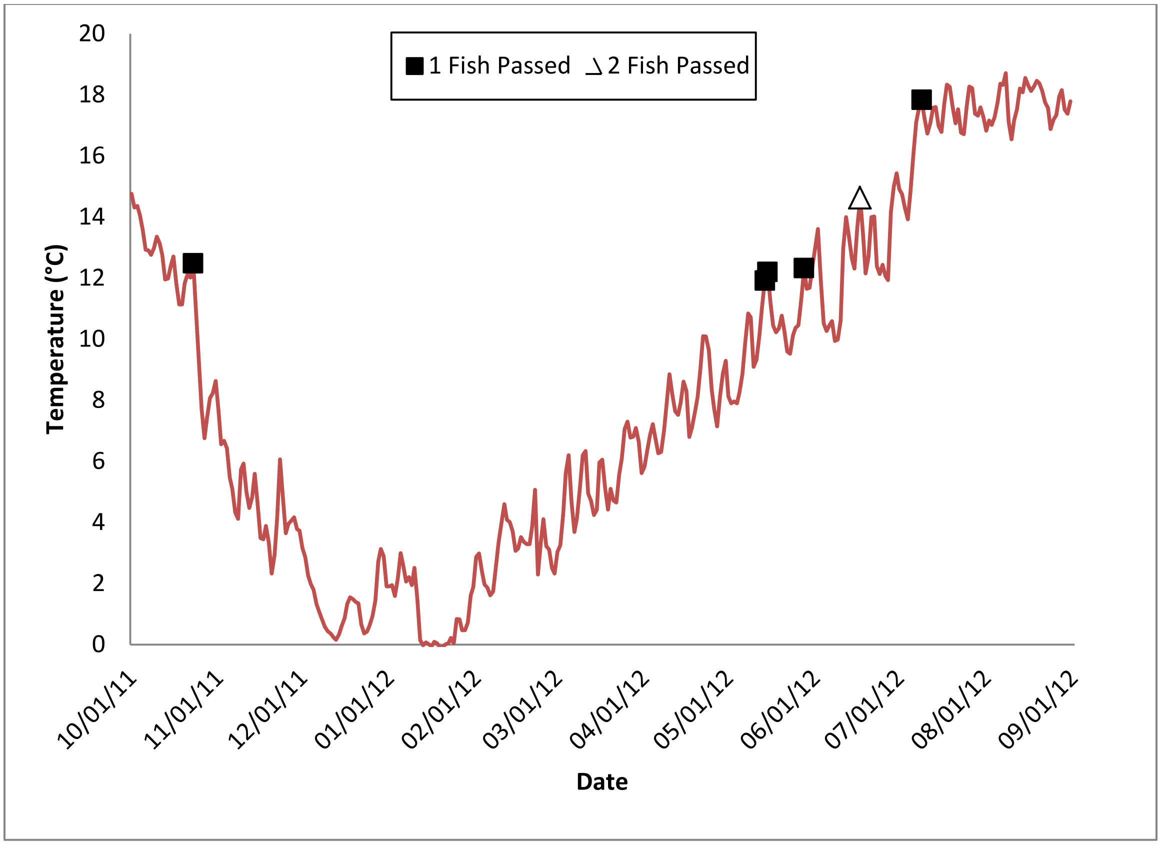

Figure 31. Average daily water temperatures of the Yakima River and dates of lamprey passage at Sunnyside Dam between October 1, 2011 and September 1, 2012.

Above Dam Residence- Only one lamprey was detected for more than a few minutes after successfully passing through Sunnyside Dam- code 5 spent 18.5 hours in the upstream vicinity of the dam before continuing its migration.

Wapato Dam

First Approach- All seven Pacific lampreys that passed Sunnyside Dam migrated upstream to Wapato Dam (Table 9). One approach occurred in the fall on November 2, 2011. The remaining six approached the dam in the spring between May 15 and July 11, 2012. Two approached using the west channel and five used the east channel. All of those in the east channel were first detected on the center island downstream aerial antenna.

Below Dam Residence- One lamprey (code 44) over-wintered at Wapato Dam in the east channel. Its fall residence at the dam lasted 26.1 days before it moved approximately 200 m downstream and over-wintered near a rock cross vane. On March 10, after an overwintering period of 102.6 days, it resumed actively trying to pass the dam. On June 5 it moved downstream and was subsequently detected passing downstream of Sunnyside as well. Its total residence time at Wapato was 216.34 days. The residence time of those that were successful in passing the dam ranged between 1.81 and 33.9 days with an average of 11.02 days. These fish were detected during daylight hours holding near the face of the dam as well as along the bank just downstream of the dam though antenna detections indicate movements occurred across the entire dam (Figures 32 and 33). Two lampreys were still residing at Wapato at the end of the study period, one in each channel.

It is not known whether these fish were holding, no longer alive, or if the tags had been shed. They were the last two fish detected approaching the dam.

Table 9. Wapato Dam approach and residence data: first and last dates of detection and number of days that radio-tagged adult Pacific lampreys resided below the dam before entering a fishway or moving downstream, October 2011 to August 2012.

Code	1st Station Detected	1st Detection Date	Last Detection Date	Days	Entered Fishway?
44	E. Center Island	11/02/11 09:13	06/05/12 17:27	216.3	No
8	E. Center Island	05/15/12 04:13	06/18/12 01:51	33.9	Yes
79	W. Center Island	05/17/12 02:57	05/18/12 22:18	1.8	Yes
6	E. Center Island	05/28/12 23:31	06/02/12 04:32	4.2	Yes
77	E. Center Island	06/17/12 23:32	06/22/12 03:33	4.2	Yes
32	E. Center Island	06/18/12 02:56	07/19/12[A]	30.9	No
5	W. Center Island	07/11/12 03:59	07/24/12[A]	12.8	No

[A] last date of movement

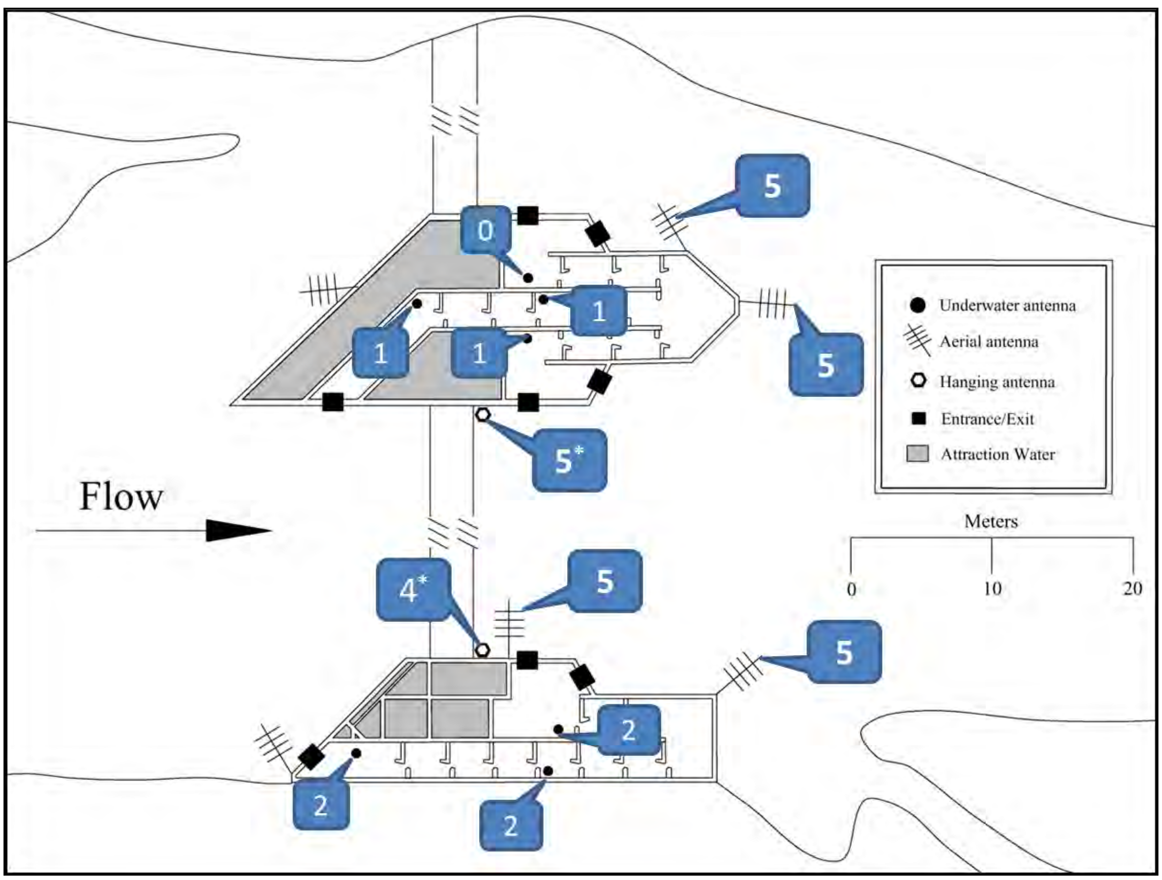

Figure 32. Number of radio-tagged Pacific lampreys detected on downstream and in-ladder antennas in the east channel at Wapato Dam, October 2011-July 2012. A (*) indicates an antenna installation date of April 5, 2012.

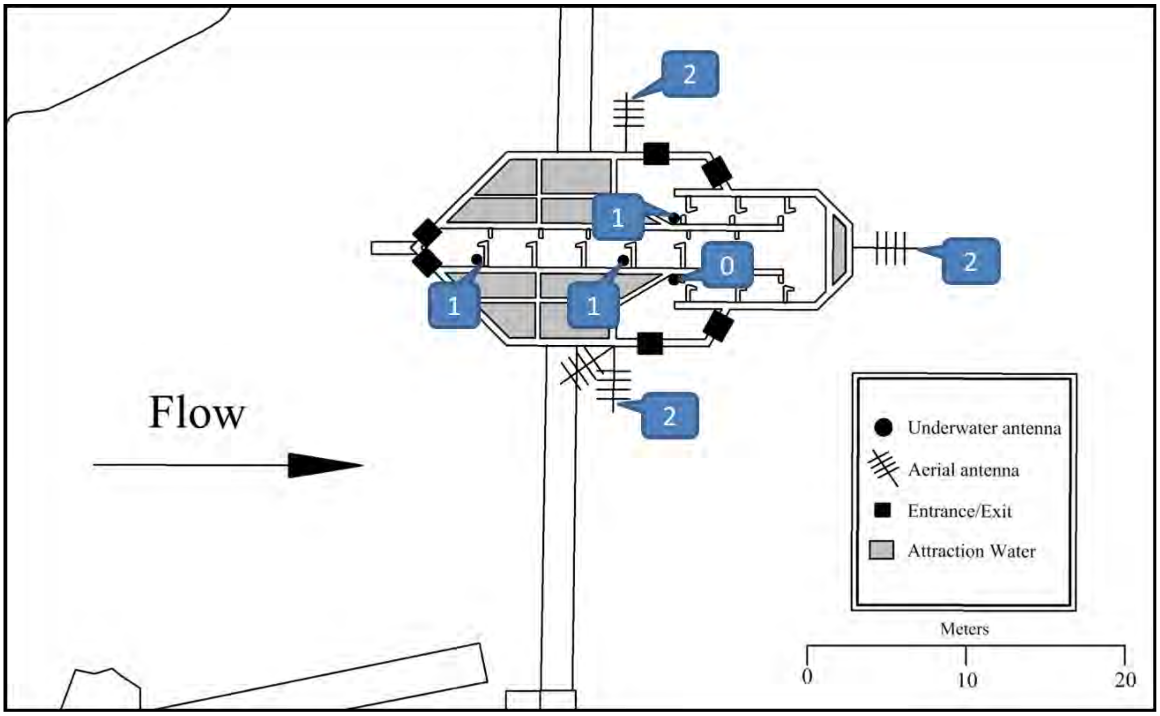

Figure 33. Number of radio-tagged Pacific lampreys detected on the downstream and in-ladder antennas in the west channel of Wapato Dam, October 2011-July 2012.

Fishway Passage- Of the seven Pacific lampreys that approached Wapato Dam, 4 (57%) successfully passed upstream using one of the fishways (Table 10). Two of the five fall-released lampreys were successful while both spring-released lampreys that made it to Wapato successfully passed it. No passage occurred during October of 2011. All passage events occurred between May 20 and June 22, 2012. One lamprey passed using the west channel island fishway, one passed in the east channel island fishway, and two lampreys passed in the east channel right bank fishway. Passage times for the lampreys in the east channel were 50 minutes or less while the lamprey that passed in the west channel took 1.4 days (Table 10).

Table 10. Wapato Dam fishway data: dates of entry and exit and total time in the fish ladder for radio-tagged adult Pacific lampreys from October 2011 to August 2012.

Code	Release Site/Period	Fishway	Entered Ladder	Exited Ladder	Time in Ladder (hr)	Temp °C
79	PRO Spr Dn	W. Center Island	05/18/12 22:18	05/20/12 08:31	34.22	10.2
6	WAN Fall Dn	E. Center Island	06/02/12 04:32	06/02/12 05:22	0.83	13.4
8	PRO Fall Dn	E. Right Bank	06/18/12 01:51	06/18/12 02:38	0.78	13.4
77	WAN Spr Dn	E. Right Bank	06/22/12 03:33	06/22/12 04:12	0.65	14.0

Discharge- Discharge at Wapato Dam ranged from a low of 586 ft^3/s on July 26, 2012 to a high of 18,924 ft^3/s on April 25, 2012. Lampreys that passed the dam did so during flows of 4,873-9,908 ft^3/s. Passage events all occurred after peak flows and like the other dams tended to be on an increase in the hydrograph (Figure 34).

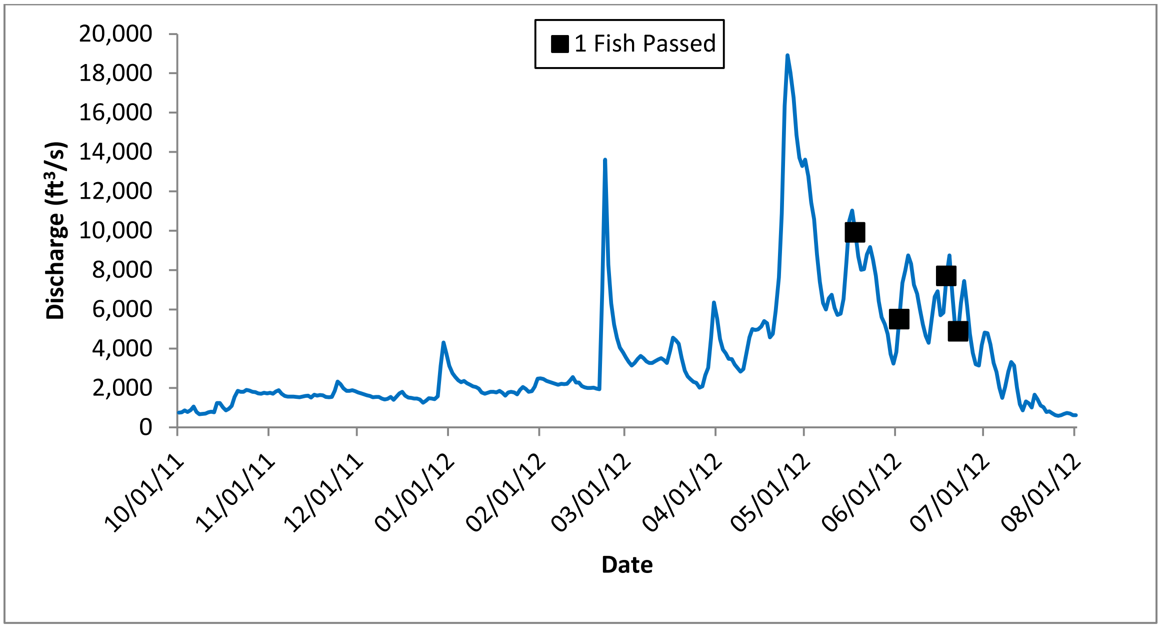

Figure 34. Graph showing the discharge and passage timing of radio-tagged Pacific lampreys at Wapato Dam on the Yakima River from October 2011 to August 2012.

Velocity at Fishways- Velocities at the Wapato Dam fishway entrances were recorded between April 6 and August 7, 2012 (Figure 35 and Appendix B). The differences in velocities between each fishway were significant (p=0.0004). The east channel center island fishway consistently had velocities below 3 ft/s. The east channel right bank and west channel center islands fishways were much more varied in their velocities. The highest velocity, 6.69 ft/s, occurred July 19 in the east channel right bank fishway while the lowest, 0.79, occurred in the west center island fishway on July 3, 2012. No negative velocities were recorded at Wapato Dam. Attraction water did not appear to be in operation at the east channel center island.

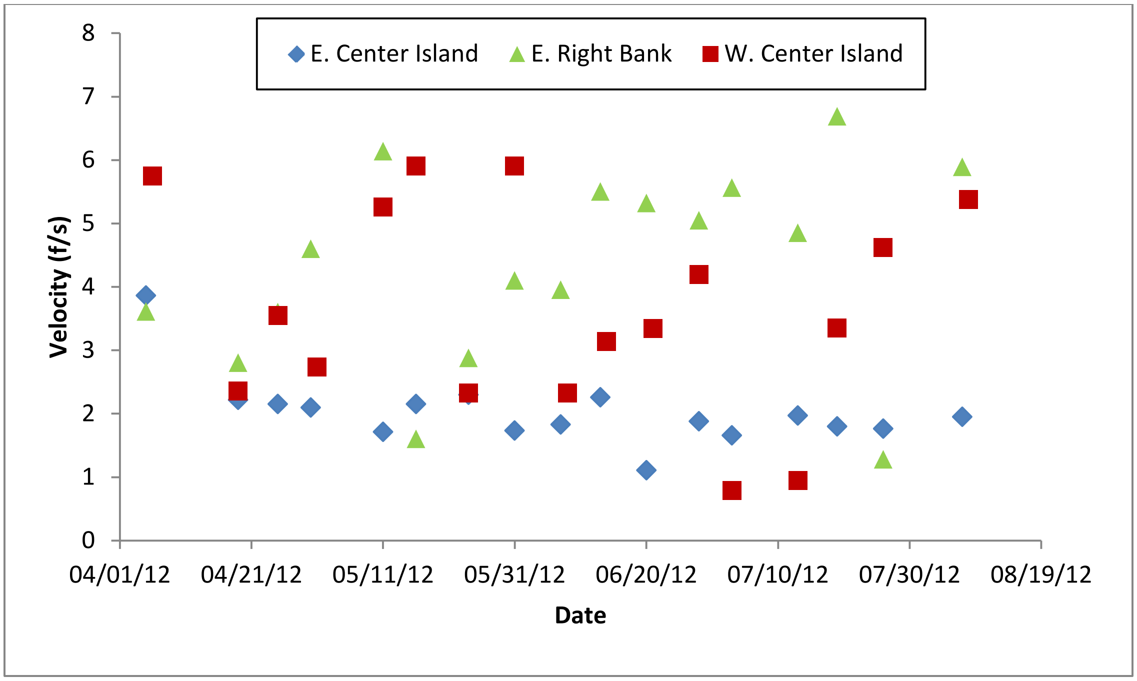

Figure 35. Entrance velocities at Wapato Dam fishways between April and August, 2012.

Temperature- River water temperatures were recorded at Wapato Dam between November 4, 2011 and September 1, 2012 (Figure 36). Temperatures were not available for the time period between June 8 and July 13, 2012. The average daily temperature varied from 0 to 18.1 °C. Lamprey passage occurred at temperatures between 13 and 15 °C with the exception of one passing at 10 °C. Two fish did pass during the time period when temperature data was not available. The temperatures during these passage events were determined using those from nearby Sunnyside Dam.

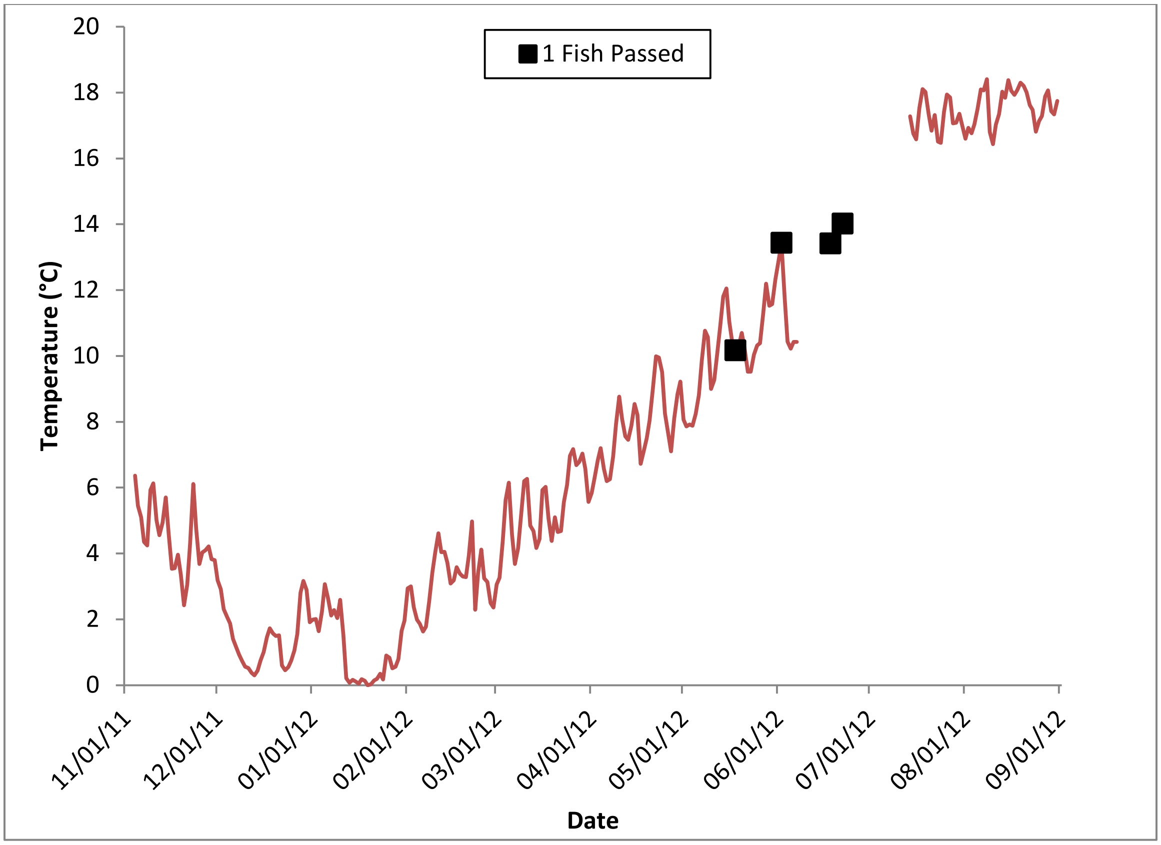

Figure 36. Average daily water temperatures of the Yakima River and dates of lamprey passage at Wapato Dam between November 4, 2011 and September 1, 2012. Data was not available for the time period between June 8 and July 13, 2012.

Above Dam Residence- The four lampreys that successfully passed Wapato Dam had above dam residence times between 32 minutes and 17 hours. There did not appear to be any correlation between fishway passage time and the length of above dam residence.

Diurnal Period of Movement

Upstream movements of Pacific lampreys past fixed stations occurred almost exclusively at night (Figure 37). First approaches to the dams and movements into the fishways both occurred at night with a frequency of greater than 75%. Lampreys initiating successful passage of a dam did so nearly all during night hours; only two entering a fishway during daylight hours. Both of these movements occurred within the last two hours of daylight. Movement downstream from the dams occurred evenly between day and night hours.

Figure 37. Diurnal periods that adult radio-tagged Pacific lampreys were active during downstream movement, upstream movement, and entry into fishways during the time period of October 2011 to August 2012.

Migration Rates between Stations

Fall Releases- Fall released Pacific lampreys had an average migration rate of 11.1 km/d (range 4 to 23 km/d) to move the 46.7 kilometers from Wanawish Dam to Prosser Dam. Migration rates for fall released lampreys between Prosser Dam and Sunnyside Dam- a distance of 92 km- averaged 7.7 km/day ranging from 1.8 to 12.7 km/day. The average migration rate for fall released lampreys between Sunnyside and Wapato dams (5 km) was 15.5 km/d, ranging from 4.2 to 30.9 km/d (Figure 38).

Spring Releases- Lampreys released in the spring migrated upstream from Wanawish Dam to Prosser Dam (46 km) at an average rate of 11.1 km/d (range 3.1 to 21.6 km/d). From Prosser Dam to Sunnyside Dam (91.4 km) lampreys averaged 7 km/d (range 4.9 to 9.9 km/d). The two spring released lampreys that migrated from Sunnyside Dam to Wapato Dam (5 km) averaged 5 km/d (range 4.1 to 30.9 km/d) (Figure 38).

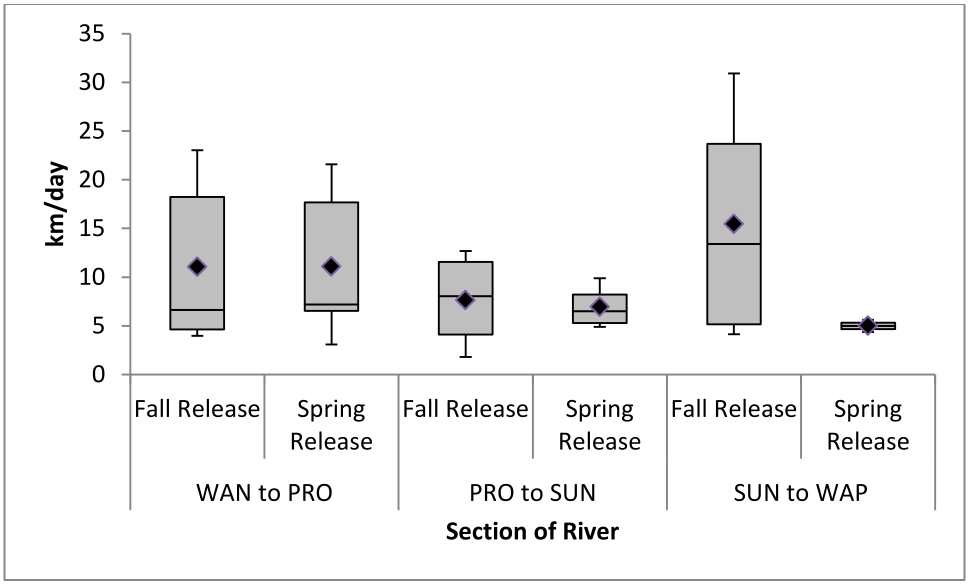

Figure 38. Kilometers traveled upstream per day by radio-tagged Pacific lampreys in the Yakima River, October 2011 to July 2012. Box plots show median and quartiles. The diamonds indicate the means.

Multiple Dam Passage

Lampreys having passed at least one dam had success rates of 39% at Prosser Dam, 50% at Sunnyside Dam, and 57% at Wapato Dam. When separated by release dates the fall group decreased in success from 50% at Prosser to 40% at Wapato while the spring group increased greatly from 30% to 100%. The numbers of lampreys passing these dams however was small. A total of five (7%) lampreys succeeded in passing two dams from all releases combined. Only two lampreys made it through three dams, one from each release group. Of the 30 lampreys released downstream of Wanawish, only two (7%) successfully passed all four diversion dams; one from each release group (Table 11).

Table 11. Release site, period, and number of radio-tagged Pacific lampreys that passed the lower four diversion dams on the Yakima River during fall 2011 and spring 2012.

		Number of Passage Events							
Release Site And Period	**n**	**WAN Fall**	**WAN Spring**	**PRO Fall**	**PRO Spring**	**SUN Fall**	**SUN Spring**	**WAP Fall**	**WAP Spring**
WAN Fall Up	5			1	2		1		
WAN Fall Dn	16	3	5	0	4		1		1
WAN Spr Up	4				1				
WAN Spr Dn	14		10		3		1		1
PRO Fall Up	4					1			
PRO Fall Dn	16			4	3		2		1
PRO Spr Up	4								
PRO Spr Dn	13				5		1		1
Totals	***76***	***3***	***15***	***5***	***18***	***1***	***6***	***0***	***4***

Dropouts between Dams

Not all lampreys that passed a dam continued their migrations upstream to the next dam. These “dropouts” consisted of both lampreys that passed a dam and never arrived at the next and also those that were unsuccessful at passing a dam and ultimately moved back downstream. Last known locations between dams were obtained for thirty of these individuals. Eight lampreys were present between the mouth of the Yakima River and Wanawish Dam (Figure 39). Eight lampreys were between Wanawish and Prosser dams (Figure 40), including six that approached Prosser Dam and then moved downstream and two that moved upstream from Wanawish but never reached Prosser Dam. In the reach between Prosser Dam and Sunnyside Dam a total of fourteen last known locations were recorded (Figure 41). Six were lampreys that had moved downstream from Sunnyside Dam. Eight ceased their upstream migrations and never reached Sunnyside Dam. No lampreys were in between Sunnyside and Wapato dams at the end of the study period. In addition to these known locations, another twenty-six lampreys dropped out in the reaches between the lower four dams (Table 12). Lampreys released in the spring upstream of Prosser Dam had the highest rate of dropouts with 100%. Percentages for all other releases were between 69% and 80%.

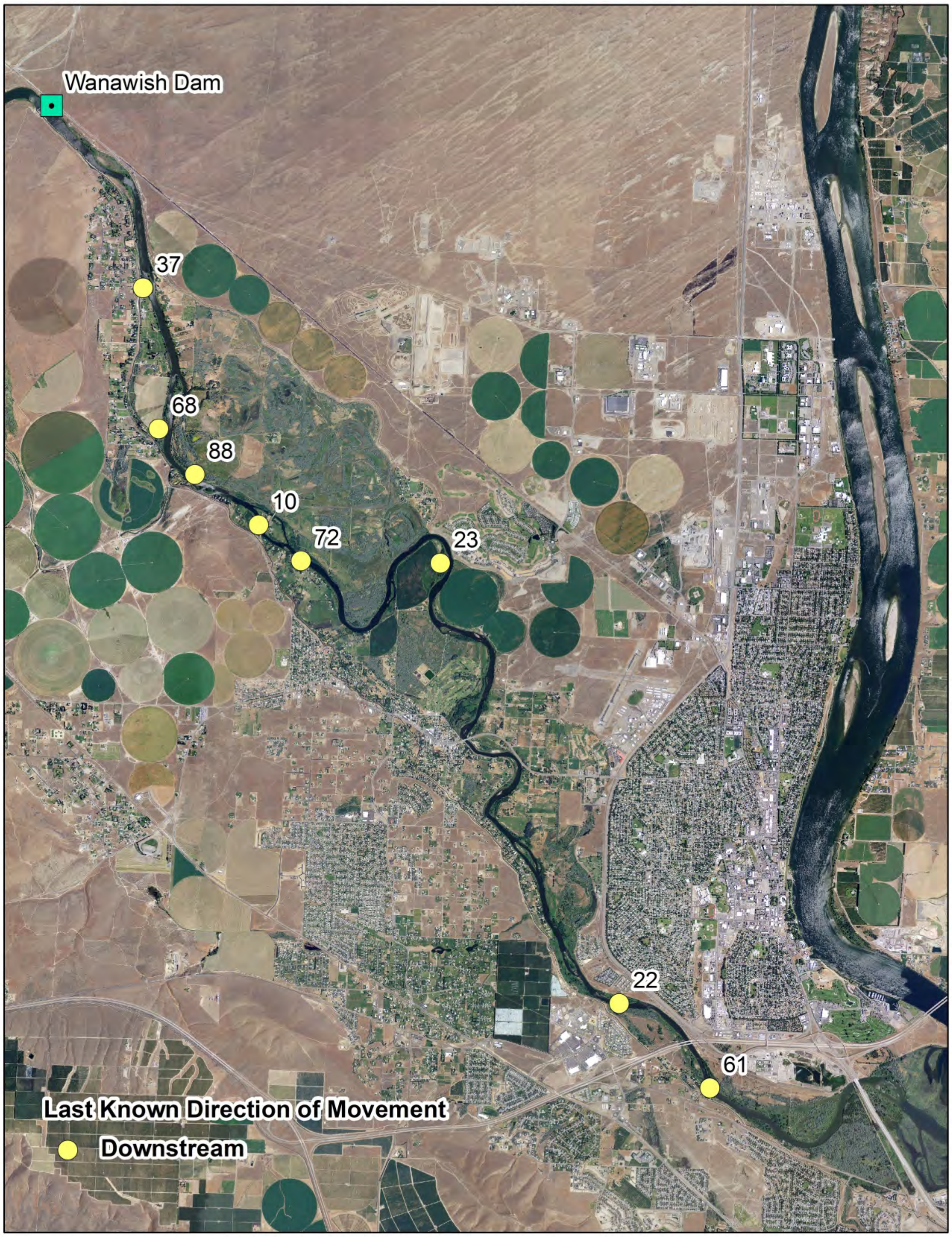

Figure 39. The last known locations of radio-tagged Pacific lampreys downstream of Wanawish Dam on the Yakima River, 2011-2012. The number represents the code of each radio tag.

Figure 40. The last known locations of radio-tagged Pacific lampreys between Wanawish Dam and Prosser Dam on the Yakima River, 2011-2012. The number represents the code of each radio tag.

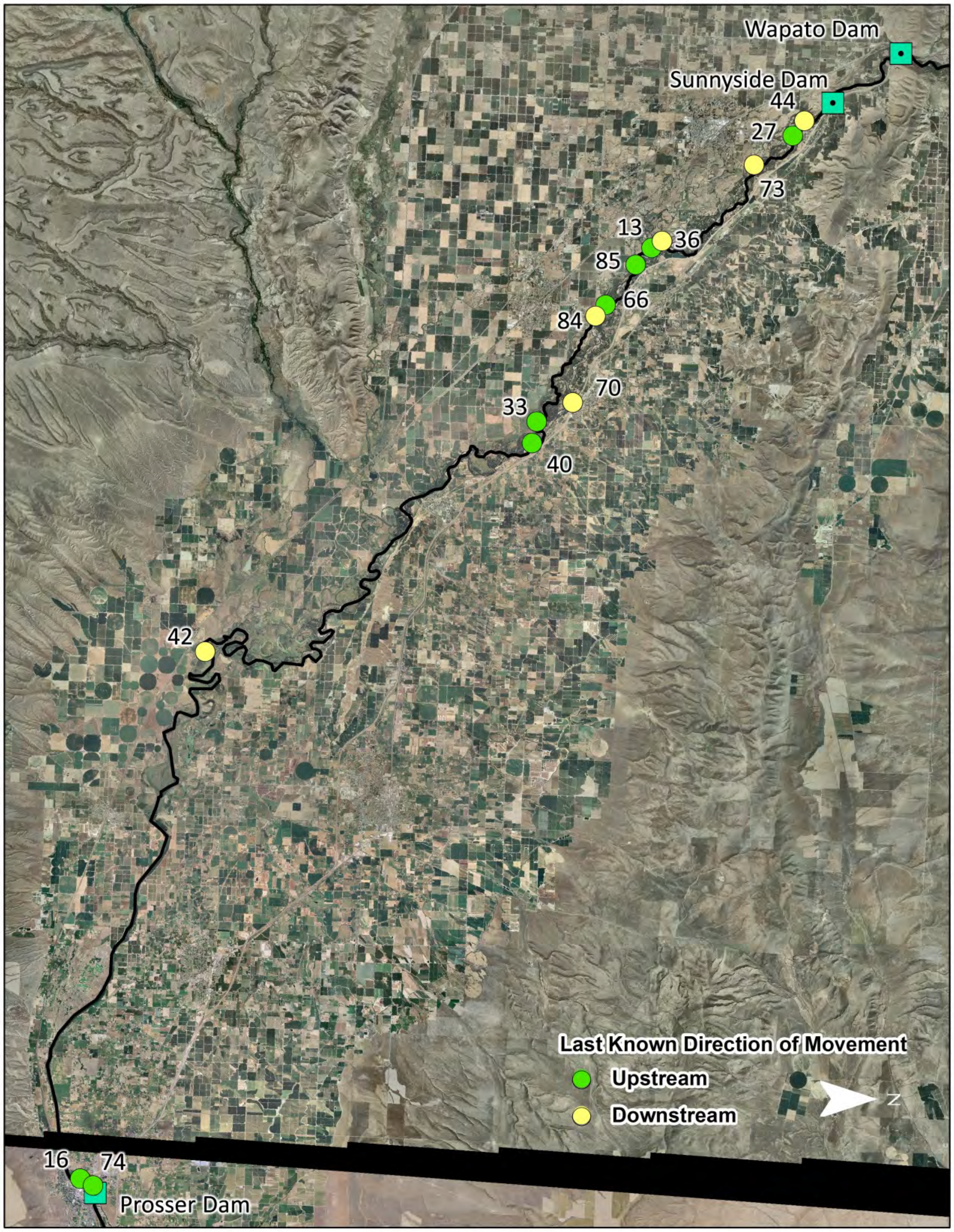

Figure 41. The last known locations of radio-tagged Pacific lampreys between Prosser Dam and Sunnyside Dam on the Yakima River, 2011-2012. The number represents the code of each radio tag.

Table 12. The number of radio-tagged Pacific lampreys that remained in between the lower dams on the Yakima River, 2011-2012.

Release Site/Period	D/S WAN n Dropouts/ n in Reach	WAN to PRO n Dropouts/ n in Reach	PRO to SUN n Dropouts/ n in Reach	Total (%)
WAN Fall Up		2/5 (40%)	2/3 (67%)	4/5 (80%)
WAN Fall dn	7/16 (44%)	3/8 (38%)	2/4 (50%)	12/16 (80%)
WAN Spr up		2/4 (50%)	1/1 (100%)	3/4 (75%)
WAN Spr dn	3/14 (21%)	6/10 (60%)	2/3 (67%)	11/14 (79%)
PRO Fall up			3/4 (75%)	3/4 (75%)
PRO Fall dn		6/16(38%)	4/7 (57%)	10/16 (63%)
PRO Spr up			4/4 (100%)	4/4 (100%)
PRO Spr dn		5/13 (38%)	4/5 (80%)	9/13 (69%)

Gate Stations

No Pacific lampreys were detected entering Satus or Toppenish creeks. Lampreys were not detected on the gate stations at the Roza Canal Wasteway outfall, Cowiche Dam on the Naches River, or at Roza Dam. No lamprey were detected on the station near the mouth, however, one lamprey was detected via truck tracking upstream of the station just out of its range.

Discussion

A total of 76 Pacific lampreys were radio-tagged, released, and tracked in the Yakima River during the 2011 migration season. Nearly all the tagged lampreys actively moved upstream and attempted to pass the diversion dams. Overall, about 50% of each release group failed to pass a dam and 25 to 40% of the lamprey that successfully passed each dam subsequently dropped out from the migration before reaching the next dam. Thus, during the 2011 migration season, only about 5% of the tagged lampreys were able to pass above Wapato Dam, the fourth diversion they encounter on the lower Yakima River.

Less than 50% of radio-tagged Pacific lampreys successfully pass each hydroelectric dam on the lower Columbia River (Moser et al. 2005; Keefer et al. 2009) and at Willamette Falls Dam on the Willamette River (Clemens et al. 2011). During our study to date, success rates for each of the lower Yakima River dams varied between 39% and 62%. Thus, although main stem Columbia River dams and the Willamette Falls Dam are much larger and more complex, our results indicate that small diversion dams on the lower Yakima River are similarly impeding and obstructing the migration of Pacific lampreys.

Dams with low passage rates and localized lamprey holding areas are prime candidates for lamprey passage structures (LPS) (Moser et al. 2006). Installed at Bonneville Dam on the lower Columbia River, LPS provide a series of ramps and pools which a lamprey can utilize to bypass the fishways and pass the dam (Moser et al. 2011, Reinhardt et al. 2008). At Prosser Dam tagged lampreys had a strong preference for residing in the pool at the corner along the left bank, which is essentially a dead end with no direct access to a fishway. Lampreys were detected residing in this pool during daylight hours and attempting to find passage across the width of the dam during night hours. Night observations showed tagged lampreys in this corner attempted to pass the dam via the exposed bedrock at the face of the dam. Velocities over the face appear to have been too swift as lampreys were unable to make the transition from bedrock to face without being swept downstream. Even if velocities were low, the overhanging lip at the crest of the dam is probably an insurmountable obstacle. Thus, this area appears to be an ideal place to install a LPS at Prosser Dam (see Appendix A for our conceptual design).

Wanawish Dam had the highest rate of passage (62%) but the average delay at the dam during the spring was 32.4 days. If there were no dams on the Yakima River, and lamprey were able to freely and naturally migrate at the overall mean speed of 7.7 km/d exhibited by our tagged lampreys between dams, after 32.4 days they would be 250 km upriver and into presumably suitable spawning areas above Roza Dam in the upper Yakima or Cowiche Dam in the Naches. Thus it is imperative that measures are developed to simultaneously reduce delays and increase passage rates at all of the dams. Any potential measures need to incorporate lamprey behavior and physiology while also considering the requirements for salmonid passage and the human factors of operation and maintenance.

At Wanawish Dam, for example, very few lampreys actually used one of the fishways. Instead, use of a concrete ledge along the right side of the dam appeared to account for the majority of passage events. This ledge extends approximately 6.5 m downstream from the face of the dam and is covered in water when flows are approximately 6,000 ft^3/s or higher. It is likely that the lampreys climbed over this ledge like a waterfall, although no passage events were witnessed. Only three lampreys passed Wanawish Dam at flows less than 6,000 ft^3/s. None of these were detected as moving through a fishway and it is possible that at lower flows lampreys are capable of climbing over the face of the dam. The left bank fishway was also closed for much of the spring season as attraction water was not flowing due to a broken gate. Miscommunications between maintenance staffs caused disruption in the routine cleaning of the trash rack at the exit of the fishway. These factors significantly reduced the amount of flow exiting the fishway. This may have inhibited the lampreys from finding the entrance and using the fishway despite the fact that more than half the lampreys first approached the dam on river left. Operating procedures however are to close both entrance gates when discharge is expected to exceed 4,000 ft^3/s for a week or longer (NMFS 1987). Discharge at Wanawish Dam exceeded this from February 23 to July 6, thereby encompassing the entire spring migration. Had the fishway been operated as normal it would still have been inaccessible to lampreys. Opening the left fishway during higher flows may increase lamprey passage so long as velocities do not significantly increase. One modification that may reduce delay and increase passage is adding rounded steps to the ledge which would allow for shorter climbing distances over a wider range of flows. Note that any modifications done to the ledge should be minor and not interfere with a lamprey's ability to use it. Any large scale modifications such as a metal ramp LPS should be done on the left bank, which receives the greatest number of first approaches.

Yakima River diversion dam fishways are much smaller and simpler than those of the main stem Columbia River. Tagged lamprey spent on average of 4.2 hours in the ladders at Yakima River dams compared to McNary Dam where tagged lampreys took an average of 67.2 hours to pass through a fishway (Boggs et al. 2008). Residence time downstream of the Yakima dams, however, was longer than for Columbia River dams (Boggs et al. 2008; Keefer et al. 2009). This suggests that finding or entering a fishway at the Yakima diversions may be more of an obstacle than the fishway itself. The fishways were designed for salmonids that swim higher in the water column. Pacific lampreys tend to be bottom oriented and the elevation of the fishway entrance may affect their ability to find and enter the ladder. This warrants additional attention and if it is an issue, we suggest the construction of "mounds" connecting the river bottom to the elevated fishway entrance to guide the lamprey to the opening (see Appendix A).

Water velocity is known to affect lamprey entry and passage in the ladders. Given the variation in the recorded velocities, particularly at Prosser Dam, we cannot be certain what the exact entrance velocities were when a lamprey entered, but most probably passed in the range of 2 to 7 ft/s. Johnson et al. (2009) found that reducing entrance velocities below 4 ft/s increased the number of Pacific lamprey entering a fishway. Moser et al. (2002) however, saw no increase in entry when velocities were reduced from 8 ft/s to 4 ft/s. Provided that adequate surfaces are available to attach for resting, it is possible for Pacific lampreys to pass through velocity barriers up to a maximum of 9 ft/s using burst swimming, though few are able to so (Moser et al. 2002; Keefer et al. 2010). Velocities at Prosser Dam's right bank lower entrance exceeded this maximum on several occasions and use of this entry did not occur until velocities dropped below approximately 3 ft/s. A reduction in velocities may encourage more entries by lampreys, particularly in the spring months when most passage occurs. Techniques to reduce velocities and still provide passage for salmonids should be investigated. If reduction of velocities is not possible, other techniques such as rounding the corners of the cement walls at the entrances and in the vertical slots have proven effective in increasing passage (Moser et al. 2002).

A wide range of velocities were recorded at the fishway entrances. Some entrances such as the center island in the east channel at Wapato Dam and the center island at Sunnyside Dam had nearly constant velocities throughout the study period. Others such as those at Prosser Dam were very inconsistent and often had negative values. High discharge and water levels made it difficult to standardize the measurement methods as the entrances were not visible. This often prevented accurate determination of where in the water column the probe was in relation to the entrance as well as keeping the probe in a constant location within the flow exiting the fishway. Large eddies formed near the entrances at high discharge and appeared to interfere with the velocity readings. Very low discharge also interfered as the water level was too low to reach and adequately submerge the probe. Daily operation of the fishways directly influenced the flow and velocity at the entrances. Fishways were closed during high discharge events to protect equipment. Attraction water was also closed at Wapato Dam's east channel center island and Wanawish Dam's left bank. The cleaning schedules of the fishway trash racks also impact the velocities. Velocity measurements were taken during weekly downloading of the telemetry stations, therefore the recorded entrance velocity was often two or three days prior to or after a passage event. Installing a more sophisticated velocity meter with a standard depth and recording schedule at the entrances is needed to precisely determine the velocity when a lamprey enters the fishway. This system would provide feedback and assist in the development of modifications of the operations to reduce velocity to increase passage of lamprey.

Fish counts at Prosser Dam are done with video recording equipment in each fishway. These data indicate that Pacific lampreys pass upstream primarily during the spring period of the migration, mostly in April and May but a few pass earlier in the migration during the previous late summer and fall period. Our results are consistent with these observations, with over half of the passage events occurring in April and May and a smaller number passing the previous October. Fifty-five percent of our tagged lampreys successfully passed through a fishway when the video cameras were operational but were not recorded. This indicates that a significant portion of lampreys are passing in the fishways at the dam without being counted. Alterations of the video procedure or the counting area may be needed if more accurate counts of Pacific lampreys are desired. Picketed leads are used to direct salmon past the counting window to increase detection and species identification. It is likely that adult Pacific lamprey pass through the 22 mm space between the bars in the leads so reducing that gap may force the lamprey to pass in front of the counting wall and increase the video detections. However, care should be taken that any changes do not make it more difficult for them to pass this area. For example, lampreys move in the ladders at night and may be passing through the leads behind the counting wall to avoid the bright electric lights used to illuminate the counting area. Decreasing the space between the bars may inadvertently delay or prevent many from passing the counting area.

Pacific lamprey telemetry studies on Columbia River tributaries (Baker et al. 2012, Courter et al. 2012) have shown that movement around dams also occurs almost exclusively at night. Pacific lampreys in the Columbia River are more likely to move during the day in areas of low gradient or low risk (reservoirs) than in high gradient or high risk areas such as fishway entrances (Keefer et al. 2012). Our results are consistent with these in that almost all entrances into a fishway occurred at night and half of the downstream movements during daylight hours. A similar proportion of daylight downstream movements occurred during the pilot year of this study (Johnsen et al. 2011).

Spawning areas of Pacific lamprey in the Yakima River basin have not yet been definitively identified. Only one lamprey was detected above Wapato Dam during mobile tracking. It was found under a logjam in a reach with potential spawning substrate but no indications of spawning were observed in the immediate area. Lampreys were also detected during aerial, truck, and boat tracking throughout the reaches between the lower four dams. Most of these reaches do not appear to hold much suitable spawning habitat, but we were unable to make in-river observations of these individuals and do not know if they were attempting to spawn. No entries into Satus, Toppenish, or Ahtanum creeks were detected despite the presence of larval Pacific lamprey and western brook lamprey *Lampetra richardsoni* (Reid 2012; Patrick Luke, Yakama Nation, pers. comm.) and the availability of likely spawning areas. The next phase of our study will include releasing lampreys at Sunnyside and Wapato dams, resulting in a greater number of individuals gaining access to potential spawning areas farther up in the basin. We will continue to monitor lamprey movements within these reaches and attempt to document reproductive behavior.

Insights from the pilot study (Johnsen et al. 2011) were incorporated into our study design. Solar power backup was added to all stations at the dams and kept the telemetry receivers operating when AC power at the dams was turned off during high flow events. Based on data from the pilot study, hanging antennas were added this year and resulted in additional information on finer scale movements and holding areas at the dams. Cowiche Dam and Roza Dam were not originally part of this year's study plan; however manpower and resources were available to equip them with telemetry stations, which reduced the amount of effort required to monitor migrations upstream of Wapato Dam. Future phases of our study will include additional antennas at these dams to better understand their impacts on Pacific lamprey passage.

Aerial tracking of our tagged lamprey was conducted on one occasion by Yakama Nation Fisheries personnel during their steelhead telemetry study. The flight detected lampreys between the dams, including many that never arrived at the next dam, and provided information we likely would not have otherwise collected. Aerial tracking will be used if possible for next year's study.

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USBOR biologist Arden Thomas acted as liaison and provided logistical and technical support.

The Yakama Nation Fisheries Program provided assistance, lampreys, radio tags, and equipment: Patrick Luke and staff collected and cared for the adult Pacific lamprey; Joe Blodgett and his staff at the Prosser Fish Hatchery housed the lamprey and provided assistance and space for the implantation surgeries; Chris Frederiksen shared gate telemetry stations and seasonally scanned for lamprey during his steelhead study and conducted the aerial survey; Keely Murdoch and the Mid-Columbia Field Station loaned telemetry receivers and equipment.

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Appendix A: Conceptual designs for improving Pacific lamprey passage at Prosser Dam

To date, our telemetry study has identified several methods that may improve passage efficiency for adult Pacific lamprey at Prosser Dam. Four concepts are developed and discussed in this appendix.

Lamprey Passage Structure

A lamprey passage structure (LPS) pumps water through a series of metal ramps and holding tanks to allow lampreys to pass over dams (Moser et al. 2006). These systems are used effectively at other dams including Bonneville Dam on the Columbia River (Moser et al. 2011) and Three Mile Falls Dam on the Umatilla River (Jackson and Moser 2012).

Justification

Telemetry data show that lampreys gather and hold in the pool area at the left bank of the dam. Adults have been observed attempting to move upstream by climbing the bedrock there (Figure A-1).

Figure A-1. Pacific lamprey (circled in red) climbing bedrock on left bank at base of Prosser Dam.

Placement and Construction

The area on the river-left side of the dam would be the best place to build a LPS for adult lamprey passage. The ramp would start at the bedrock on the downstream side of the dam between the canal and the river (A-2). The ramp would then angle up and over the dam in the space between the gatehouse wall at the head of the canal and a wall at the end of the dam (Figure A-3).

Figure A-2. Proposed site of LPS on the left bank of Prosser Dam at low flow.

Figure A-3. Prosser dam and the head of the Chandler Canal. The ramp would be placed in the space (circled in red) between the gate house and the slanted wall at the left bank of the dam.

The entire system would consist of a covered ramp, a pump, and either a collection box at the top end of the ramp or an outlet into the river above the dam (Figure A-4). Water would be pumped from the river on the upstream side of the dam to the highest section of the ramp and then flow down the ramp, out the entrance, and over the bedrock. At base flows, this pumped water would be the only attraction water in the area.

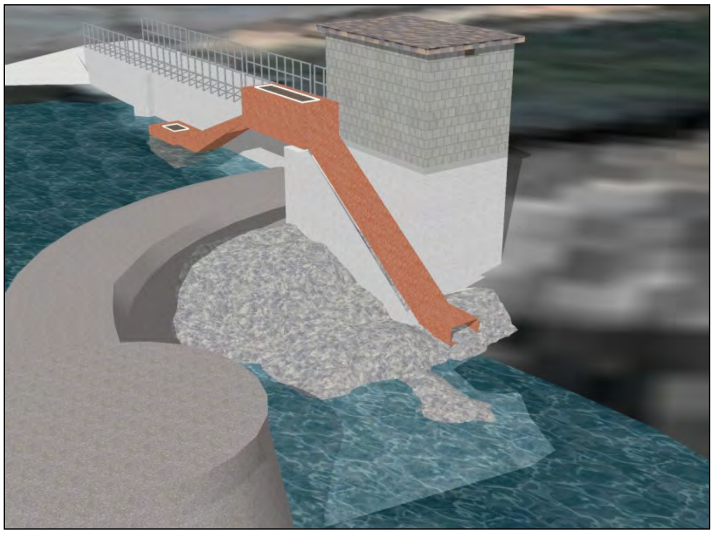

Figure A-4. Concept of proposed LPS on the left bank at Prosser Dam. The existing structures of the dam are shown in grey with the proposed lamprey ramp in red.

Advantages

The LPS at this site has several advantages. The system would be protected from floating logs and debris as the proposed site is sheltered between two concrete walls. AC power is available in the gate house at the location and water for the ramp would be pumped and regulated, allowing for constant velocities and operation regardless of river flow. The system could also be used as an adult trapping facility to aid in collection of lampreys for propagation or future studies. Finally, building the ramp here would not require any modifications to the dam structures or river channel.

Disadvantages

The ramp system relies on water being pumped from the river to the higher elevation of the ramp. Thus, the system requires electricity and potentially more maintenance than passive systems. The outfall ramp of the LPS needs to be carefully positioned in order to avoid entrainment of lampreys back over the dam or down the canal.

Underground Lamprey Passage Structure

Telemetry identified another possible location for a LPS on the right bank of the river. One radio tagged lamprey entered and traveled up the existing drain pipe into the fish trapping facility, suggesting that lampreys looking for passage would find a LPS ramp entrance in the area.

Placement and Construction

The ramp would begin on the downstream side of the dam near the drain outflow pipe and then proceed underground to exit upstream of the dam (Figure A-5). By placing the LPS in a concrete trough under ground-level, the structure would not interfere with access to the right bank facilities or with operations of the trap and the fish ladder.

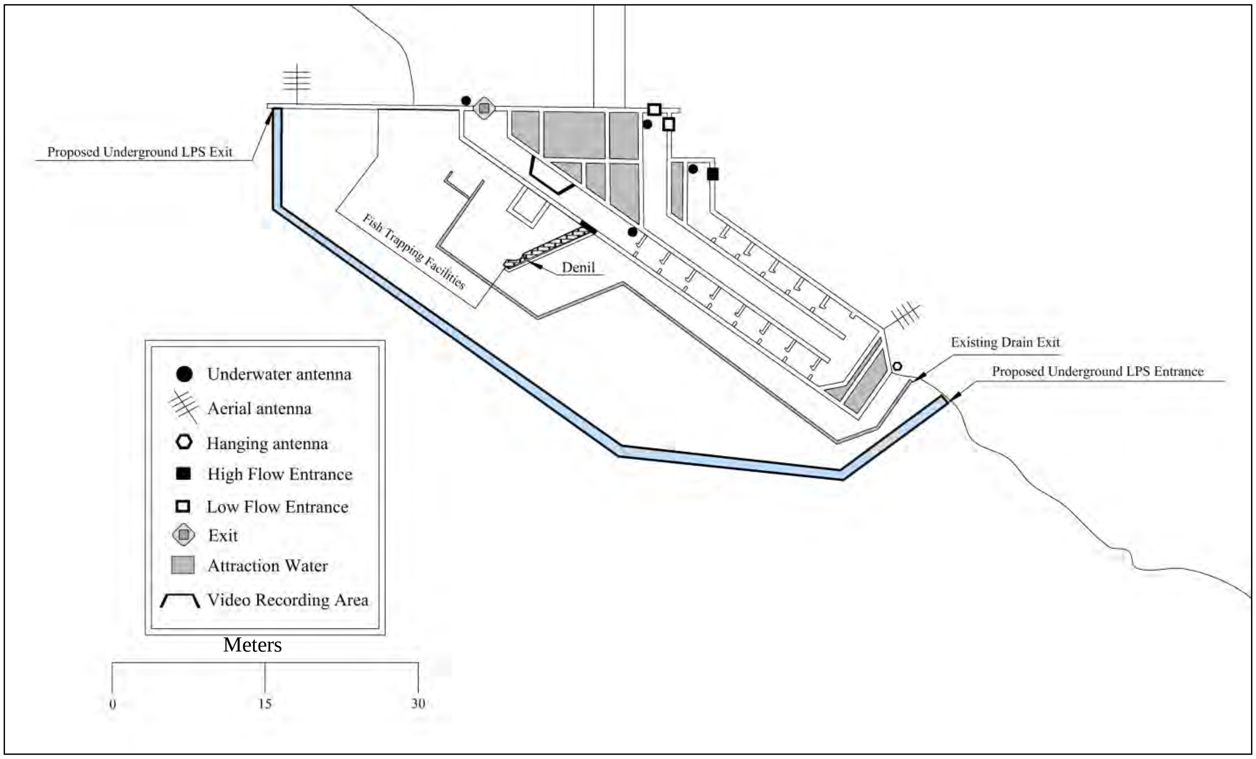

Figure A-5. Proposed site and concept for an underground LPS on the right bank of Prosser Dam.

Rock Ladder

A “natural” pile of rocks extending from the crest of the dam to the river bed on the downstream face of the dam could provide passage for up-migrating adult Pacific lamprey.

Justification

Provided suitable surfaces to hold onto, Pacific lampreys have the ability to climb over steep and turbulent sections of river. For example, Pacific lampreys are known to climb Willamette Falls (Clemens et al. 2011). We observed lampreys at Prosser Dam attempting to move upstream by climbing natural bedrock but the rock does not extend up to the dam crest (Figure A-6).

Figure A-6. Pacific lamprey climbing bedrock at the base of Prosser Dam.

Placement and construction

The bedrock on the left bank of Prosser Dam is the best location for the rock ladder (A-7). Lampreys have been observed climbing bedrock in the area and telemetry data show that lampreys congregate there. Additionally, a log boom just upstream of the dam in the area reduces debris going over the dam face at that location.
The construction of a rock ladder would require placing large rocks and boulders at the base of the dam and building them up to the crest. This construction would use the bedrock as a base with the added rocks cemented or otherwise secured to ensure that they stay in place during high flow events. The rock ladder needs to be designed so that there are areas of varying velocities and that water is flowing over the rocks at a wide range of discharges. This would provide a variety of paths for the lampreys to take over the dam as conditions change.

Figure A-7. Proposed site at Prosser Dam of rock ladder showing bedrock at low flow. The head of the Chandler Canal is just right of the edge of the frame.

Advantages

The rock ladder holds several advantages over other potential systems. First, the rock ladder is passive and does not require water to be pumped, eliminating the need for personnel to monitor and maintain a pump. Second, the base of the ladder could be quite large to make it easier for lampreys to find a place to start climbing. This may increase passage compared to a single ramp with a small entrance. Finally, as lampreys recover and are once again plentiful in the future, a rock ladder would better serve as a tribal fishery location where lampreys could be captured using traditional methods.

Disadvantages

A rock ladder may be prone to catching tree trunks, branches, or other debris and it may be necessary to clear the area at times. Construction would likely be a regulatory challenge requiring permits to do work in the river and on the dam. The proposed site of the rock ladder is dry at base flows, so the dam crest may need to be modified to keep water flowing over the rocks. Finally, lampreys using an open and uncovered system such as this may be more susceptible to predation or illegal harvest before a fishery is established.

Fish Ladder Modification: Entrance Mounds

Mounds could be built at the base of the entrances to the existing fish ladders (Figure A-8). These structures would slope down on all three sides from the lower edge of the entrance to the river bed.

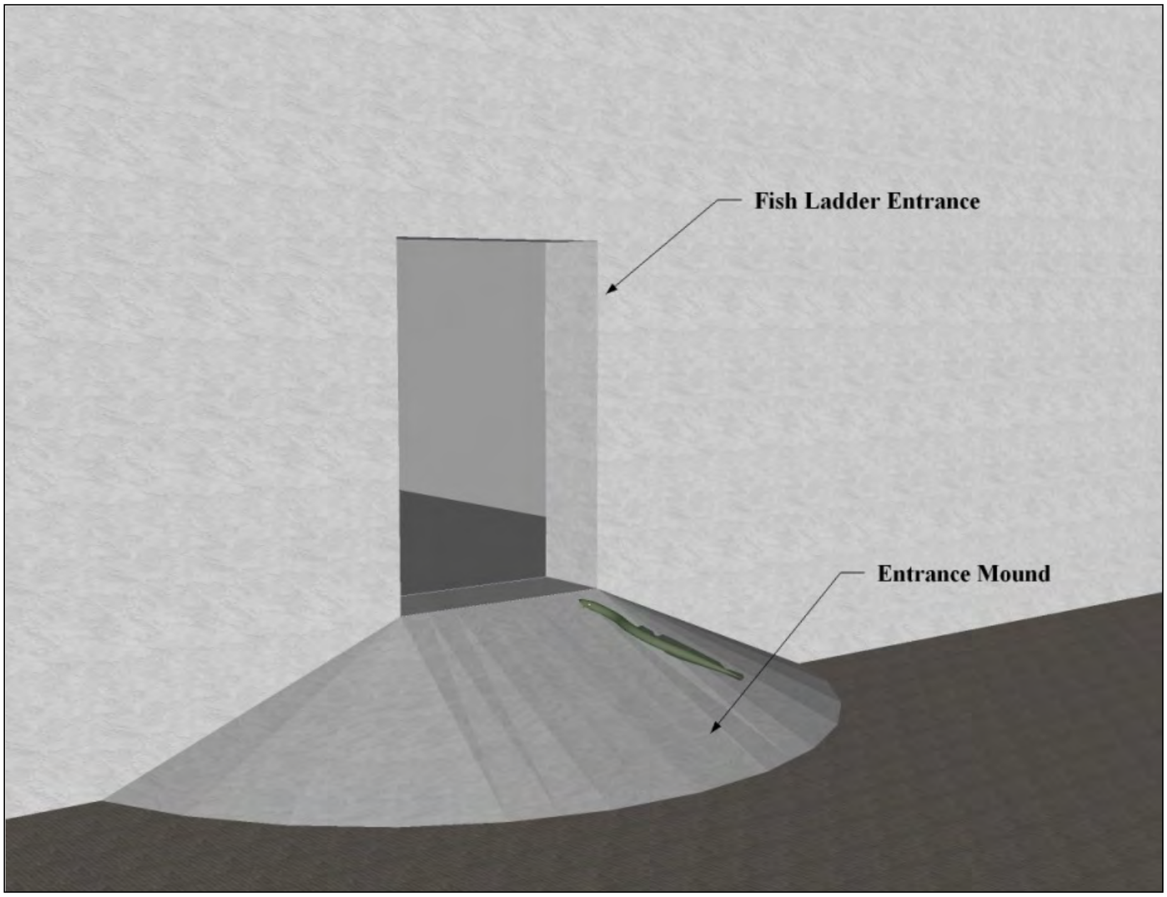

Figure A-8. Concept of proposed fish ladder entrance mound.

Justification

One factor contributing to the difficulty faced by lampreys in using the existing fishways may be an inability to find the ladder entrances. The ladders were designed for salmonids that swim in the water column, but Pacific lampreys move close to the river bed, often anchoring themselves to rocks. Thus, lampreys may not be swimming high enough in the water column to discover those ladder entrances that may be located above the river bed. Entrance mounds could guide lampreys to the entrances and provide an attachment surface to negotiate higher velocities (Figure A-8).

Placement and construction

Modifications would be made to the existing fish ladder entrances. Initially, a single ladder could be modified in order to test the effectiveness of mounds and then other ladders could be modified later if the changes increase passage. The river left ladder could be changed first as telemetry data suggest lampreys congregate in the area. Passage through the ladder is monitored by video, so effectiveness of modifications could be quantified.

The construction of concrete mounds would require coffer dams and diverting water from the base of the ladder. Concrete would be used to form mounds sloping to the river bed from the bottom of the ladder entrances. This new concrete would need to be secured in place, possibly using rebar or by excavating in front of the entrances so that it is sufficiently buried. Permits would be needed for working in the river and on the dam.

Advantages

Adding mounds to the fish ladder entrances would be a relatively simple modification to an existing fish passage system. Constructing the mounds may be cheaper than constructing an entirely new system for lamprey passage. The system is passive and it should not require any maintenance beyond what is currently required to keep fishways clear. Finally, the modifications could be undertaken as a trial, and if proven effective could be implemented at other dams that have similar fishway entrances.

Disadvantages

Constructing mounds at fish ladder entrances would require working in the river and modifying the dam structures. Permits and various agency approvals would be needed. Also, it is currently unknown by us how many entrances are elevated and whether it makes it more difficult for lampreys to find the ladder or if other factors are preventing them from entering (e.g. high water velocities or squared edges at fishway entrances).

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Appendix B: Water velocities at the entrances of fish ladders at Yakima River diversion dams during 2102.

The following tables contain the velocities of water flowing out of fish ladder entrances at Wanawish Dam (Table B-1), Prosser Dam (Table B-2), Sunnyside Dam (Table B-3), and Wapato Dam (Table B-4). Velocities at open gates were measured with a portable flow meter (Marsh McBirney Flo-Mate™ 2000). Gate labels for each entrance (NMFS and BOR 1992a-e) are shown in Figures B-1 through B-5.

Table B-1. Water velocities (ft/s) measured at fish ladder entrances on Wanawish Dam during 2012.

Date	Left Bank G1*	Right Bank G2
4/5/2012	5.77	3.34
4/18/2012	5.4	3.7
4/25/2012	6.75	2.8
4/30/2012	4.61	3.08
5/10/2012	5.41	2.89
5/16/2012	6.85	
5/23/2012	6.56	2.61
5/31/2012		0.6
6/7/2012	5.06	3.16
6/13/2012	0.76	2.4
6/20/2012	-0.325	-0.81
6/27/2012	5.66	1.96
7/2/2012	-1.42	-1.17
7/12/2012	4.22	-0.7
7/18/2012	3.18	4.92
7/25/2012	2.03	6.92
8/7/2012	3.7	5.84
9/12/2012	3.5	3.63

*The fishway entrances appeared to be closed during the study and the measured velocities represent the speed of the river current moving across the ladder opening.

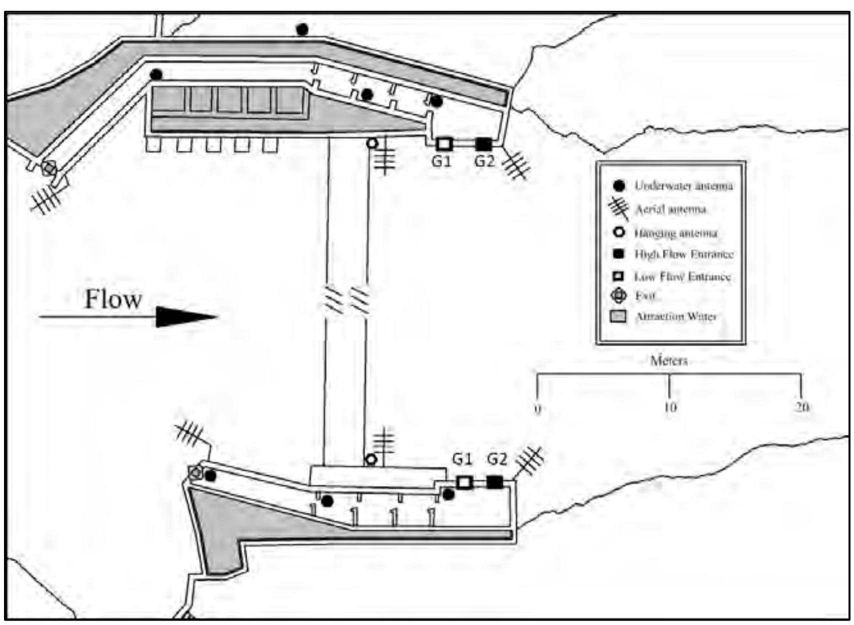

Figure B-1. Wanawish Dam fishway gate labels.

Table B-2. Water velocities (ft/s) measured at fish ladder entrances on Prosser Dam during 2012.

	Left Island				Center Island				Right Bank		
Date	**G1**	**G2**	**G3**	**G4**	**G1**	**G2**	**G3**	**G4**	**G1**	**G2**	**G3**
4/5/2012			4.7	4.7		6.4		3.9	3.6		9.6
4/19/2012			6.39	5.14		7.23		6.57	2.05		9.2
4/25/2012			-0.9	-0.9		7.65					2.6
4/30/2012			0.93	0.99		1.76		-0.33			1.45
5/10/2012			7.05	6.53		6.89		5.9	-0.48		6.94
5/16/2012						8.18		7.9			6.5
5/23/2012						4.68		6.23			6.87
5/31/2012			3.79	4.22		6.27		6.25			6.13
6/7/2012						4.58		3.64			2.99
6/13/2012			6.67	6.12		8.24		6.73			8.3
6/20/2012		-0.74	1.1	0.47		4.19		3.78			2.99
6/27/2012		-0.63	0.14	0.83		4.63		4.28			2.53
7/2/2012		4.83	9.86	7.62	2.34		4.91			5.31	7.48
7/12/2012		4.32	7.32	5.53			8.48			6.24	6.86
7/18/2012			6.36	6.82						4.56	3.77
7/25/2012					4.23		7.18		6.27	5.74	
8/7/2012	5.77				5.03		6.02			5.01	5.51
9/6/2012					6.32		6.52			6.51	4.88
9/12/2012					7.67		6.46		0.4		6.7

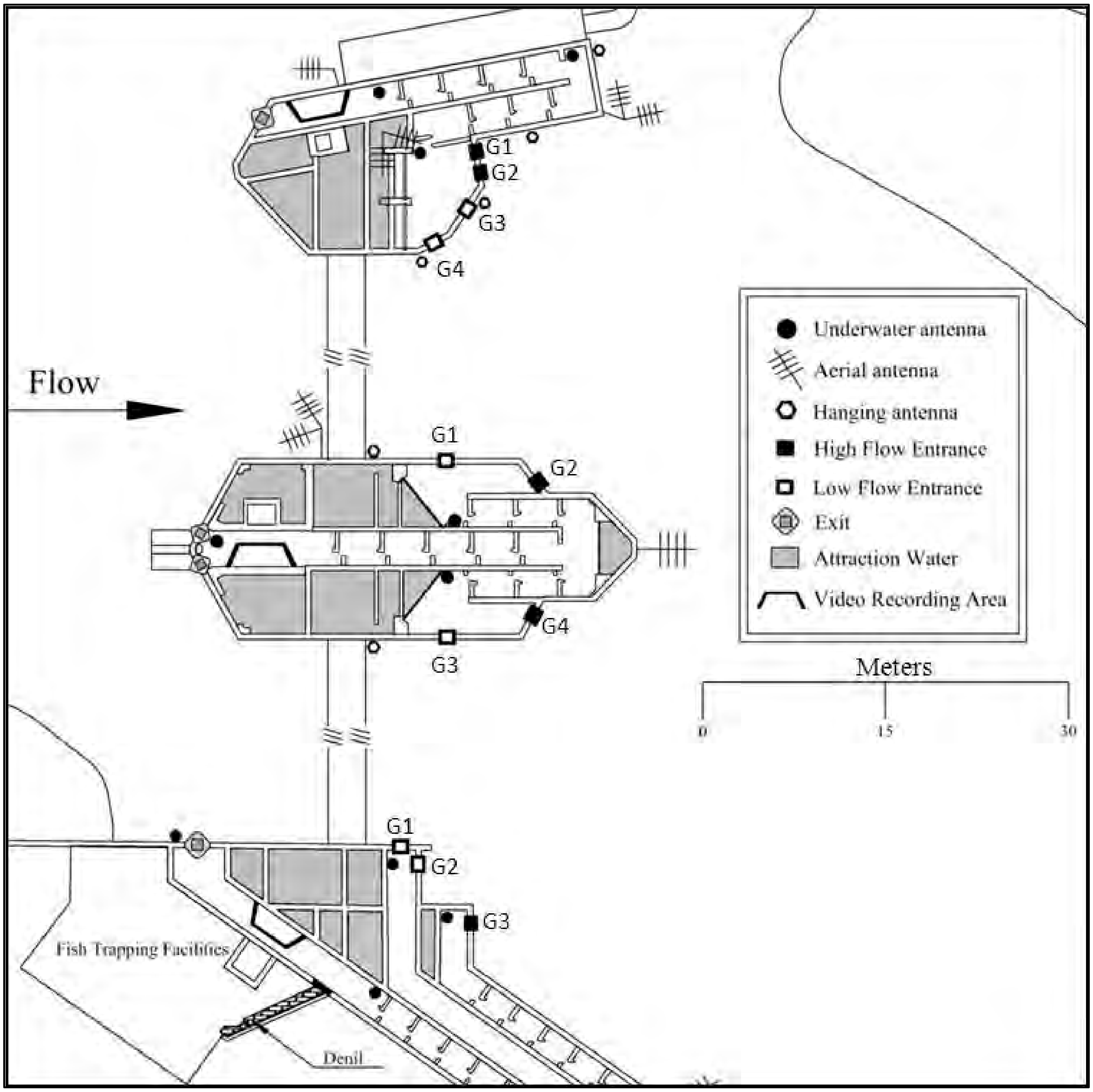

Figure B-2. Prosser Dam fishway entrance gate labels.

Table B-3. Water velocities (ft/s) measured at fish ladder entrances on Sunnyside Dam during 2012.

	Left Island		Center Island				Right Bank	
Date	**G17**	**G18**	**G11**	**G12**	**G13**	**G14**	**G3**	**G4**
4/5/2012								6.6
4/6/2012		6.33						
4/19/2012		8.6		7.81		8.23		6.71
4/25/2012								-0.1
4/30/2012		3.05		-0.52		-0.53		0.13
5/11/2012		8.26		7.22		9.67		4.89
5/16/2012		8.1		6		5.2		4.4
5/24/2012		8.82		6.17		6.41		5.3
5/31/2012		7.9		9.67		9.28		5
6/7/2012		3.18						1.13
6/13/2012		8.55		8.99		8.62		7.41
6/21/2012		6.46		6.71		6.44		4.58
6/28/2012		10.09		8.39		8.93		7.51
7/3/2012		8.63		5.2		6.54		4.68
7/13/2012		6.79	6.63		6.95		1.62	
7/19/2012		6.89	6.17		6.1		4.2	
7/26/2012		6.78	7.31		7.02		5.28	
8/7/2012		8.49	7.57		7.22		5.35	
9/5/2012	7.81		6.93		7.97		8.02	
9/13/2012	7.95		4.35		6.58		4.92	

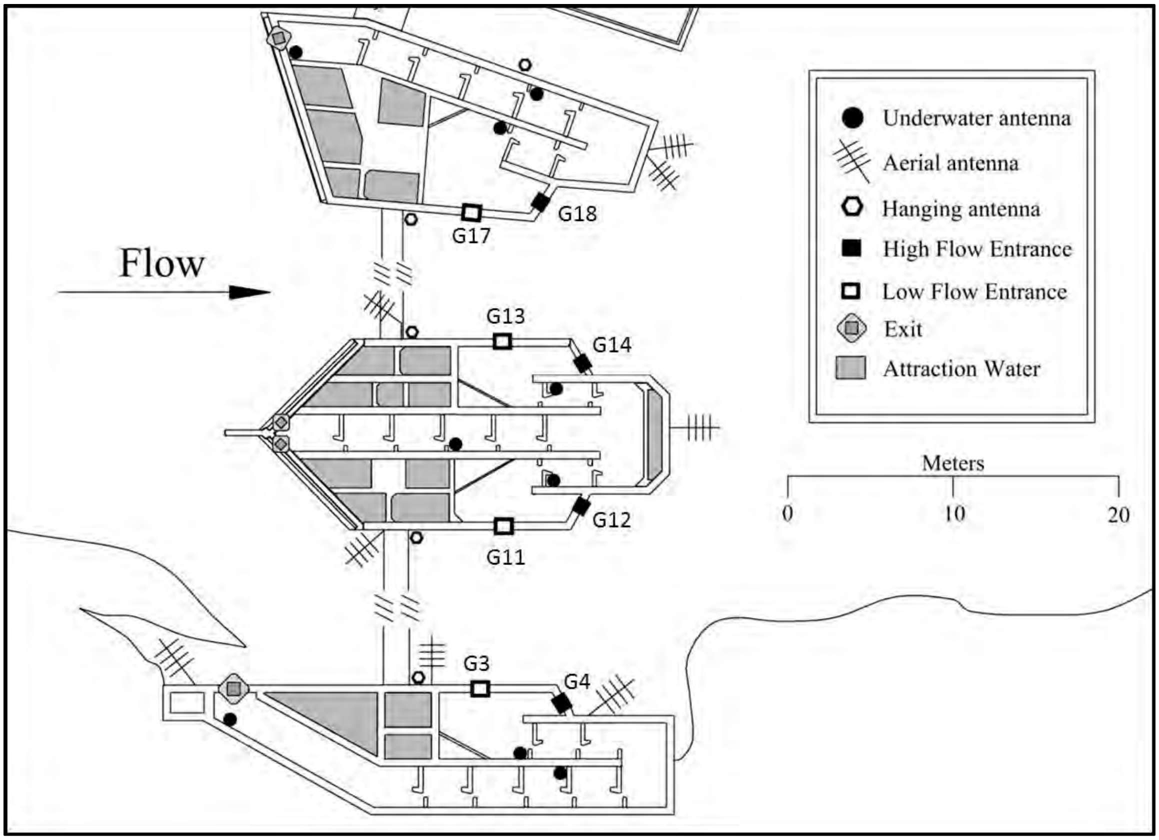

Figure B-3. Sunnyside Dam fishway entrance gate labels.

Table B-4. Water velocities (ft/s) measured at the entrances to fish ladders at Wapato Dam during 2012.

	East Branch Center Island		East Branch Right Bank	West Branch Center Island			
Date	**G8**	**G10**	**G4**	**G7**	**G8**	**G9**	**G10**
4/5/2012	4.21	4.21	4.1				
4/6/2012					7.4		4.8
4/19/2012	2.13	2.3	2.8		2.45		2.26
4/25/2012	2.2	2.1	3.6		3.9		3.2
4/30/2012	2.19	2	4.6				
5/1/2012					3.29		2.18
5/11/2012	1.83	1.59					
5/16/2012	2.3	2	1.6		6.2		5.6
5/24/2012	2.41	2.18	2.88		2.66		1.99
5/31/2012	1.81	1.65	4.1		6.76		5.04
6/7/2012	2.34	1.32	3.95				
6/8/2012					2.12		2.53
6/13/2012	2.36	2.15	5.5				
6/14/2012					2.91		3.37
6/20/2012	1.37	0.84	5.32				
6/21/2012					3.33		3.35
6/28/2012	1.96	1.8			4.76		3.62
7/3/2012	1.6	1.71	5.56	0.71		0.87	
7/13/2012	1.96	1.98	4.85		0.94		0.95
7/19/2012	1.9	1.7	6.69	3.28		3.41	
7/26/2012	1.54	1.98	1.28		4.69		4.55
8/7/2012	1.92	1.98	5.89				
8/8/2012					4.4		6.35
9/5/2012	1.98	2.03	5.7		5.71		5.39
9/13/2012	3.07	3.36	4.76		3.75		3.83

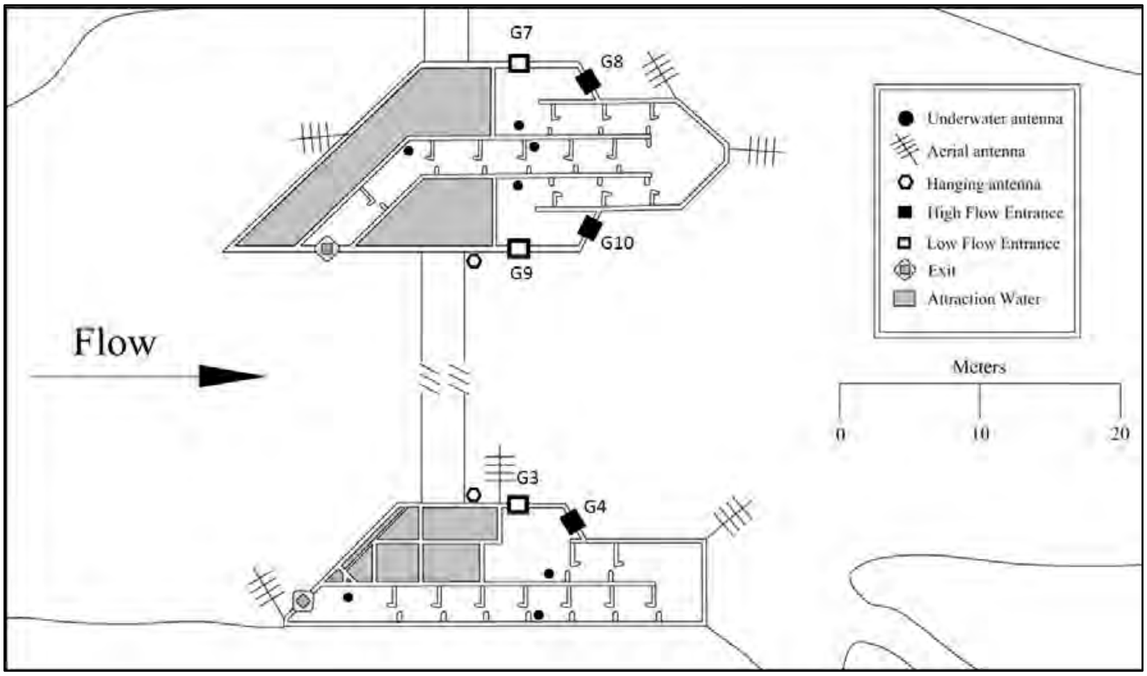

Figure B-4. Wapato Dam east branch fishway entrance gate labels.

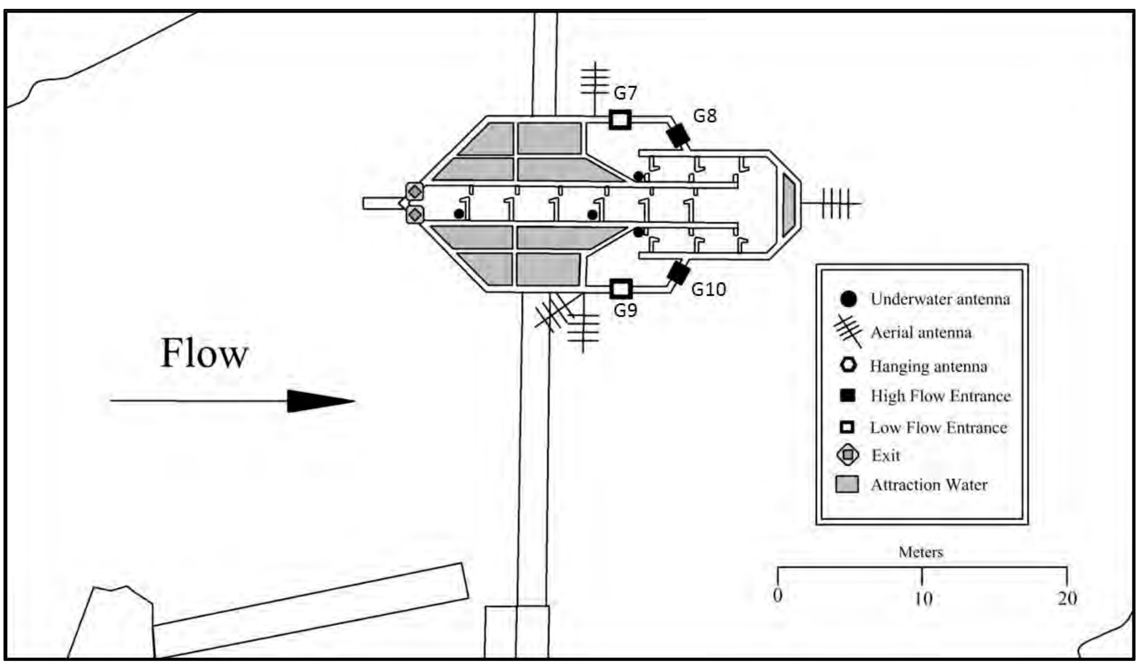

Figure B-5. Wapato Dam west branch fishway entrance gate labels.

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National Marine Fisheries Service and US Bureau of Reclamation. 1992e. Operating procedures, Wapato west branch ladder.

Attachment D

Assessment of Lamprey Presence in Irrigation Diversions and Canals in the Yakima Basin

Assessment of Lamprey Entrainment in Irrigation Diversions and Canals in the Yakima Basin

Taneum Diversion

Date: October 15th and 16th 2012
Location: The Taneum Creek Diversion is located outside of Thorp off of Thorp Cemetery Rd.
Screens: Drum
Temp: 13.5°C

Above Screen Survey Dates (Total Days): 10/15, 10/16 (2)
Lamprey Total Above Screens (Total Observed): 47 (53)

Size Class (mm)	0-40	41-70	71-95	96-110	111-135	>135
%	20	30	20	5	5	10

Total Survey Area (m²): 75
Mean Density (#/m²): .49

Below Screen Survey Dates (Total Days): 10/15, 10/16 (2)
Lamprey Total Below Screens (Total Observed): 10 (12)

Size Class (mm)	0-40	41-70	71-95	96-110	111-135	>135
%	35	40	20	4	1	0

Total Survey Area (m²): 52
Mean Density (#/m²): .15

Observations:

The first area that was surveyed on the Taneum Diversion of was above the screens while the water was still high on October 15th. Here the only section that was surveyed was along the bank where the Eschocker could reach both above and below the screens with a total area of 4m. There were 4 lampreys found on this day and they were released into the Yakima River.

The next survey session was on October 16th and it began above the screens after the canal was dewatered. The sediment in this area was fine and coarse sand mixed with lots of woody debris and detritus along the screens and the further upstream you traveled cobble and gravel became spaced around about 6m up. In this area we captured 44 lampreys, 17 of which were stranded on top of the dry sand after the dewatering. All were still alive and was a mixture of ammocoetes and macropthalmia. There were also crawfish, water skippers, worms, sculpin and trout observed. One 4in trout and one 7in trout were captured and released into Taneum Creek.

The next area surveyed was below the screens after surveying above the screens. The area we surveyed was piles of sediment spaced around on top of the cement bottom and 9 lampreys were captured. The sediment here was a combination of fine and coarse sand mixed with detritus. The lamprey captured on October 16th was released into the Yakima River off of Old Hwy 10 outside of Thorp.

Figure 1: Overview of Taneum Diversion

Figure 2: Close up of Taneum Screens

Yakima-Tieton Diversion

Date: October 17th 2012
Location: Yakima-Tieton Diversion is located off of Highway 12 outside of Naches on the Tieton River
Screens: Drum with a wall screen with automated cleaning brush
Temp: 11.4°C

Above Screen Survey Dates (Total Days): 10/17 (1)
Lamprey Total Above Screens (Total Observed): 0 (0)

Size Class (mm)	0-40	41-70	71-95	96-110	111-135	>135
%	N/A	N/A	N/A	N/A	N/A	N/A

Total Survey Area (m^2): 71
Mean Density (#/m^2): .00

Below Screen Survey Dates (Total Days): N/A
Lamprey Total Below Screens: N/A

Lamprey Total Above Screens: No Lamprey Found
Observations:

Only above the screens was sampled because there were no collections of sediments below the screens on the cement floor. The area that was sampled was along the bank in the more shallow water and was composed of thick clay, and fine and coarse sand with some large woody debris mixed in. The survey started at the screens and we worked our way upstream and more gravel and cobble became present to where there was no more sediment to sample. There were no lampreys found here as well as no other life seen.

Figure 3: Overview of Yakima-Tieton Diversion

Figure 4: Close up of Yakima-Tieton Screens

Westside Diversion

Date: October 17th 2012
Location: Westside Diversion is located off of N. Thorp Rd. on the Yakima River
Screens: Drum
Temp: 10.8°C

Above Screen Survey Dates (Total Days): 10/17 (1)
Lamprey Total Above Screens (Total Observed): 3 (3)

Size Class (mm)	0-40	41-70	71-95	96-110	111-135	>135
%	0	33	33	33	0	0

Total Survey Area (m²): 28
Mean Density (#/m²): .11

Below Screen Survey Dates (Total Days): 10/17 (1)
Lamprey Total Below Screens (Total Observed): 1 (4)

Size Class (mm)	0-40	41-70	71-95	96-110	111-135	>135
%	0	0	100	0	0	0

Total Survey Area (m²): 89
Mean Density (#/m²): .01

Observations:

At this diversion, the first survey was conducted above the screens in the shallow areas nearest to the diversion because the further upstream you traveled the deeper the water got and we were unable to sample with the backpack Eshocker. In this area the sediment was composed mostly of fine sand with mixed with coarse sand along the banks and also had many long aquatic grasses growing out of it decreasing visibility. We found three lampreys before moving to the next sampling section

The next area that was sampled was below the screens starting where the cement ended. There was very little sediment that collected on the cement while the entire channel bottom past that point for 20yds was composed of fine and coarse sand mixed with silt, clay, long aquatic grasses, small and medium woody debris and small amounts of detritus. In this area there was only one lamprey found while small sculpin, crawdads, and stickleback fish were observed. The lampreys that were caught were released in the Yakima River below the diversion.

Figure 5: Overview of Westside Diversion

Figure 6: Close up of Westside Screens

Cowichee Diversion

Date: October 17th 2012
Location: Cowichee Diversion is located west of Yakima off of Highway 12
Screens: Drum
Temp: 11.2°C

Above Screen Survey Dates (Total Days): N/A
Lamprey Total Above Screens (Total Observed): N/A

Below Screen Survey Dates (Total Days): 10/17 (1)
Lamprey Total Below Screens (Total Observed): 10 (15)

Size Class (mm)	0-40	41-70	71-95	96-110	111-135	>135
%	20	50	30	0	0	0

Total Survey Area (m²): 11
Mean Density (#/m²): .94

Observations:

The only area that was sampled on the Cowiche Diversion was directly below the screens due to the lack of water and available habitat. In this area there was a small pool touching the screens and then about 2m away was a small puddle. The sediment was composed of clay and silt mixed with small amounts of cobble and gravel. There were at one time long aquatic grasses that were no dried up along the bottom of the thick mud. There were 10 lamprey found here and were released into the Naches River at the 16th St. Ext. outside of Yakima.


Figure 7: Overview of Cowiche Diversion


Figure 8: Close up of Cowiche Screens

Union Gap Diversion

Date: October 18th 2012

Location: The Union Gap Diversion is located behind Bureau of Reclamation office on Terrace Heights outside of Yakima

Screens: Drum

Temp: 11.6°C

Above Screen Survey Dates (Total Days): 10/18 (1)

Lamprey Total Above Screens (Total Observed): 217 (267)

Size Class (mm)	0-40	41-70	71-95	96-110	111-135	>135
%	**35**	**30**	**20**	**5**	**5**	**5**

Total Survey Area (m²): 413

Mean Density (#/m²): .53

Below Screen Survey Dates (Total Days): N/A

Lamprey Total Below Screens (Total Observed): N/A

Observations:

The Area that was surveyed in this diversion was the channel above the screens. We started behind private property and walked .60miles down to the screens surveying the entire section. At the start area there was a deep pool with thick clay and silt mixture along the banks with cobble spaced around. This was where the only macropthamia were found through the survey while only a few ammocoetes were observed.

Walking further down the canal was more sediment made of thick clay and silt with long aquatic grasses that grew in and out of the water. Throughout the midsection of the canal there was no more cobble, and the grasses made visibility very poor to the point where we were unable to capture the entire lamprey that emerged from the sediment. This midsection was where most of the lamprey was found and a majority of them were below 40mm in length. Other fish that were observed included whitefish and other salmonids, sclupin, crawfish, and caddis flies. The area below the screens was composed of bare sediment so it was not surveyed due to lack of habitat. There were 217 lamprey captured and taken to Prosser for further study

Figure 9: Overview of Union Gap Diversion

Figure 10: Close up of Union Gap Screens

Kittitas-Easton

Date: October 23rd 2012
Location: Kittitas-Easton Diversion is located just outside the Easton along the Iron Horse Trail
Screens: Drum

Above Screen Survey Dates (Total Days): N/A
Lamprey Total Above Screens (Total Observed): N/A

Below Screen Survey Dates (Total Days): N/A
Lamprey Total Below Screens (Total Observed): N/A

Observations:

The diversion was accessible but there was no habitat to sample. The bottom of the cement floor was exposed with very little sediment spaced around in a thin layer. There was some large woody debris but no detritus below the screens. Above the screens there was gravel and cobble with a very small amount of coarse sand mixed in but no good depositional areas.

Figure 11: Overview of Kittitas-Easton Diversion

Figure 12: Close up of Kittitas-Easton Screens

New Cascade Diversion

Date: October 23rd 2012

Location: The New Cascade Diversion is located off of Old Hwy 10 outside of Ellensburg behind private property

Screens: Drum

Temp: 12.2°C

Above Screen Survey Dates (Total Days): 10/23 (1)

Lamprey Total Above Screens (Total Observed): 1 (3)

Size Class (mm)	0-40	41-70	71-95	96-110	111-135	>135
%	100	0	0	0	0	0

Total Survey Area (m^2): 29

Mean Density (#/m^2): .03

Below Screen Survey Dates (Total Days): 10/23 (1)

Lamprey Total Below Screens (Total Observed): 3 (4)

Size Class (mm)	0-40	41-70	71-95	96-110	111-135	>135
%	0	0	100	0	0	0

Total Survey Area (m^2): 39

Mean Density (#/m^2): .08

Observations:

The first area surveyed was below the screens where there was still water collected. In this area it was over the cement floor but there was some sediment that collected along the edge of the water. It was thick clay and silt mixture with long aquatic grasses growing out of it and only one lamprey was found here. There were many small trout and one salamander observed.

The next area that was surveyed was above the screens and the sediment here was composed of fine sand with a small amount of clay mixed in along with long aquatic grasses. The sediment here was raised above water level in the midsection of the cemented area before the screens and there were a variety of bird and small animal tracks in the mud. There were 3 lampreys found in this area and all lampreys were released at the Ringer Loop public fishing area outside of Ellensburg near the Yakima Canyon.

Figure 13: Overview of New Cascade Diversion

Figure 14: Close up of New Cascade Screens

Ellensburg Mill

Date: October 24th 2012

Location: The Ellensburg Mill diversion is located in Ellensburg and must travel though the granite company's property

Screens: Drum

Above Screen Survey Dates (Total Days): N/A
Lamprey Total Above Screens (Total Observed): N/A

Below Screen Survey Dates (Total Days): N/A
Lamprey Total Below Screens (Total Observed): N/A

Observations:

The gates were locked and there was no access to this diversion so no survey was conducted. While there we observed that the water was still high and long grasses were growing in and out of the water decreasing visibility.

Figure 15: Overview of Ellensburg Mill Diversion

Figure 16: Close up of Ellensburg Mill Screens

Lower WIP Diversion

Date: October 24th 2012

Location: Lower WIP Diversion is located off of 79th Ave. in Union Gap on Ahtanum Creek

Screens: Drum

Temp: 7.4°C

Above Screen Survey Dates (Total Days): 10/24 (1)

Lamprey Total Above Screens (Total Observed): 17 (21)

Size Class (mm)	0-40	41-70	71-95	96-110	111-135	>135
%	30	40	10	10	10	0

Total Survey Area (m²): 3

Mean Density (#/m²): 5.01

Below Screen Survey Dates (Total Days): N/A

Lamprey Total Below Screens (Total Observed): N/A

Observations:

The first area that was surveyed was above the screens. At this diversion there are two small drum screens so the sample area was only a 3mx2m section above them. The sediment was composed of thick silt and fine sand mixed with large, medium, and small woody debris and detritus. There were also long grasses and cattails growing out of the water that decreased visibility with their stalks. There were 17 ammocoetes found in this area and sculpin, crawfish, stickleback, and small trout were also observed. The lamprey was found in all areas above the screens but none were found below the screens. Below the screens the water was deeper and murky so visibility was very low. The sky had a cloudy overcast that created a glare on the water, the breeze created ripples, and there was no current to the mud took a while to settle and that all decreased visibility. All lampreys were taken to Prosser for further study.

Figure 17: Overview of Lower WIP Diversion

Figure 18: Close up of Lower WIP Screens

Upper WIP Diversion

Date: October 30th 2012

Location: The Upper WIP Diversion is located 1 mile up of the Museum off of Ahtanum Rd. oh Ahtanum Creek

Screens: Drum

Temp: 10.0°C

Above Screen Survey Dates (Total Days): 10/30 (1)

Lamprey Total Above Screens (Total Observed): 0 (0)

Size Class (mm)	0-40	41-70	71-95	96-110	111-135	>135
%	N/A	N/A	N/A	N/A	N/A	N/A

Total Survey Area (m²): N/A

Mean Density (#/m²): N/A

Below Screen Survey Dates (Total Days): 10/30 (1)

Lamprey Total Below Screens (Total Observed): 0 (0)

Size Class (mm)	0-40	41-70	71-95	96-110	111-135	>135
%	N/A	N/A	N/A	N/A	N/A	N/A

Total Survey Area (m²): 30

Mean Density (#/m²): .00

Observations:

The Area that was sampled was located below the screens on the Upper WIP Diversion. While Eshocking, 2 dead lampreys were found on top of the silt, fine sand, woody debris, and detritus mixed sediment. There were also 50 sculpin and 30 crawfish observed during this survey. The screens were lifted up after the dewatering and the sediment depths were 36cm, 10cm, and 18cm.

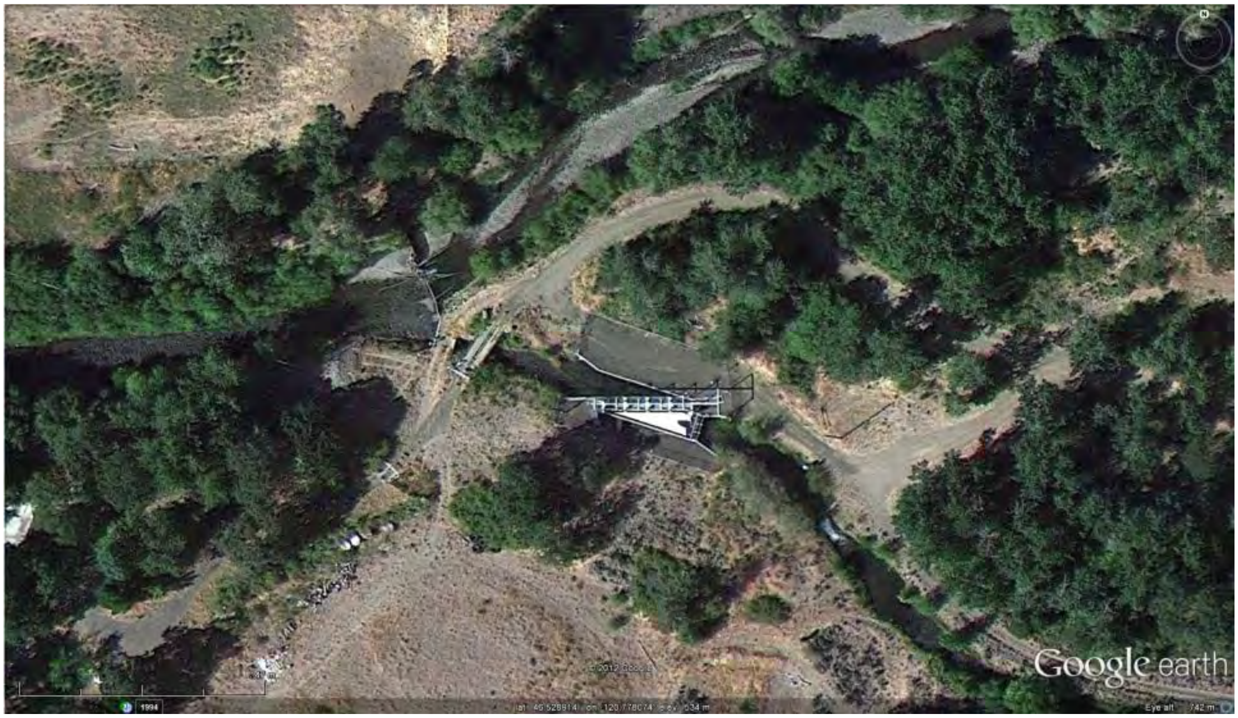

Figure 19: Overview of Upper WIP Diversion

Figure 20: Close up of Upper WIP Screens

Selah-Moxee Diversion

Date: October 24th 2012

Location: The Selah-Moxee Diversion is located outside of Selah in Pamona on the back side of Private Property at the end of Pamona Rd.

Screens: Drum

Temp: 11.3°C

Above Screen Survey Dates (Total Days): 10/24 (1)

Lamprey Total Above Screens (Total Observed): 29 (39)

Size Class (mm)	**0-40**	**41-70**	**71-95**	**96-110**	**111-135**	**>135**
%	**80**	**13**	**6**	**1**	**0**	**0**

Total Survey Area (m²): 261

Mean Density (#/m²): .11

Below Screen Survey Dates (Total Days): N/A

Lamprey Total Below Screens (Total Observed): N/A

Observations:

The only area that was surveyed was the section above the screens to the head gate. The area below the screens had no available habitat to survey and was composed of an armored channel. The sediment that was located above the screens was a mixture of fine sand and silt with long aquatic grasses growing out of it which decreased visibility. The entire section was also cement and the sediment thinned and eventually was no long along the bottom near the head gate. In the section where the sediment was raised above the water level there was a mixture of smells being emitted, such as plant decomposition, manure and other animal fecal matter. There were also some oil residues on top of the mud which could have been natural plant oils or pollution. There was also a variety of bird and small animal tracks imprinted into the mud.

There were 29 ammocoetes found above the screens along the midsection of the canal and all measured below 100mm. There were water skippers, small aquatic beetles, worms, and leeches observed in this area. The entire lampreys captured were taken to Prosser for further study.

Figure 21: Overview of Selah-Moxee Diversion

Figure 22: Close up of Selah-Moxee Screens

Chandler Diversion

Date: October 25th 2012
Location: The Chandler Diversion is located along side of the Prosser Salmon Hatchery in Prosser
Screens: Drum
Temp: 11.1°C

Above Screen Survey Dates (Total Days): 10/25 (1)
Lamprey Total Above Screens (Total Observed): 0 (0)

Size Class (mm)	0-40	41-70	71-95	96-110	111-135	>135
%	N/A	N/A	N/A	N/A	N/A	N/A

Total Survey Area (m²): 427
Mean Density (#/m²): .00

Below Screen Survey Dates (Total Days): 10/25 (1)
Lamprey Total Below Screens (Total Observed): 0 (0)

Size Class (mm)	0-40	41-70	71-95	96-110	111-135	>135
%	N/A	N/A	N/A	N/A	N/A	N/A

Total Survey Area (m²): 390
Mean Density (#/m²): .00

Observations:

The first day of surveying the diversion was the day of the fish salvage for Chinook and Coho Salmon. Our crew got clearance for the survey during the salvage before the canal was watered up again. The first area that was surveyed was above the screens between the screens and the trash racks. This diversion has not been dredge for a few years so the sediment build up was around 4ft at its deepest. The sediment was composed of coarse and fine sand mixed with small amounts of woody debris and detritus located against the screens and trash racks. The sediment top formed mounds and water had collected in the valleys creating small areas to survey along the midsection. The only places to survey other than that were directly in front of the trash racks and screens with an average width of 1m due to the lack of water flow. No lamprey were found above the screens but over 100 whitefish were seen stranded on top of the sand barely in the water and small juvenile salmon, stickleback, chisel mouth, channel and bullhead catfish, worms, and crawfish were also observed.

The next area of the diversion that we surveyed was below the screens. There wasn't nearly as much sediment behind the screens as there was above. The cement shelf that was built under the drums screens was exposed with no sediment on top. The water depth average 40cm in its deepest parts and was shallower along the sediment banks. The survey area was composed of coarse sand and fine sand mixed with small woody debris and detritus with cobble and gravel spaced around. There were many aquatic insects and large numbers of catfish observed but no lamprey were found.

Figure 23: Overview of Chandler Diversion

Figure 24: Close up of Chandler Screens

C-Town Diversion

Date: October 29th 2012
Location: C-Town Diversion is located off of Old Hwy 10 outside of Thorp
Screens: Drum

Above Screen Survey Dates (Total Days): N/A
Lamprey Total Above Screens (Total Observed): N/A

Below Screen Survey Dates (Total Days): N/A
Lamprey Total Below Screens (Total Observed): N/A

Observations:

All gates were locked and we did not have a key so no survey was conducted at this diversion.

Figure 25: Overview of C-Town Diversion

Figure 26: Close up of C-Town Screens

Sunnyside Diversion

Date: October 29th, 30th, and 31st 2012

Location: Sunnyside Diversion is located off of Yakima Valley Hwy outside of Union Gap on the Yakima River

Screens: Drum

Temp: 14.0°C

Above Screen Survey Dates (Total Days): 10/30, 10/31 (2)

Lamprey Total Above Screens (Total Observed): 199 (235)

Size Class (mm)	0-40	41-70	71-95	96-110	111-135	>135
%	40	30	20	10	0	0

Total Survey Area (m^2): 393

Mean Density (#/m^2): .50

Below Screen Survey Dates (Total Days): 10/29 (1)

Lamprey Total Below Screens (Total Observed): 357 (416)

Size Class (mm)	0-40	41-70	71-95	96-110	111-135	>135
%	30	30	10	10	10	10

Total Survey Area (m^2): 408

Mean Density (#/m^2): .87

Observations:

The first area that was surveyed at the Sunnyside Diversion was located below the screens. The diversion had not been dredge before we started our survey so there were large mounds of coarse and fine sand that had collected throughout the year. Because of this, we were only able to survey along the screens where the water ran alongside the sediment banks. There was a total of 357 lamprey captured throughout the entire survey area and small juvenile fish were observed as well. There was a large area of exposed sediment that was raised above the water level and there were many bird and small animal tracks imprinted into it. There were also approximately 20 dried up dead lamprey found on top of the dry sediment that must have gotten stranded during the dewatering process.

The next area that was surveyed was above the screens. During this survey, we joined Joel Hubble's fish salvage crew assisting in capturing salmonids along with lamprey. The area that was surveyed above the screens was located along the screens, the trash racks, and part of the bank due to the available habitat. These areas were composed of fine and coarse sand mixed with high densities of woody debris and detritus. The majority of lamprey found here were macropthalmia and large ammocoetes. The midsections of the survey area were composed of large cobble mixed with small amounts of sand and gravel.

Most of the lampreys were taken to Prosser for further study while the lampreys captured on October 29th were released into the Yakima River in Zillah.

Figure 27: Overview of Sunnyside Diversion

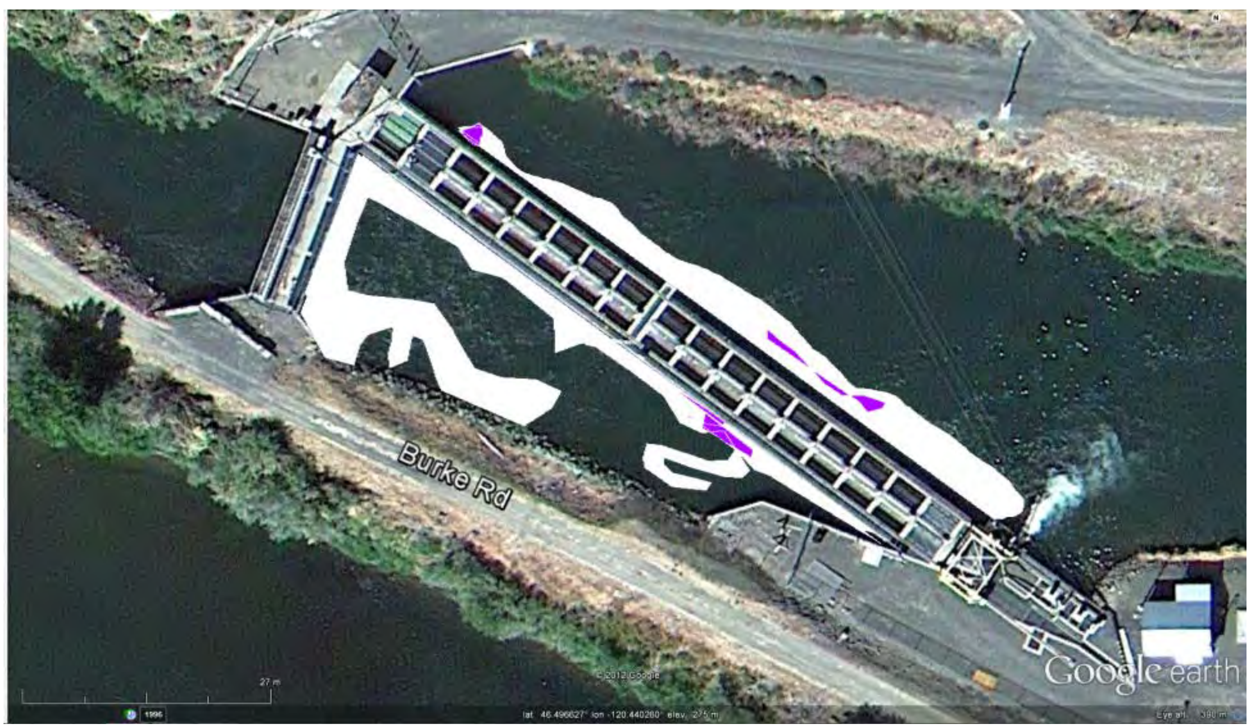

Figure 28: Close up of Sunnyside Screens

Toppenish-Satus Diversion

Date: October 31st 2012
Location: The Toppenish-Satus Screens are located off of Hwy 22 just outside of Toppenish
Screens: Drum
Temp: 13.2°C

Above Screen Survey Dates (Total Days): N/A
Lamprey Total Above Screens (Total Observed): N/A

Below Screen Survey Dates (Total Days): 10/31 (1)
Lamprey Total Below Screens (Total Observed): 0 (0)

Size Class (mm)	**0-40**	**41-70**	**71-95**	**96-110**	**111-135**	**>135**
%	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**

Total Survey Area (m^2): 119
Mean Density ($\#/m^2$): .00

Observations:

Only below the screens were sampled, above the screens was completely locked so there was no access and above the trash racks was stagnant water with very little sediment mixed with cobble along its armored bottom. Below the screens held the most habitat with many good depositional areas along the bank consisting of thick clay, silt, and fine sand. In most areas there were long aquatic grasses growing out of the sediment decreasing visibility. While there, a water pump was on and was lowering the water level decreasing the available habitat for the survey. No lampreys were found at this site but other life was observed including worms, leeches, beetles, skippers, stickleback, and spotted dace. Sediment samples were also taken and frozen at the Toppenish Fisheries office for further study.

Figure 29: Overview of Toppenish-Satus Diversion

Figure 30: Close up of Toppenish-Satus Screens

Unit 2 Feeder Diversion

Date: October 31st 2012

Location: The Unit 2 Feeder Diversion is located at the end of Harrah Rd. off of Fort Rd. outside of Toppenish

Screens: Drum

Temp: 14.1°C

Above Screen Survey Dates (Total Days): 10/31 (1)

Lamprey Total Above Screens (Total Observed): 0 (0)

Size Class (mm)	0-40	41-70	71-95	96-110	111-135	>135
%	N/A	N/A	N/A	N/A	N/A	N/A

Total Survey Area (m^2): 16

Mean Density (#/m^2): .00

Below Screen Survey Dates (Total Days): 10/31 (1)

Lamprey Total Below Screens (Total Observed): 0 (0)

Size Class (mm)	0-40	41-70	71-95	96-110	111-135	>135
%	N/A	N/A	N/A	N/A	N/A	N/A

Total Survey Area (m^2): 20

Mean Density (#/m^2): .00

Observations:

Both above and below the screens was sampled but no lamprey were found. There seemed to be good depositional areas with thick clay, silt, and sand mixed with woody debris and detritus although the only fish observed were stickleback and small dead trout. There were also water skippers, crawfish, leeches, and small aquatic beetles seen. In the sample area there was a variety of garbage and also an oily substance in parts of the stagnant water.

Figure 31: Overview of Unit 2 Feeder Diversion

Figure 32: Close up of Unit 2 Feeder Screens

Roza Diversion

Date: October 30th and 31st 2012

Location: The Roza Dam is located in the Yakima Canyon outside of Selah on the Yakima River. We gained access with the help of Joel Hubble.

Screens: Drum

Average Temp: 10.4°C

Above Screen Survey Dates (Total Days): 10/30 (1)

Lamprey Total Above Screens (Total Observed): 98 (123)

Size Class (mm)	**0-40**	**41-70**	**71-95**	**96-110**	**111-135**	**>135**
%	**15**	**15**	**20**	**20**	**20**	**10**

Total Survey Area (m²): 54

Mean Density (#/m²): 1.82

Below Screen Survey Dates (Total Days): 10/31 (1)

Lamprey Total Below Screens (Total Observed): 125 (155)

Size Class (mm)	**0-40**	**41-70**	**71-95**	**96-110**	**111-135**	**>135**
%	**10**	**10**	**25**	**50**	**3**	**2**

Total Survey Area (m²): 400

Mean Density (#/m²): .31

Observations:

The first area that was sampled was above the screens on the upper most part of the diversion. This area had a very thin layer of sediment in all areas except directly in front of the screens. In that area there was sediment mounds with lots of woody debris and detritus and is where the entire lamprey was captured from. There were 98 lampreys captured in this area. There were also small trout, stickleback, and spotted dace observed as well.

The next area that was sampled was located below the screens and was composed of hard clay along the banks with soft clay and sand mixed with gravel and cobble along the midsection. The best depositional areas collected below the screens where the cement had ended leaving a drop off for sediment to settle. Here there was woody debris and detritus. Along the banks there were many animal tracks from birds and small animals and even a few dried up dead lamprey. There were small trout, stickleback, spotted dace, crawfish, skippers, and other small aquatic insects observed.

There was no sampling further downstream because the canal was made up of cement for 11 miles down. After that point the canal widens and is composed of an armored bottom of gravel, cobble, and boulders with very little sediment.

Joel Hubble, who works for the Bureau of Reclamation, runs two live boxes that are attached to Roza canal and collect fish during dewatering and are later released into the Yakima River. This year we checked both and found lamprey, one held 18 which were all either large ammocoetes or macropthalmia and were separated into a bucket for easy pickup. The second live box has not been cleaned out for the past couple years so there was sediment that collected along the bottom. We climbed into the box and sifted through the mud and found small, medium, and large sized ammocoetes along with macropthalmia with a total of 32 Lamprey.

ALL lampreys that were captured were taken to Prosser to the Hatchery for further study.

Figure 33: Overview of Roza Diversion

Figure 34: Close up of Roza Screens

Kelly-Lowery Diversion

Date: November 1st 2012
Location: Kelly-Lowery Diversion is located in Naches off of N. Naches Rd.
Screens: Drum

Above Screen Survey Dates (Total Days): N/A
Lamprey Total Above Screens (Total Observed): N/A

Below Screen Survey Dates (Total Days): N/A
Lamprey Total Below Screens (Total Observed): N/A

Observation:

We were unable to access this diversion at an earlier date due to the gate being locked and no key but when we finally did there was no water in the diversion. Because of the lack of water no survey was taken although there would have been a good depositional area. The thick mud consisted of clay, silt, and fine sand mixed with small amounts of detritus.

Figure 35: Overview of Kelly-Lower Diversion

Figure 36: Close up of Kelly-Lowery Screens

Wapatox Diversion

Date: November 1st and 5th 2012

Location: The Wapatox Diversion is located in Naches off of Hwy 12 and is supplied by the Naches River

Screens: Panel

Average Temp: 10.3°C

Above Screen Survey Dates (Total Days): 11/1 (1)

Lamprey Total Above Screens (Total Observed): 87 (107)

Size Class (mm)	0-40	41-70	71-95	96-110	111-135	>135
%	40	20	30	5	5	0

Total Survey Area (m²): 77

Mean Density (#/m²): 1.13

Below Screen Survey Dates (Total Days): 11/5 (1)

Lamprey Total Below Screens (Total Observed): 52 (61)

Size Class (mm)	0-40	41-70	71-95	96-110	111-135	>135
%	14	85	0	0	0	1

Total Survey Area (m²): 39

Mean Density (#/m²): 1.32

Observations:

This Diversion was only surveyed above and below the screens and not down the canal due to lack of sediment along its cement bottom. The first place that was sampled was above the screens and required a ladder for access. The sediment here was thick and composed of clay, silt, and fine sand with long aquatic grasses growing along the bottom. 87 lampreys were captured above screens and were taken to Prosser to the hatchery for further study. The next area that was sampled was below the screens. This area was composed of clay and fine sand and 52 lampreys were captured. After captured, data was collected, they the lamprey were released back into the diversion were they were found for further study. The lamprey that was found varied in sizes from 5mm-150mm, indicating different age groups.

Figure 37: Overview of Wapatox Diversion

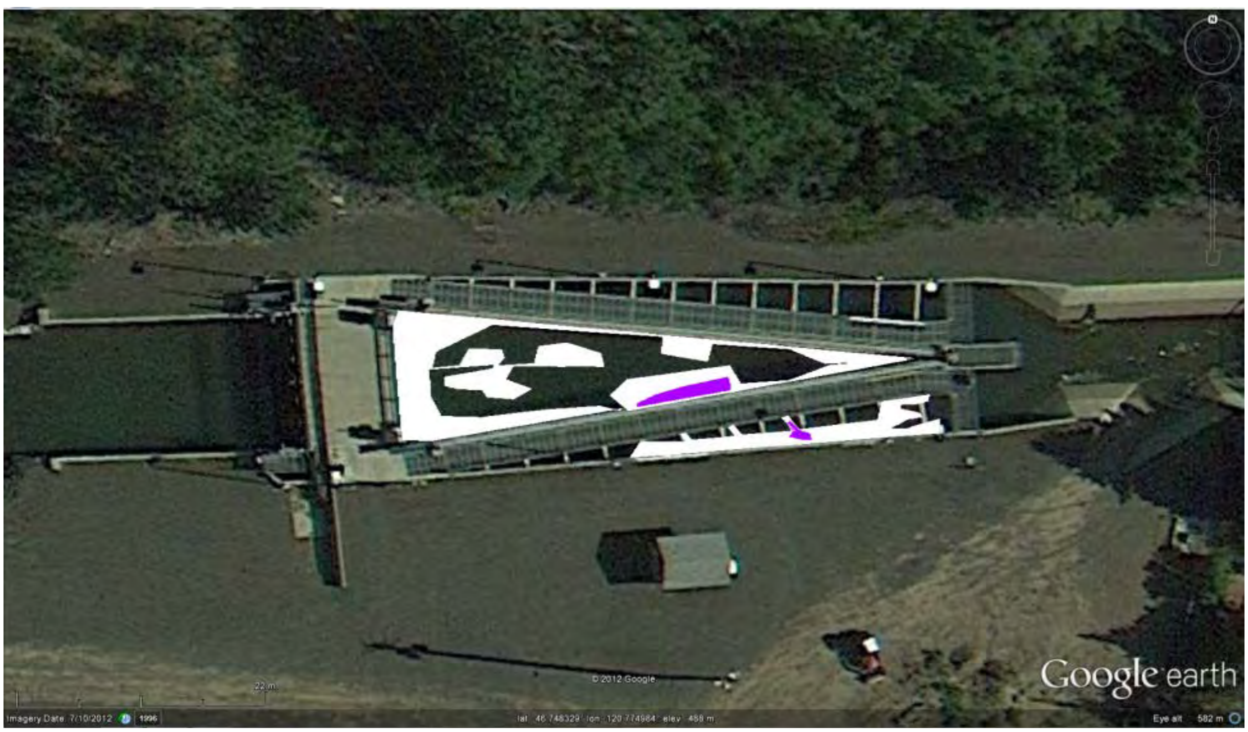

Figure 38: Close up of Wapatox Screens

New Rez Diversion

Date: November 7th, 8th, 9th, 14th, 15th, 16th, 20th, and 28th 2012

Location: The New Rez Diversion, also known as Parker Diversion or Wapato diversion, is located Highway 97 just outside of Union Gap and is supplied by the Yakima River

Screens: Drum

Average Temp: 9.1°C

Above Screen Survey Dates (Total Days): 11/7, 11/8, 11/15, 11/16, 11/28 (5)

Lamprey Total Above Screens (Total Observed): +1118 (1514)

Size Class (mm)	**0-40**	**41-70**	**71-95**	**96-110**	**111-135**	**>135**
%	**50**	**10**	**15**	**10**	**10**	**5**

Total Survey Area (m²): 3842

Mean Density (#/m²): .29

Below Screen Survey Dates (Total Days): 11/7, 11/14, 11/20, 11/28 (4)

Lamprey Total Below Screens (Total Observed): 66 (132)

Size Class (mm)	**0-40**	**41-70**	**71-95**	**96-110**	**111-135**	**>135**
%	**50**	**40**	**5**	**5**	**0**	**0**

Total Survey Area (m²): 1616

Mean Density (#/m²): .04

Observations:

The diversion consisted of a mixture of gravel, cobble, fine and coarse sand, silt, and clay with small amounts of detritus and woody debris located near the screens (above and below) and above the trash racks toward the head gates. In some areas the sediment was thick and up to 3ft deep below water level while some areas the mounds were raised above creating islands. On the sediment mounds there were a variety of tracks from small animals and birds. There was also many small dried up dead lamprey in all areas with exposed sediments. Sediment samples were also taken and frozen at the fisheries office for further studies. In the canal there was also an oily residue located along the banks in the mud and on the water along with garbage consisting of tires, plastics, glass, cans, large metal bars and other house hold containers. Traveling down the canal there was significantly less sediment and gravel, cobble, boulders, and long aquatic grasses. There was other life observed including squawfish, carp, stickleback, spotted dace, whitefish, steelhead, sculpin, trout, crawfish, and many aquatic insects.

Many lamprey were found in this diversion ranging from above the screens past the trash racks to below the screens down the canal approximately 8 miles downstream including Westernbrook's and Pacific's ranging in sizes from 5mm-170mm indicating different age groups. There were many new born fish of this year seen and were unable to catch due to their small size because they would slip right through the net of there would be too many to catch at once. Out of the lamprey captured, some were taken and preserved while others were taken to Prosser to the hatchery for study, or were released into the Yakima River at the Zillah public fishing area in the Wapato Reach.

Figure 39: Overview of New Rez Diversion

Figure 40: Close up of New Rez Screens